MINUTES OF CAIB MEETINGS
Book 1 of 2

(Feb. – May 2003)

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 6, 2003
These Minutes Contain Sensitive Information

The CAIB met on February 6, 2003 at 10:30 a.m. at Johnson Space Center (JSC) Building 1, Room 966. The topics for discussion were as follows:

1. Board Business
2. NASA Centers/Divisions Reports/Status
3. Board Charter
4. Hardware Release Issues
5. Organizational Chart
6. Agendas for February 7 and KSC Visit
7. MOD/MCC Briefing
8. Shuttle Program Safety Mission Assurance Briefing
9. Board Business
10. MRT Meeting Summary

Discussion:

1. **Board Business**

Frank Buzzard will keep a log of CAIB (Board) requests for trips, or information with a tracking system that allows retrieval of data. He will operate out of Johnson Space Center (JSC) and the Board will operate from the Regent's Park Office Facility. Steve Nesbit will keep the Board apprised of press communications.

Bill Readdy and Sean O'Keefe will be arriving at JSC on February 7 at 11:30 A.M.

Five significant findings of human remains have been found. DNA testing is ongoing to identify the remains.

Organizational charts were reviewed by the Board and approved. The Board will split into three sub-Boards: plus an Independent Analysis and Support Team, a Task Force headed by Mr. Buzzard, and a Mission Response Team headed by Linda Ham.

Prior to each briefing Admiral Gehman will indicate whether the purpose is to gather information or recording witness statements. Witnesses are protected through statement taking procedures. If the data collected is not from a witness then the information provided is not protected.

The Board requested copies of 07700 Appendix R. Data has been impounded at MSFC, KSC and JSC. Dave Whittle at Barksdale AFB asked for computer capability to integrate agency data into a complete database.

Budget and contracts personnel are needed to work with the Board for Configuration Management support, for minute writing, secretarial work and report writing. IT and hardware support will be needed immediately.

The Shuttle program will not be shut down entirely because the Station Program requires support.

Telemetry data indicated the tires did not explode, and that temperature sensors failed incrementally.

2. NASA Centers/Divisions Reports/Status

Mr. Whittle, Chairman of the Missap Investigation Team reported from Barksdale AFB. Representatives of his team have been dispatched to Fort Worth and Lufkin, Texas. Shuttle debris has been recovered from California, Arizona, and New Mexico. Plans are in work to correlate trajectory with positions on earth in relation to times and events and have beaches surveyed for debris as well as the areas between Ft. Worth and California. The process to be used to deputize individuals to pick up debris has been approved and is in work. Debris has been returned by the Department of Public Safety (DPS). The Board is interested in building an automatic interactive database so that working groups can search the database for what has been recovered. Debris recovered will be entered into a database beginning on February 7. Personnel in Louisiana will flag debris information. Interactive mapping of information will be available online soon.

Ralph Roe with the Orbiter Vehicle Engineering Working Group (VEWG) reported no issues or concerns at the present time. He briefed the Board in detail earlier in the day.

Bill Roeh spoke from the Emergency Operations Office. His office takes and records calls from the public and distribute calls about debris and human remains to Barksdale. A database has been established for debris and non-debris calls and for controlling all public video and photographs coming in to Barksdale. An email address and a secure website has been set up to receive information which is then distributed for evaluation. Admiral Gehman asked that all information be collected into a central interactive database with search capabilities. The Mishap Response Team (MRT) was asked to assist in the development of the central database and will report on their findings to the Board. Actions from the Board for the MRT will be logged and sent to Ms. Ham. Mr. Buzzard asked that actions from the Board requiring NASA or outside source data, be given to him to coordinate and assign to the proper person.

Bob Heselmeyer from the Data Handling Working Group discussed guidelines for data handling and protection and logging in of data. A formal policy document has been drafted and will be finalized in the next few days. He gave actions to organizations to provide an inventory of data and transaction logs of copies of data. A process is in development to exclude impounded non-STS-107 data. DOD and network data was also impounded.

Paul Hill from the Debris Sighting Team said searches are focusing on California through west Texas. Ground, air traffic control and meteorological radar has been used to aid in identifying visual sightings and debris. A 10,000 square foot area must be searched for debris. Fifteen high-resolution sightings have been made so far. His team is focusing on pictures taken 40 miles away with still cameras. Some telescope views have been recovered as well. The western most confirmed debris was found in Ft. Worth, Texas. Teams are tracking down reports of debris in California, Arizona and New Mexico. Good images have been submitted that show Columbia was shedding debris as it crossed the California coast. The DOD received a prioritized list of the types of data the Debris Team is looking for. The data will be forwarded to Barksdale as it is refined.

Jay Stevtoe sent a notice today to NASA Centers and Headquarters' Legal and Public Affairs Divisions on procedures the Board may use for the release of information relating to the Shuttle accident. Admiral Gehman requested Steve Wallace with the Federal Aviation Administration (FAA) meet with Paul Hill to provide proactive debris prediction analysis.

Project Manager Jerry Smelser from the External Tank Group at MSFC reported that immediately after the incident contingency teams were deployed to New Orleans. A new fault tree was built with three primary branches involving two kinds of debris. The third branch concerns interface issues that might have happened on separation. Mr. Smelser's go-forward plan is to add people as needed from other NASA centers. Thirteen other teams will work on tasks that grow from the fault tree. (The tree has over one thousand failure paths and is being "pruned" to one hundred paths.) The steering committee will prioritize two priority scenarios under consideration: loss of varying amounts of ramp including the possibility that foam hitting the Orbiter was not a ramp but something near the ramp, and if varying amounts of ramp or foam are missing, if the hardware was exposed to an environment that was in a non-designed configuration. Test plans are in work to investigate the incident when tank insulation hit the Orbiter. The top event on the fault tree is "ET caused loss of Orbiter." The team is also using a fault tree that describes debris coming from the External Tank and SRB together.

George Hobson of the SSME Working Group reported that during flight the engines were operating normally. At the present time nothing off nominal has been found. Ron People has developed a failure scenario tree for the time the event occurred. All data was impounded but has since been released for those working the investigation. The hardware was locked down but has been released. All primes and major subs are back up and running. Engine testing will begin next week. The flight data was nominal on ascent. They are working on the fault tree for the time of deorbit burn to contingency. There was no credible reason identified for why the engine would have contributed to the incident but the top-level event on their fault tree is "Loss of Orbiter Due to Engine." A scenario was described where hydraulic power to a given actuator was lost which would allow the engine to ramp down and hit the body flap causing the loss of the Orbiter. Three APUs on the Orbiter redundantly furnish hydraulic pressure to keep the engines tucked in. Parts of the engine have been found and identified from photographs. Pumps, a bellow and strut assembly from the fuel duct, and turbine inlet housing veins were identified.

Jody Singer of the RSRM Working Group reported that at time of the accident the nozzle and safe and arm devices had been removed and shipped to the vendor for refurbishment. After the incident all work was halted and data impounded. After reviewing post flight data, no issues were identified. A team went to KSC to examine post flight hardware and make assessments. Paul McConnaughey reported on the findings of the team so far: the fault tree for this event assumes the motor initiated an event at the systems level. Three sub-levels were identified: the motors and ignition, internal and external to the motor; the solid rocket motor which could introduce anomalous loads through interfaces at ET attach points resulting in a failure; and motor introduced anomalous induced environments to the Orbiter such as acoustics and radiation. The motor data set with respect to mission phases, post flight assessment and hardware is being examined. Interviews will be held with individuals who looked at the data during build and post-fire. So far all ballistic data of this motor and all post flight inspections indicate a good motor pair. Formal interviews or witness statements have not been recorded, as this is only background gathering of information. The left-hand motor has been unstacked. Segments have been broken apart and are in the assembly facility. The right hand motor has not been unstacked. Motors were checked for debris impacts. None were found but photos and videos will document the examination of case segments. There is now slag and seawater in the righthand motor which, if not cleaned in a short time, will begin to corrode in the joints. No segments will be processed until the Board approves. Jody Singer asked for Admiral Gehman's signature on the hardware release form submitted yesterday. Mr. Buzzard gave Sandy Coleman the action to put together critical items from RSRM that could cause the loss of the Orbiter on reentry, and prepare a presentation on why none of those things happened for presentation to the Board.

Pete Rodriquez of the SRB set up a fault tree with the top-level event "SRB Caused Loss of Vehicle During Ascent." Three major sub-events in the tree are Electrical or Instrumentation Problems, SRB Dynamics During Ascent, and Debris Generated From the SRB. Hardware will be prioritized that is most likely to have caused the event. A finalized list will be ready tomorrow. Lambert Austin is working on integration hardware hazards between MSFC elements and Orbiter elements. Seven major and seven sub teams related to hardware elements are reviewing all hardware and documentation. Findings will be reported every afternoon. There were no issues to report at this time. Any photographic data on the Orbiter wing at the time of SRB separation and of wing debris is needed. The Board will address approving hardware release requests at the end of the meeting. Hardware will be assumed not released unless the Board releases it.

The top-level event for the Space Shuttle Systems Working Group's fault tree is "Loss of Vehicle During Reentry Due to Propulsion Systems Interaction." The fault tree begins when the SRB is stacked and mated, followed by ET SRBs stacked and Orbiter mated. Main propulsion systems with SSMAs and flow lines are included in the tree. The sequence follows through to rollout to pad, through liftoff, ascent, and booster and ET separation, to on orbit. Ten teams are working on the fault tree, organized by discipline. As data is collected from the flight for the different groups, the findings will be reported up through JSC systems. Ms. Ham said the group would be reorganized, coming from systems integration at JSC. Mr. Austin is building a timeline on how the work will be completed within sixty days. He will need input from all working groups on their completion dates. Mr. Austin manages the System Integration Office for the Space Shuttle program. He is responsible for physical and functional interfaces for the vehicle while in orbit, for the internal cargo bay, for JSC, MSFC and integration functions at KSC. He works with organizations and technical experts to make sure math models and databases correctly characterize the environments the vehicle will be exposed to. He is also responsible for integrated ascent flight vehicle analysis; preflight predictions on the day of launch and post flight reconstruction of the ascent flight profile. An incident reconstruction integration plan over all program elements will be developed and maintained with a focus on key products that each element provides. Waivers and hazard controls will be reviewed and provided as part of the integrated plan. Data at all sites was impounded and is being cataloged and logged for movement between groups. Mr. Austin reviewed the integration fault tree with MSFC to understand their requirements. Math models will be provided as needed.

Mike Wetmore at KSC with MRT Shuttle Processing reported their processing systems are being activated as they verify the impounding is complete. Two hundred and fifty-one people are supporting Mr. Whittle in Louisiana, Texas, Arizona and California on the Vehicle Engineering team, on photo support, with the Orbiter Vehicle Engineering Team, and MSFC as requested. The KSC processing sub team is going through all paperwork generated for processing of Orbiter Vehicle (OV)-102 for compliance with requirements. Site maps, lists of all documents and narratives summarizing test data are under reviewed. When the STS-107 flow is completed they will review the STS-109 flow and will organize a team to support the reconstruction of the Orbiter at KSC. The Shuttle landing facility hanger used for this purpose. A NASA and contractor organization has been set up to support the MIT and the Board. Debris will be decontaminated and assembled as the Board directs. OV-105 and OV-103 have been cleared for processing. OV-104 was locked down because it is attached to the external tank and has been put in a safe configuration. They will wait for the Board's decision if the vehicle is to go to the pad or disconnected to be returned to the OPF for long-term storage. Processing continues on Pad B and a request was submitted to clear Pad A. A final video review will be done and MRT will present the video to the Board. United Space

Alliance (USA) scanned the beach on Monday but found nothing of evidence for this flow. A written report has been sent to the Board for review.

Debbie Ellen spoke for Bob Cabana, the Flight Crew Operations Director on Flight Crew Operations, the Astronaut Office and the Aircraft Operations Division. Their group includes the Aviation Safety Office at Ellington Field, and the Vehicle Integration Test Office. An astronaut has been assigned to the investigation team and as a member of the rapid response team deployed from KSC. Astronauts have been sent into the field to assist with recovery operations of human remains, their primary responsibility. The primary Point of Contact (POC) between the Board and Astronaut Office is Shuttle Commander Mike Blume.

Jon Harpold with the Mission Operations Directorate is responsible for both Shuttle and Station operations, including Mission Control. His office is trying to define debris footprints in the trajectory area, correlating trajectory data with systems problems that have been identified. They will be supporting the technical panels with flight controllers. All real time data that came into the Control Center during the accident has been impounded. The POC for all flight controllers will be Leroy Cain.

Frank Benz said the Engineering Directorate is an independent engineering organization with the Space Shuttle Program reporting to General Howell. They support the ISS and SSP in all major programs at JSC. Their office includes aeroscience and flight mechanics, structural engineering, avionics systems, energy systems, crew thermal systems, medical systems, automation, robotics and simulations. They work on analysis and testing and with hardware and system experts. Most of their work is with the Orbiter Engineering Working Group. They have dispatched members of their team into the field to look for and identify debris. An Engineering Directorate organization chart was forwarded to Mr. Buzzard. Vanessa Ellerbe spoke for Payloads and Cargo. Payloads on STS-107 were the Spacehab Research Double Module, the Crossbay Carrier with Hitchhiker Payloads, and various experiments on the mid deck. The payloads were international, from Europe, Israel, and Japan. All facilities were locked down on February 1, including data and hardware. During the mission there were some subsystem anomalies reported, having to do with failure of the condensation system and temperature issues, and other issues that were experiment related. During entry ten payloads were powered. The Spacehab subsystem data came down with experimental data. That data was reviewed and a complete report was given to Ralph Roe. Nothing unusual was found in the payload data. There are no contingencies on the books that have a payload problem resulting in loss of an Orbiter. There were no payloads onboard with that capability.

Dr. Jeff Davis with Space and Life Sciences discussed his areas of responsibility: for crew health, mission operations, physiology and biomedical research, human factors and crew equipment. Stress response teams were deployed after the accident. The doctor's team provided the Station crew on orbit and the Shuttle crew's family with support. Thirty-five trained responders are on site and 135 are on call. The clinics have been open for flight medicine and occupational health. Occupational health materials were provided about the toxic hazards of debris. His office reviewed policies that went out to public service personal.

Yolanda Marshall spoke for Safety and Mission Assurance/Safety Reliability and Quality Assurance. Her office's responsibility is to support programs with hazard analysis, to review the certification process and how hardware is qualified for flight, to manage records for government furnished equipment and acceptance data packages, to assist with safety training, and for mishap investigations done in the training facilitates. Mark Erminger is the Shuttle Manager responsible for Certification of Flight Readiness (CoFR) and Mission Management Team (MMT) activities. They are working with all organizations on the

investigation with fault trees and hazard analysis. Mr. Erminger coordinates all Shuttle Safety issues.

Admiral Gehman expressed his appreciation to the participants for their briefings and complimented them on their diligence and superb work. The Board is scheduled to visit NASA Centers next week. Mr. Buzzard will meet via telecon with Center Directors at 4:00 pm today, February 6 to establish next week's agenda for the Board. They will appoint key representatives from each center to interface with the Task Force and to facilitate the Board's travel. The Board will visit Marshal on February 12, the Michoud Assembly Facility (MAF) on February 13, and KSC on February 14 and 15. The Admiral asked for each group to help complete their timelines in order to completed the Shuttle investigation in sixty days.

3. **Board Charter**

Mr. Buzzard will release the Board's Charter to USA today. He distributed copies of the Charter for review. The Board's changes were accepted but not put into the document correctly. The Board requested that "Board Responsibilities" be changed to "Columbia Accident Investigation Board Responsibilities." Other changes to clarify Board responsibilities were suggested. Further refinement of the charter is needed to correct wording, typos, and to clarify the duties and responsibilities of the Board. Under "Columbia Accident Investigation Board Activities", the Board requested that Section 5, line #2 read, "Schedule Board activates, Interim Board reports, and submission of the final Board report in coordination with the NASA Administrator."

4. **Hardware Release Issues**

The Hardware Release Form will be called "STS-107 CAIB Hardware release Form." Requests for hardware releases were discussed at the MRT on February 5, and the MRT will obtain Board approval to release hardware. RSRN requested that nozzles be released to complete disassembly assessment and preservation activities. The nozzles were 60% completed in disassembly evaluation on January 28, 2003. The Admiral requested that the Board approve the release conditionally on the fact that the material be marked as part of the Columbia Accident Investigation and be tracked accordingly, subject to 100% red-tagging of every piece of hardware. The suggestion was made to avoid confusion a different term be used than "red tag," as that phrase is used to designate items that are to be condemned. The suggestion was to establish hardware release guidance procedures such as: if the hardware is part of the investigation it be processed, blue tagged with a NASA Representative present; if the hardware is determined not to be a part of the investigation, and needed for the next flight, it must be identified that as such and released; if the hardware is generic but not associated with the next flight, it should not be released. Until a different form is devised, the Board will use the present release form. Admiral German said the Board will study the release process and that a NASA representative does not need to be present for these processes. Ms. Ham said when the release form for the nozzle comes before the Board for signature the hardware must be marked as Columbia Accident Investigation Evidence to be made available for investigation. The RSRM team would like to continue disassembly evaluation for igniters, sifter rings and segments. Post-flight evaluation was about 95% complete. Ms. Ham suggested the same restrictions be applied as on the first item. The RSRM Safe and Arm device was recovered with the SRM. It is not considered to be a threat to the Orbiter. No issues were raised for this item.

Other requests to the MRT not yet admitted to the Board were for experimental hardware and supplies that did not fly on Columbia. The customer requested the items be returned by

February 12 to avoid losing data. Admiral Gehman asked for those requests to be brought before the Board immediately.

MMT meeting minutes are available for those who need them. The STS-107 MMT minutes will be burned onto a CD disk and FRR briefings and L-2 and L-1 minutes will be published to the Internet for the Board to review. The three sub boards formed from the Board will begin to meet independently after next week. The single point of contact will be Mr. Buzzard.

5. **Org Chart**

Modifications made to the Shuttle investigation's organizational charts were sent out and revisions and dates were added. Further redlines or comments should be forwarded to Mr. Buzzard.

6. **February 7 Agenda and KSC Visit**

Agendas for the February 7 Board meeting and Kennedy visit were handed out for redlines and comments. All redlines were to be turned in to Frank Buzzard. Mr. O'Keefe was scheduled to arrive at JSC at 11:30 A.M. The Admiral and Mr. O'Keefe were to meet at Noon, and with the full Board from 12:30 until 2:00 P.M. Mr. O'Keefe was scheduled to meet with the Space Station Program from 2:00 P.M. until 4:00, leaving for Ellington at 4:30 P.M. A JSC airplane was requested for the Board at 3:00 P.M. on February 7, as a direct flight from Ellington Field to Washington, D.C. A short tour of the MCC was scheduled for the Board on February 7, from 8:30 to 10:00 A.M. after which the sub boards were to meet until the arrival of Mr. O'Keefe. The Monday and Tuesday trip itineraries were to be discussed in the afternoon.

7. **MOD Briefing**

Leroy Cain, ascent and entry Flight Director for STS-107 was on console at MC at the time of the accident. The control team is trained to assist and direct the crew and resolve problems, contingencies and perform nominal operations. They are only allowed to operate outside the framework of flight rules if it is deemed critical for crew and vehicle safety to do so by the Flight Director, and if there is not enough time to consult with mission management teams. KSC has primary control of the vehicle in prelaunch, end-of-mission landing and return to launch status. JSC provides backup to KSC during countdown for vehicle systems monitoring at SRB ignition, after which control is transferred to MC in Houston. Goddard Space Flight Center provides tracking and Tracking and Data Relay Satellite System (TDRSS) satellite data systems. White Sands is responsible for the ground terminals where all data is relayed to and from TDRSS to the ground and the vehicle. The Space Station Flight Controllers work closely with MC during a mission but were not required for STS-107 because it was not a Station mission. Mission Evaluation Room (MER) engineers are an extension of Mission Control (MC) Flight Directors. They can support the mission with details on any system problem. The Flight Directors set the priority for mission execution. The Flight Controller is responsible for that area of expertise in his discipline.

8. **Shuttle Program Safety Mission Assurance Briefing**

William Harris, the Manager of Safety and Mission Assurance (S&MA) is the manager of reliability, maintainability, quality assurance engineering functions, Quality Assurance (QA), and the Defense Contract Audit Agency (DCAA) delegation process through NASA contracts. He serves as the contracting authority over the USA contract. MSFC, KSC, and Stennis elements are included in his group. Senior Vice President levels and directorates at each of

the contractors, and quality assurance teams within their organizations are also his responsibility. He is also the risk manager. He has oversight of all S&MA activities in support of the Shuttle Program. He has not transitioned any of the oversight responsibilities to the USA contract. NASA is still in control of requirements and responsibilities. Contractor teams implement those requirements. He explained that the Shuttle has several hundred Level One single points of failure. After notification of a contingency, his team's emphasis was shifted to public safety.

9. Board Business

The Admiral will not hold daily press briefings, but the Board will hold periodic press conferences. He suggested the press be allowed to take video without sound of Mr. Whittle's command center. Mr. Nesbitt of NASA Public Affairs will coordinate locations for video filming, such as the Vehicle Assembly Building at KSC or the Debris Hanger at Barksdale AFB. No human remains will be filmed. Bryan O'Connor suggested press briefings focus on team leaders as experts.

Admiral Gehman asked that the Board break into groups and submit task lists for Frank Buzzard and NASA to work on over the weekend. A copy was to go to Theron Bradley, the Executive Secretary. The Board was to review the February 7 agenda. The Board was to meet Building 1 for an 8:30 A.M. walking tour of MC and then conduct Board work until the 12:30 P.M. briefing with Mr. O'Keefe. The Board will reconvene in Houston on February 9. The Hilton Hotel will provide semi permanent accommodations.

The Board prepared a generic day's agenda for the purposes of scheduling meetings and interviews. The Board will begin with a tag up meeting at 8:00 A.M. with the Task Force to give status and share inputs. From 9:00 A.M. to 1:00 P.M. the subboards will meet independently. From 1:00 to 2:30 P.M. the Board will meet and discuss Board business. From 2:30 to Close of Business (COB) sub panels meet, conduct interviews, and visit locations as needed. There were no objections to this generic agenda.

A "witness statement" will be prepared immediately for the purpose of conducting interviews. Digital cameras and tape records will be provided to each subboard for documentation purposes. A liaison will be chosen to interface with the subboards and technical experts. A technical writer will be chosen to write the investigation report.

From 8:00 to 11:00 A.M. on February 11, the Board will have an opportunity to use the full motion simulator.

10. MRT Meeting Summary

Two canisters of film were found from Columbia that may be personal film made by the astronauts, or ET evaluation photos. The film will be processed and copied. Ms. Marshall will educate the Board on the fault tree process. Park Rangers walked the beach at KSC after the launch but no debris was found. They were asked to submit a formal report. On February 3, foam was found on the beach after the accident, but it was old foam and not related to STS-107. Shuttle training and astronaut training will be presented on February 11 for Board members. The Board adjourned into sub-groups for remainder of day.

The meeting was adjourned at 5:30 P.M.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 6, 2003
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Attending the CAIB at JSC were:

Admiral Harold Gehman, Chair			
Lambert Austin	Barbara Combs	Linda Ham	Yolanda Marshall
John Barry	Jeff Davis	Lorie Hanson	Bryan O'Connor
Frank Benz	Duane Deal	Jon Harpold	Ralph Roe
Mike Blume	Vanessa Ellerbe	Milt Heflin	Roger Tetrault
Theron Bradley	Mark Erminger	Bob Heselmeyer	Stephen Turcotte
Frank Buzzard	Phil Engelauf	Kenneth Hess	Steve Wallace
Leroy Cain	James Hallock	Scott Hubbard	
Sandy Coleman from Marshal Space Flight Center (MSFC) joined the meeting via telecon with representatives from Reuseable Solid Rocket Motor (RSRM), Solid Rocker Booster (SRB), External Tank (ET) and Space Shuttle Main Engine (SSME). Dave Whittle joined from Barksdale Air Force Base (AFB). Bill Roeh attended from the Emergency Operations Office at JSC.			

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 1, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting on Formation of Columbia Accident Investigation Board

Date: 1 February 2003 **Time:** 1700

The COLUMBIA Accident Investigation Board was constituted by Administrator O'Keefe in accordance with the NASA Agency Contingency Accident Plan for Space Flight Operations, dated January 10, 2003. Per Appendix D of the Plan, the Board was initially titled "International Space Station and Space Shuttle Mishap Interagency Investigation Board. Based on discussions between Administrator O'Keefe and senior staff members, its initial composition is:

ADM Harold R. Gehman, USN Ret.; Chairman
Maj. Gen. Ken W. Hess, USAF
Mr. Steven B. Wallace, FAA
Maj. Gen. Michael A Hamel, USAF
RADM Stephen Turcotte, USN
Dr. James N. Hallock, DOT
Brig. Gen. Wilbert D. Pearson, USAF
Mr. G. Scott Hubbard, NASA HQ
Mr. Bryan D. O'Connor, NASA; *ex officio*
Mr. Theron M. Bradley, Jr.; Executive Secretary

The Board members were notified by Fred Gregory by telephone of the formation of the Board. In addition, Board senior staff were appointed:

Steve Schmidt, NASA Code A
David Lengyel, NASA Code L
Liam Sarsfield, NASA Code AE

Staff members departed 1800 for Barksdale Air Force Base, Bosier City, LA, to establish initial working facilities for the Board.

The Board participated in a telephone conference at 1700 Saturday 1 February and agreed to meet at Barksdale to begin work on Sunday afternoon, February 2.

In addition to Board staff, points of contact include:

Dave Whittle, Mishap Recovery Team (MRT debris recovery team leader at Barksdale
Dave King, MRT PAO/Management (256) 682-3428
Dave Ludrich, NASA Action Center (318) 456-7441

ADM Gehman raised several initial issues:

- The name for the Board
- Introduction of the Board to the press
- "how many" members the Board should have and how new members would be added
- the Board's relationship to Dave Whittle's MRT group.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 2, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting on Board Formation

Date: 2 February 2003 **Time:** 1400

Maj. Gen. John Barry, USAF, has been appointed in lieu of Maj. Gen. Hamel.
Brig. Gen. Duane Deal, USAF, has been appointed in lieu of Brig. Gen. Pearson.

Individual Board members held informal discussions prior to the first Board meeting later today to develop potential issues and areas of interest. Areas suggested for discussion at the first meeting included:

Admiral Gehman:

- Scheduling an initial press briefing by ADM Gehman
- Getting an initial briefing from Steve Schmidt in the CAIB conference room at Barksdale for orientation as well as for an initial report on recovery efforts and facts as currently known
- Discussion of administrative issues. Board members were asked to develop a list of such issues for further discussion.
- Division of responsibilities among the Board members
- Scheduling regular meetings several times a day to compare notes
- Planning of field trips (learning, as well as investigatory) to DC, Houston, Kennedy, etc.
- Having daily process/procedural meetings as well as technically substantive meetings.
- How active should the Board be in the field (i.e., direct investigation versus NASA reports)?
- Timing preliminary and final reports to accommodate our needs and NASA's needs
- How to best cover the large amount of NASA ground support/field activities potentially under our managerial responsibility in directing the investigation.
- How to interface with support organizations outside NASA.
- How full-time the Board's activities would be.
- Work attire – not suit and tie except for public appearances.
- Providing name tags.
- Staying organized at least two days in advance.

Bryan O'Connor:

- Use of NASA investigation guidelines. Bryan will provide a tutorial for members.
- Use of the word "accident" (contrary to recent NASA practice, but we should call things what they are.)
- Do not usually use "sworn statements" that imply legal culpability; rather use NASA "witness statements" that make it clear we are solely interested in fact-finding.

- Need to retain a non-even number of voting members. (Resolved by agreeing that the Chairman can both vote and then break ties if required.)
- Define the *ex officio* role based on the investigation NASA Procedures and Guidance (NPG).
- Need to understand the roles of USA and other contractors at KSC, JSC, MSFC, and elsewhere
- Need to understand the role and reporting structure of the Mishap Investigation Team (MIT) at JSC, the Office of Space Flight, and Code M.
- Getting a brief from Dave Whittle on the progress of debris recovery and any initial findings from the debris.
- Settling where to set up the Board's HQ.

Jim Hallock

- Arranging for further specialized teams and field trips
- Technical training for Board members as necessary and appropriate.
- For debris reviews, availability of experts to explain "what we are looking at."
- Specific background information on shuttle operations.
- Coordination of photographic records.
- Settling a protocol in case we individually get media inquiries.
- Arranging an Orbiter tour at KSC.

Theron Bradley

- Establishing a formal liaison and interface between the Board and NASA
- Establishing the roles and responsibilities of the Executive Secretary, not defined by the NPG or Contingency Action Plan
- Establishing operational processes for the Board

Steve Wallace:

- Interface with the NTSB
- Don't wait to point out problems we see so they can be fixed promptly
- Need to provide clear findings and conclusions
- Considering use of FAA "witness statements" which seem similar to NASA witness statements.
- Need for independence in reality, and to be publicly perceived that way
- Importance of open relationship with media, especially aerospace specialized media
- Building on offer of assistance from FAA

Steve Turcotte

- Prompt establishment of Board infrastructure
- Prompt education on specialized technical areas
- Coordinating public testimony

- Dealing with legal issues concerning debris
- Coordination of evidence collection and theory development
- Education on NASA organizational structure including contractor relationships

John Barry

- Need to build on and compare with CHALLENGER, recognizing that COLUMBIA is a different environment than CHALLENGER was.
- Need to be open but still retain ability to get candid and sensitive input from NASA and contractor employees; this is not a public witch hunt.
- Need to establish how COLUMBIA fits into the historical context.
- Need to establish policy on responding to FOIA requests, especially with any privileged testimony.
- Need to establish routine of internal working meetings and frequent public hearings.

All agreed that the imperative of the Board to prevent a repeat accident.

Fred Gregory also provided input to several Board members prior to the first meeting:

- There has been a lot of initial White House interest and follow of this accident and its follow-up.
- NASA has resisted the push for a Presidentially-appointed or Congressionally-appointed commission.
- Congress is supportive of the Gehman Board, at least until it gets screwed up.

Members will provide biographical sketches to Steve Schmidt for inclusion in the press package (currently being handled through NASA HQ; to be transferred to the CAIB "soon.")

John Barry provided a good set of Air Force accident investigation guidelines and checklists for consideration by the Board.

These minutes are hereby submitted for the record.

Approved

FOR

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 3, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting on Space Shuttle Information

Date: 3 February **Time:**

ADM Gehman was ill; Steve Wallace conducted the meeting.

Steve Schmidt and Dave Lengyel have arranged for a briefing on space shuttle design by the USA shuttle training team from KSC, for four hours on Wednesday, February 5. (Closes action from February 2).

Doug Cooke was introduced as a technical liaison to the Board. Doug formerly worked on the shuttle program, but is not currently working for NASA. His expertise includes re-entry aerodynamics, including hypersonic flight and breakup mechanics. Doug provided a briefing on many of these areas, and agreed to provide a copy of his presentation materials. In addition, he agreed to provide (or otherwise recommend a method of access to) a profile of entry g-forces and maneuvers, and corresponding control surface deployment.

Bryan O'Connor provided an overview of the NASA mishap investigation process as prescribed in NPD 8621.1 at http://nodis.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PD_8621_001H_&page_name=main NPG and NPG 8621.1 at http://nodis.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PG_8621_0001_&page_name=main. There was specific discussion on:

- The need to train investigators on proper techniques. NPG 8621.1 and the material previously provided by John Barry contain requirements and coaching on these techniques. It was concluded that investigators should read this information before having members or staff conduct interviews.
- The definition of "root cause." It was agreed that the Board should pursue causes as far as necessary to determine underlying root causes of identified problems.
- The final report will include (1) facts, (2) conclusions, (3) opinions, and (4) recommendations. In particular, opinions need to be identified as such and explained or justified as appropriate.

The current crew rotation for the International Space Station is March 1. This date is driven by the need to re-supply astronauts currently at the Station. While this date will likely be modified and/or accommodated by Soyuz, this is a reminder that there is a real-life need driver to complete at least the basic cause identification reasonably soon.

There was a follow-up discussion on FOIA and witness statements. It was agreed that privileged witness statements should not be subject to FOIA. The best recollection of NASA people on the

Board was that there had not been a successful FOIA challenge to the NASA witness statement policy. This is an important ingredient in building witness trust in providing sensitive information candidly and openly.

There was discussion of the importance of Board independence:

- CAIB records should be kept separate and apart from NASA records.
- The contractor is also required to do mishap investigations; the CAIB should get copies of such reviews and again they should be maintained separate from the CAIB records. (That is, the CAIB record may include access to the contractor and NASA records, but not vice-versa.)
- Independent means having the Board's own administrative staff (not rely on NASA support.)
- Independent means having the Board's own technical experts (not rely on NASA support.)
- The Aerospace Safety Advisory Panel (ASAP) is a semi-independent group from NASA. We should solicit their input but not their participation as members in the Board's review. (ASAP is tasked with some NASA safety oversight and as such may be "part of the problem.")

The Board discussed several detailed points with NASA (via the MRT) concerning ongoing issues and background information:

- The Board released recovered data collection equipment for processing, per discussion with Dave Whittle.
- The Board requested that NASA (shuttle program) provide data on historic tile damage by flight, with photographs where available.
- John Casper provided a briefing on the organization, flight history, and failure sequence (as known) for STS-107 specifically and the shuttle fleet in general.
- Recovered tile to date largely does not have intact serial numbers on the tile, making location identification difficult but not necessarily impossible based on tile geometry and other physical characteristics.

The Board requested further information be obtained from NASA in several areas:

- Statistics on missing or damaged tiles from previous flights (as discussed above.)
- A failure time line from the MRT (being developed and used by the MRT)
- The shuttle Probabilistic Risk Assessment, particularly those sections relevant to failure on re-entry
- NASA's record of the CHALLENGER lessons learned, actions, and follow-up
- Records of the Flight Readiness review for STS-107
- Results of previous debris damage reviews
- Updated background books for Board members

- Information on how to tie in to ongoing NASA processes, including Board requests for information and daily MRT, HCAT, and press briefings
- Details on continued personnel logistic support for the Board and staff members
- NASA press clipping service or Early Bird service to Board (PAO to follow up on previous request).

The Executive Secretary and Senior Staff reported actions to establish open items lists and standard processes for many of the above items. It was generally recognized that this would likely remain a work in progress for some time, adjusted as necessary to suit the emergent needs of the Board.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 4, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting on Board Charter Issues

Date: 4 February 2003 **Time:**

The Board spent the morning on a field trip to the Nacogdoches, Texas, Incident Command Post directing recovery of debris. This included an initial press availability by ADM Gehman. The trip included a review of debris and recovery in the field at several locations, and review of debris identification and evidence preservation in the hangar at the Nacogdoches airport.

Robert W. (Moose) Cobb (NASA IG) was introduced as an observer to the Board.

The Board discussed/received an update on several open issues from February 3:

- Copies of the Rogers report are available electronically; a limited number of printed copies are also available.
- The status of the Aerospace Safety Advisory Panel was re-emphasized and clarified as stated in the February 3 minutes, based on inquiries from ASAP to "participate with the Board in the investigation."
- The Board discussed relocating to Houston rather than Washington DC as had been preliminarily discussed on February 3. See below for further discussion.
- Travel arrangements were settled for a visit to JSC later this week and KSC, MSFC, and MAF the next week, for background discussions.
- The Board agreed to have an initial division into teams, further discussed below.
- The Board would like to complete basic shuttle design training prior to the trip to JSC later this week. Steve Schmidt is completing arrangements.
- The Board discussed the role and composition of the NASA MRT task force and its relationship to the Board's work. It was agreed this task force should operate under the auspices of the Board once the Board was sufficiently familiar with shuttle operations and recovery activities, expected to be early next week.
- The Board observed the need to have a process for dealing with unsolicited input from either the public or NASA. Pending establishment of a more formal process, such input would be provided through the Executive Secretary to the Board Counsel for appropriate action and retention.
- The Board agreed to formalize the process for releasing debris (review by Executive Secretary, review by the cognizant Board team once teams are established, approval by the Chairman.) The Board Counsel has the lead to work with the MRT to provide a procedure for executing this process.
- The Board agreed to similarly formalize a process for releasing impounded equipment, data, facilities and so on. The process is similar to that for releasing debris. The Board

Counsel has the lead to work with the MRT to provide a procedure for executing this process.

ADM Gehman reported his discussions with Sean O'Keefe and Fred Gregory concerning possible expansion of the Board membership to include recognized experts in certain fields, now that the nature of the accident was better understood. In particular, expansion to academia and business would provide a broader experience base for the Board. Suggestions have been received from the Administration and Congress; additional suggestions were solicited.

The Board held a more detailed discussion of the best location for the Board for the next month or so, specifically with regard to the advantages and disadvantages of Washing ton and Houston. The Board agreed that, for the near term, the center of gravity for the investigation is in Houston, so that's where the Board should be. The travel schedule for the next two weeks was approved as discussed yesterday, and then two weeks in Houston. The Board would re-evaluate its appropriate location after that time (first of March), with the plan being to move to Washington when the focus of review shifts to institutional issues.

Several open items were identified/discussed:

- The Senior Staff (Chuck Ensinger) will develop and maintain a contact list for the Board and staff.
- A review/synopsis/report of NASA press briefings will be provided to the Board daily (PAO and Steve Schmidt)
- A summary of mishap tagups will be provided by NASA (Steve Schmidt)
- NASA should provide the Flight Readiness Review records electronically (Bryan O'Connor lead).
- Getting the NASA Early Bird daily and timely (Steve Nesbett).
- Ensuring everyone is getting reimbursed for travel (Steve Schmidt, Steve Miley, Vicki Novak).
- Establish a CAIB Analysis and Support team (Theron Bradley)
- Include mention of the Board in NASA press releases as one element of transitioning to Board direction of the NASA investigation (Glenn Mahone).
- Including MRT operations and impoundment in the agenda for the JSC meeting later this week.

Several issues relating to the Board charter were discussed. The Board agreed that current charter may not be uniformly clear on these points and may warrant revision:

- The Board should <u>independently</u> establish the facts.
- The Board should determine an actual or probable cause
- The Board should recommend actions.

The Board will "sleep on these" for further discussion in the next day or so.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 4, 2003
These Minutes Contain No Sensitive Data

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. For
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 7, 2003
These Minutes Contain No Sensitive Data

The CAIB met on February 7, 2003 at 1030 a.m. at Johnson Space Center (JSC) Building 1, Room 966. The topics for discussion were as follows:

1. Introductions
2. Board Business
3. Fault Tree Analysis Presentation

Discussion:

1. Introductions

Admiral Harold Gehman asked for each member of the CAIB to introduce himself. Those attending the meeting were: Steve Wallace, Director of Accident Investigation/FAA; Duane Deal, Space Operations/21st Space Wing Command; John Barry, Plans and Programs/Air Force Materiel Command; Theron Bradley, Executive Secretary of the Board; Steve Schmidt, POC for Sean O'Keefe; Frank Buzzard, Task Force Command; Scott Hubbard, NASA Ames Research Center Director; Steve Turcotte, Naval Safety Center Command; Ken Hess, Air Force Safety Center; Jim Hallock, U.S. Department of Transportation/Manager Aviation Safety; Brian O'Connor, Associate Administrator/NASA Safety; Jim Bagien, Director National Safety/VA; Bill Sikora, Legal Advisor; Robert Cobb, NASA Inspector General; Steve Nesbitt, NASA Public Affairs/Houston; and Roger Tetrault, former CEO of McDermit International.

2. Board Business

The Admiral announced several schedule changes. Sean O'Keefe was delayed and would not be present to address the Board until 1:45 PM., after which he was to meet privately with Admiral Gehman at 2:30 PM. A 3:00 PM All Hands Meeting was scheduled to take place with the NASA community overall. When Mr. O'Keefe concluded his address to the Board, the Board members were excused. The Board is schedule to reconvene on Monday, February 10. All Board members were to check into the Hilton on Sunday night, February 9. Permanent accommodations have not been finalized. On Monday, February 10 the members were to report to their new offices in the Regent's Park Office Facility located near USA Headquarters. Board members who were to complete write-ups for Groups 1 and 2 were requested to turn those into Mr. Bradley before departing.

The Board has been divided into 3 sub-Boards: the Technical Evaluation and Post-Flight Analysis Board; the Flight Operations/Crew Performance and Mission Evaluation Board; and the Materials and Production Board. The Admiral asked Mr. Tetrault to serve on the Technical Evaluation Board. The sub-Boards met on February 6 and created data tasks that were forwarded to NASA for completion over the weekend during their absence.

Some of the Board members required new orders be issued to replace those that expired on February 9. Biographies of Board members were requested for press and Congressional meetings. Copies of the Board's charter and Board members' biographies were given to Board members. The Air Force at Port Canaveral will survey the beaches at KSC for any Shuttle debris or that may have washed ashore. The Board was dismissed for lunch and for private work time.

3. Fault Tree Analysis Presentation

The meeting reconvened after lunch with a Fault Tree Analysis presented by Bob Graber. This type of analysis is used as an accident investigation tool and as a design tool for systems engineering and for safety mission assurance groups. The Fault Tree Analysis provides a framework as a graphically description to examine all possible causes of a top-level event. When applied to an existing system the tree can identify existing weaknesses. Present NASA working groups are evaluating sub-trees within their field of expertise to validate accuracy and to "prune" the tree to focus on possible causes for the Columbia accident. The Board members were given a copy of a top-level fault tree framework, which described possible causes for the loss of the STS-107 crew and vehicle. A peer review process by subject matter experts on multiple levels by those outside the NASA organization will be used if needed to help identify unknown unknowns in the fault tree. Hazards Analysis, Failure Modes Effects Analysis (FMEA), Fault Tree Analysis and Probabilistic Risk Assessments (PRAs) were discussed.

The meeting was adjourned at 2:30 PM.

Attending the CAIB at JSC were:

Admiral Harold Gehman, Chair			
Jim Bagian	Frank Culbertson	Kenneth Hess	Steve Schmidt
John Barry	Duane Deal	Scott Hubbard	Bill Sequora
Theron Bradley	Mark Erminger	Stephen Nesbitt	Roger Tetrault
Frank Buzzard	Bob Graber	Bryan O'Connor	Stephen Turcotte
Robert Cobb	James Hallock	Kerry Ramirez	Steve Wallace

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 10, 2003
These Minutes Contain No Sensitive Data

1. Some administrative matters:
    a. JSC has used up all assets to support transportation needs and cannot provide additional vehicles to the board. Additional transportation will be at the discretion of each member.
    b. A catalog of lodging options is being prepared. The Admiral has declared it is not necessary for the team to collocate.
    c. Additional cell phones and blackberries will be provided by JSC. The original equipment distributed by NASA HQ may be returned so that all equipment comes from one source.
    d. Lyn Vernon at JSC is working to get digital cameras and voice recorders for board members.
    e. The trip departs Ellington Field at 0800, Wednesday, 12 February. Depart hotel at approximately 0730.
    f. IT architecture requirements for the RPIII building are in flux. There was a suggestion not to use PKI.
    g. The web site will be on line tomorrow (11 February).
2. Lt Col Rick Burgess provided an MRT update:
    a. The latest version of the organization chart was distributed. More debris was shipped to Florida.
    b. A 35MM camera was found and extreme care is being taken to attempt to salvage the film found in it.
    c. 1 of the General Purpose Computers (GPC) was found.
    d. Also found was:
        i. A 2 foot section of the left wing
        ii. A piece of elevon
        iii. A main landing gear
        iv. A piece of the payload bay which "looked like it was hit by a blow torch".
    e. Debris has been confirmed to have been found as far west as Ft. Worth, TX and as far east as Ft. Polk, LA.
    f. Some 17 re-entry videos are being pieced into a time line. After a discussion on the need for the board to see this information as quickly as possible, Paul Hill will brief the board tomorrow (11 February) on the status of the reconstruction.
    g. On 16 January, Mission day 2, the Air Force tracked something approximately 50 cm in size that drifted away from Columbia. The AF tracked it for 2 days when it apparently burned up in the atmosphere.
    h. Special testing being done on External Tanks and (ET) and Solid Rocket Boosters (SRB) is not scheduled to be accomplished within the window for completing this investigation. A total of 5 ET tests will be completed in Mid-April while the SRB tests will not be completed until 9 May.
    i. Dave King is to be replaced by Mr. Rudolphi from Stennis.
3. There was discussion of a process needed for the board to get questions to the MRT. It was decided that the board needed a 15 minute session with Linda Ham after each MRT. F. Buzzard is working the plan to accomplish this.

4. A draft process for requesting special testing has been distributed to each board member. It will be discussed and a final process approved tomorrow
5. Admiral Gehman came into the meeting and reemphasized that the afternoon meeting is for technical matters and he expects each sub-panel to brief status and share progress.
6. The meeting adjourned at 1430 hrs.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 11, 2003
These Minutes Contain No Sensitive Data

Purpose: STS-107 Mission Overview
Presented by Kelly Beck

Date: 11 February 2003 **Time:** 1110 hrs to 1140 hrs

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA Website.

Chart 1 – Purpose is to introduce Columbia's mission at a high level.

Chart 2 – No questions/comments

Chart 3 -

General Barry questioned whether the number of maneuvers was the most ever made. Ms. Beck was not sure other than to say the number of attitude maneuvers (~250) was at the high end for the program. She agreed to obtain the data.

General Barry also asked whether there had been a risk assessment performed relative to orbital debris. Ms. Beck responded this analysis was accomplished for the Flight Readiness Review (FRR). Mr. O'Connor added that the results of this analysis indicated a 1 in 350 chance of striking orbital debris and that 1 in 200 was the safety limit. It was agreed to provide the orbital debris risk analysis to the board.

Chart 4 –

There was a question as to whether the Orbital Acceleration Research Experiment (OARE) was on all of the time. Some of that data is available through the payload recorder but the experiment was not active on flight day 2.

Chart 5 –

There was a question about astronaut interface to the payloads aft of the Spacehab Module. Ms. Beck explained there was electronic interfaces for activation and deactivation of the Freestar Pallet Payloads as well as the ability for ground commanding but that there was no physical interface between the flight crew and the payloads in question.

There was a question as to how many payloads has a data downlink. Ms. Beck several did but she was not aware of the precise number. That information will be provided.

Chart 6 –

There was a question as to high-pressure items on board. Ms. Beck replied that some gas delivery systems were on board.

There was a question as to which side of the orbiter the combustion experiments were performed. Ms. Beck replied the port side.

Chart 7 –

Ms Beck explained this chart is a "generic" view of the Spacehab Research Double Module. She pointed out the configuration differences for STS-107 and emphasized the port-side location of the combustion experiment.

Charts 8 through 11 generated no questions or comments.

Chart 12 – Payload descriptions (4 pages)

There was some post-presentation discussion relative to overall payload safety. The Payload Safety Review Panel report can be made available.

There was a question as to whether any of the experiments planned to eject anything from Columbia. Ms. Beck answered no although the Combustion Module interfaces with the Vacuum Exhaust System. The board will be provided data describing the days of operation of the Combustion Facility.

There was a question about whether there was any combustion work done on the port side. Ms. Beck responded there was not and added that all payload experiments were in a "safe" mode for re-entry. She reviewed the operations safety constraints for those payloads that were given special safing attention.

Ms. Beck was asked to provide a macro description of the waste dumping procedure. She responded that waste dumping was planned around when the tanks became full as in accordance with the water plan. She added that for STS-107 payload operations were also considered so as not to contaminate the cameras on those payloads with such equipment. The board was promised data on the STS-107 waste dumps.

There was a question regarding placement of OARE accelerometers in relation the Columbia center of gravity. Ms. Beck indicated the accelerometers were not located at the Columbia CG and that she will determine where they were located and will provide that information to the board. She also reiterated that there was no OARE operations on flight day 2.

The meeting adjourned at approximately 1140hrs.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

The attendees were as follows:

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 11, 2003
These Minutes Contain No Sensitive Data

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Mr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Mr. O'Connor	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mr. Bradley	CAIB Exec. Secretary	281-283-7525
Joe Hartman	CTF	281-483-8457
Lisa Chu-Thielbar	CAIB Sup.	650-259-5474
Jim Mosquera	CAIB Sup.	703-887-3906
Paul Wilde	CAIB Sup.	202-385-4720
Kevin Templin	JSC/MV	281-483-6618
Pat Goodman	CAIB Sup.	
Matt Granger	CAIB Sup.	
Mike Francis	CAIB Sup.	757-270-8024
David Kral	CAIB Sup.	
Don White	CAIB Sup.	
Steve Nesbitt	AP	281-483-5758
Kyle Herring	AP131	281-483-8653
Steven Schmidt	CAIB Sup.	202-494-9162
Robert Cobb	NASA	202-358-2391
John Shannon	NASA DA8	281-851-5331
Paul Sean Hill	NASA DA8	281-244-1092
Bill Arceneaux	CTF	281-244-8075
Bill Sikora	NASA	216-789-6696
Jim Bagian	CAIB Sup.	202-285-0241
Jim Arnold	CAIB Sup.	650-604-5265
Leroy E. Cain	NASA DA8	281-483-0705
Mike Bloomfield	NASA CB	281-244-2233
Pat Pilola	CTF	
Deb Byerley	CTF	

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 11, 2003
These Minutes Contain No Sensitive Data

Purpose: Mishap Response Team (MRT) Update

Date: 11 February 2003 **Time:** 1300 hrs To 1330 hrs

The list of attendees is appended to the end of this report.

There were no presentation materials used at this meeting although the latest organization chart showing the addition of the Reconstruction Team under Mike Lembech at KSC was distributed. A product from the Date Review and Timeline Team showing a Simplified STS-107 Entry Timeline was also distributed.

For their forthcoming trip, 12 February through 15 February, to KSC, MSFC, Stennis, and Michoud the board is looking for generic capability briefings, not investigative matters. The only exception to this rule might be any reconstruction work at KSC. Designated board members will travel to individual sites when addressing investigative matters. The board is permitted to collect publicly available facts. In summary, this is an educational trip.

Mishap Response Team (MRT) Report:

1. The board owes the MRT a "debris hot item list" of key pieces of equipment that will be exempt from handling rules so it can be shipped directly for laboratory testing or other special procedures.
2. All board tasking goes through Frank Buzzard to Linda Ham.
3. All flight crew equipment is being kept in Lufkin, TX until a plan is put into place.
4. There have been ~1600 parts catalogued; not necessarily identified.
5. There have been 105 sightings in California of which 105 have been closed as not being of interest.
6. The Navy will mount a 30-day effort to search Toledo Bend Reservoir and Lake Sam Rayburn.
7. There is no current plan to attempt a high fidelity reconstruction of Columbia at KSC.
8. The 60-day window for release of a final report is contained in the NASA NPG document, which governs MRTs. Mr. O'Connor has authority from the NASA Administrator to waive this time constraint. It was pointed out that some of the testing and analysis from several working groups is planned to finish outside the 60-day window.
9. Air to Ground and Flight Directors voice loops will be released to the public after the press conference.

There were no action items or requests for information generated from this meeting.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 11, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Mr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Mr. O'Connor	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mr. Bradley	CAIB Exec. Secretary	281-283-7525
Joe Hartman	CTF	281-483-8457
Linda Ham	MRT	
Jim Bagian	CAIB Supt.	
Jim Arnold	CAIB Supt.	650-604-5265
Doug Cooke	CAIB Supt.	281-483-8422
Steve Nesbitt	AP	281-483-5758
Dave Lengyel	NASA HQ	202-358-0300
Paul Wilde	CAIB Supt.	202-385-4720
Steven Schmidt	CAIB Supt.	202-494-9162
Pat Goodman	CAIB Supt.	
Jim Mosquera	CAIB Supt.	703-887-3906
Lisa Chu-Thiellor	CAIB Supt.	650-259-5474
LtCol Rick Burgess		

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 11, 2003
These Minutes Contain No Sensitive Data

Purpose: Present Status of Re-Entry Video
Presenters: Paul Hill & Greg Byrne

Date: 11 February 2003 **Time:** 1140 hrs through 1210 hrs

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA website.

There were no action items or requests for information generated from this meeting.

Public response to a call for Columbia re-entry video has been very good. Approximately 60 videos have been received. Most of these are unusable but approximately 20 are useful. These, while of poor quality, are good enough to infer certain major events with good GMT.

Work is under way to create a complete, composite video timeline with annotations of telemetry and position data as well as trajectory, systems, ground sightings and virtually everything that is known will be put on a single storyboard.

A trajectory plot was shown with major events annotated on the trajectory. It was noted that not much is available from Albuquerque, NM to the high plains of north-central Texas but from the coastline to Albuquerque approximately 12 events have been identified and annotated on the plot. Work continues. Relative motion analysis is being accomplished in an attempt to reduce the size of the debris impact boxes. National Transportation Safety Board (NTSB) and DoD radar data is also being used to further reduce search areas.

There was a discussion on time tagging the data. The board was concerned that different time referencing systems and sensor delays may creep into the process. The board was assured that all time tags would be time homogeneous and would be based upon the time tagging of telemetry, which was done on board Columbia.

Mr. Byrne pointed out that based on the videos it will be apparent that debris was being shed as far west as California and before communications were lost with Columbia. What can be seen from the videos is not the actual vehicle (nor parts of debris) but rather the plasma field associated with the re-entering hardware. Because of this phenomenon we can characterize neither the size nor shape of the Columbia or any piece of debris. We can however, do velocity analysis with high confidence. Finally, all these videos came from the public, many of whom have requested to remain anonymous.

There was a question from Admiral Gehman regarding authority for public release of these videos. Mr. Byrne responded that Mr. Ralph Rowe has that authority. Admiral Gehman advised not to release anything without Mr. Rowe's approval.

Following playing of the videos it was apparent that they showed 6 debris events. There is a group concentrating on the luminosity of the shed materials in the hope of gaining some insight.

In response to a question about data from other federal agencies Mr. Hill indicated some classified data had been received from DoD last week plus radar data from the Navy and Beale AFB was being made available and he expected more of the same.

There was a question as to when Columbia entered sunlight. Mr. Byrne wasn't sure of the precise time but it was approximately over central Arizona.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 11, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
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Brigadier General Deal	CAIB	281-283-7507
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Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Mr. O'Connor	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mr. Bradley	CAIB Exec. Secretary	281-283-7525
Joe Hartman	CTF	281-483-8457
Lisa Chu-Thielbar	CAIB Sup.	650-259-5474
Jim Mosquera	CAIB Sup.	703-887-3906
Paul Wilde	CAIB Sup.	202-385-4720
Kevin Templin	JSC/MV	281-483-6618
Pat Goodman	CAIB Sup.	
Matt Granger	CAIB Sup.	
Mike Francis	CAIB Sup.	757-270-8024
David Kral	CAIB Sup.	
Don White	CAIB Sup.	
Steve Nesbitt	AP	281-483-5758
Kyle Herring	AP131	281-483-8653
Steven Schmidt	CAIB Sup.	202-494-9162
Robert Cobb	NASA	202-358-2391
John Shannon	NASA DA8	281-851-5331
Paul Sean Hill	NASA DA8	281-244-1092
Bill Arceneaux	CTF	281-244-8075
Bill Sikora	NASA	216-789-6696
Jim Bagian	CAIB Sup.	202-285-0241
Jim Arnold	CAIB Sup.	650-604-5265
Leroy E. Cain	NASA DA8	281-483-0705
Mike Bloomfield	NASA CB	281-244-2233
Pat Pilola	CTF	281-483-8463
Deb Byerley	CTF	281-483-8578

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 11, 2003
These Minutes Contain No Sensitive Data

Purpose: Flight Preparation And Launch Decision Process
Presenter: Randy Segert (KSC via Telecon)

Date: 11 February 2003 **Time:** 1530 hrs Through 1610 hrs

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found in the PBMA folder where these minutes are located.

There were no action items or requests for information generated from this meeting.

Chart #7

Mr. Hubbard: What is the relationship with United Space Alliance?
ANS: Contractors mostly make the presentations to NASA at the project level reviews, which precede the program level reviews. At the program level, contractors sometimes give the presentations but the decision making rests with NASA.

Chart 12

Admiral Gehman: What is a CoFR endorsement?
ANS: Signatures of responsible officials in response to specific questions relating to the organization, which the official is representing.
Mr. O'Connor went on to explain the philosophy of CoFR endorsements explaining about those with in-line responsibilities for implementing flight requirements and those who concur that everything is in readiness..

General Barry: Are there exceptions to face-to-face meetings?
ANS: No, face-to-face meetings are hard and fast rules.

Chart 14:

Admiral Gehman: Is this the real MMT? {Referring to the pre-launch MMT}
ANS: Yes, per volume 8 of 07700

General Barry: Are there different MMTs?
ANS: The MMT post launch is a smaller group because elements have completed their job; SRBs, ET, etc.

Chart 15:

General Hess: Is there any oversight of the in-flight MMT process?
ANS: Program management at Headquarters and JSC is tied in during MMT meetings.

Admiral Gehman: What is the chain of command for making a significant mission profile change?
ANS: Flight rules covering all conceivable contingencies are pre-approved by program management. If time is available to consult with the MMT and program management this will be done otherwise the flight director has the authority to implement the flight rules on his/her own authority. When MMT is consulted the program management participates. STS-86 offers a good scenario.

Meeting adjourned with no further discussion

Attendees are as follows:

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Joe Hartman	CTF	281-483-8457
Jim Mosquera	CAIB Supt.	
Paul Wilde	CAIB Supt.	281-483-0969
Roger Tetrault		
Bill Sikora	CAIB Supt.	
D. Lengyel	HQ	
Bob Vallister	CAIB Supt.	
CDR Mike Francis	CAIB Supt.	

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 17, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Tag-Up

Date: 17 February 2003 **Time:** 1305 hrs Through 1350

The list of attendees is appended to the end of this report.

There were no presentation materials used at this meeting.

There were no action items or requests for information generated from this meeting.

There will be an aging aircraft briefing from Rand Corporation at 1500 hrs today (2/17/03).

Admiral Gehman explained he was looking for a 5 minute briefing from each working group. He reminded the members that the purpose of this meeting was to compare investagatory notes and processes and to insure the groups were complementing each other and not overlapping.

Group 3 Report from Mr. Hallock

- Everything is still a work in progress
- Group 3 is checking many things about the object ejected from Columbia on flight day 2.
  - The DoD will be submitting analysis results later this week.
  - Photo analysts are working very hard.
- Data has been captured from the first 5 seconds of the 32 second gap as well as a single full frame of data at the very end of the 32 second period.
  - This data shows all 4 thrusters coming on which is a very abnormal occurrence.
  - It also shows an APU running at the end but no sign of fluids being pushed. Mr. O'Connor later cautioned members not to rush to conclusions about the meaning of 2 pieces of data that show an APU running but no fluid pressure.
- Admiral Gehman requested increased sensitivity from the members as to the priority of DoD getting analysis data to NASA. Apparently the media is reporting that DOD is dragging its feet in this area. Mr. Arnold pointed out that some analysis must be done in order to put captured data in context so one can make sense out of it.
- Group 3 is also working lots of other things such as how the plasma (or hot gas) achieved entry to the structure; via the leading edge or some other avenue.
- The AMOS telescope took pictures of Columbia while on orbit and these are being analyzed. A sample of an AMOS picture was passed around the table.

- Group 3 believes the on-going thermal and aerodynamic studies will provide strong clues as to where the breach occurred.
- There was a discussion about JSC never having done an integrated top-down fault tree analysis of the orbiter. They have done many more focused analyses to support anomaly investigations. It was pointed out that all STS elements under MSFC supervision have had a top down fault tree analysis levied on their contractors but JSC never levied such a requirement for a similar effort for the orbiter.
- Admiral Gehman asked if there was any need to know how hard the tiles are. Admiral Turcott responded that his group has requested a history of tile impact testing. His group has also asked exactly what data Boeing had available when the decision was made to continue the STS-107 flight after the foam impact on launch.
- General Deal announced that DoD has some 3200 observations of Columbia; most of which are from radar.

Group 2 from Gen Hess:

- His group is trying to put specificity to a vast area of interest.
- They are working with Group 1 in examining the conduct of the MMT. There will be joint Group 1 & 2 activities in this area.
- Admiral Gehman again emphasized the need for coordination among the teams.

Admiral Gehman interjected that there are 2 forces pushing on the board. NASA wants the board to discover the cause of the mishap as quickly as possible. Congress wants the board to go beyond this scope so that the final report of the board can form the basis for a national debate on space policy. He expects the charter of the board will eventually be expanded.

Admiral Gehman will rethink the relationship of CAIB panels and the Mission Investigation Team (MIT) in order to clarify responsibility for the map showing the location of debris.

Group 1 from Gen Barry:

- Gen Barry passed out a copy of the Sunday Houston Chronicle summary of accident theories.
- His group is looking at:
  - Government oversight of outsourced work
  - Boeing contract management movement from California to Texas.
  - Shrinking base of suppliers to the Shuttle Program
  - Material
    - They will assess all anomalies back to the last OMM of Columbia

    - Aging spacecraft in an R&D environment and how NASA is balancing operations vs. R&D.
    - Move of OMM from Palmdale to KSC
- Group 1 will largely be traveling next week. They are planning to go to Thiokol and Palmdale early in the week and KSC and MSFC later in the week. Details to be ironed out.
- There was a discussion of pyros:
    - Admiral Gehman wants an accounting of all pyros on the vehicle
    - There is concern being raised that DoD is detonating pyros as they are found in the debris field. The worry is that evidence will be compromised.

Mr. Hubbard raised the question as to whether there should be a CAIB representative in the debris room at KSC. The discussion indicated support for such a move but no decision was taken

General Barry observed the board needed an expert in plasma and hot gases in the regime of the Columbia re-entry.

Admiral Gehman announced there would be no board meeting tomorrow (2/18/03) due to the press conference.

The meeting adjourned at 1350 hrs.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

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Mr. Wallace	CAIB	281-283-7508
Joe Hartman	CTF – Recorder	281-483-8457
D. Lengyel (Acting Exec. Secy.)	CAIB Support	
LtCol D. White	CAIB Support	
LtCol Rick Burgess	CAIB Support	
Steven Schmidt	CAIB Support	
Jim Arnold	CAIB Support	
Wade Thompson	CAIB Support	
Lisa Chu-Thielbar	CAIB Support	
Jim Bagian	CAIB Support	
Bill Sikora	CAIB Support	
Bob Vallaster	CAIB Support	
Steve Nesbitt	CAIB Support	

CAIB MEETING MINUTES

Purpose: Daily Investigation Meeting

Date: 19 February 2003 **Time:** 1300 hrs

The list of attendees is appended to the end of this report.

There were no presentation materials used at this meeting.

KSC Ice and Debris Team Video

Mr. Hubbard stepped through the KSC Ice and Debris Team Video. Mr. Hubbard provided a handout which described what his panel expected from the video, what they think they saw – an unexpected sequence, and what comes next. This handout is reproduced below.

Expected:

- Object breaks loose, enters laminar flow air stream in down direction.
- Object strikes either left wing leading edge or underside of left wing.
- Object breaks up at or under left wing and debris field will become visible at trailing edge.

Unexpected sequence – what we think we see

- The bipod appears to be visible.
- The object breaks away at the bipod attachment point.
- The object moves upward for a substantial period.

  Why? Reverse flow occurs from SRB at separation (120 sec.)

  Does reverse flow occur earlier? See SRB plume expansion as air density decreases. If reverse flow occurs, is ramp design (Blunt bottom) a good design?
- Object reverses direction and appears to break into 2 pieces.
- Some indication that one piece shatters above the wing. Does it strike bipod strut?
- Remaining piece appears to disappear under the left wing.
- Debris field may possibly be seen early at the wing tip area.
- Debris can be seen moments later at trailing edge with one solid piece visible.
- Debris fingers can be seen at SRB skirt.

What next?

- Discussion with Stanford flow expert – Bob MacCormack
- Review NASA review of incident and interpretation of film.

Gen Barry indicated Bill Schneider of Texas A&M University, formerly at JSC, indicated the plume observed halfway through the clip is tile debris.

There are many alternatives to explain the observed phenomena and each must be considered.

Admiral Gehman wondered if analysis of the flame color would yield any useful information. Boron burns a bright blue for example.

Could be any one of 5 things – tile, foam, ablative material, metal, or ice

Velocity of the debris is an issue. Initially assumed 700 ft/sec but # doesn't make sense.

Boeing report done during orbital operations does not bring up any of these detailed features. The Board has a viewgraph version but not a text report.

General Barry then amplified on his conversation with Bill Schneider alluded to above.

- During early ferry flights Columbia tiles were damaged by foam applied to protect the tiles during ferry operations in 1979.
- He is also concerned about support for the tiles around the gear door.
- Densified tiles cannot handle impacts, just serious heat.
- Dust comes off when tile disintegrates.
- Believes the wheel well seals were bad, let in air, and a tire blew.
- Schneider is coming in on Saturday (2/22/2003) at 1000 hrs.

Admiral Gehman questioned the orientation of the Columbia and the relative pressure on the wing. ANS: The vehicle was in a right hand turn coming over CA but both pressure and temperature on each wing were equalized due to the velocity vector.

Board should avail themselves of the data in the Linda Fortenberry reports, which are now available.

Group 3

Mr. Hubbard passed out 2 handouts that are reproduced below

Group 3
Technical and Engineering Evaluation
OV-103 Flight
Working Groups

Lead	Topic
Roger	Debris collection. Storage, analysis, testing (KSC)
Scott	Debris photographic, videographic, radar, photometry, (launch, on-orbit, reentry
Jim	Fault tree closeout review
Jim	Flight telemetry relevant to anomalies
All	Accident reconstruction/Integration of results

Criteria for Tests Requiring Concurrence/Approval of the Columbia Accident Investigation Board (CAIB)

All test approval requests (TARs) meeting the following criteria shall require the concurrence if CAIB Group 3 and signature approval of the CAIB Chairman:

- The test is (or has the potential to be) destructive or irreversible in nature and:
  - Is to be performed on recovered hardware from OV-102, or
  - Is to be performed on ET-94, or
  - Is to be performed on OV-102-unique flight spares or flight-like hardware

    "Flight-like" hardware as defined here is intended to reflect qualification articles of flight production equipment.
- The TAR should be accompanied by the test plan with objectives and rationale to support evaluation of the request.

Item 2 is a proposal to Admiral Gehman for a process to handle requests from the MRT for testing. Group 1 needs to coordinate on requests dealing with ET-94.

Mr. O'Connor suggested that ET-94 is not a sister to the STS-107 tank. He suggested that only a tank which used the same ramp process to apply the foam as was used for STS-107 be used for any tests. Mr. Buzzard offered the observation that any work done to that tank other than Michoud would change the process.

There will be a discussion tomorrow *(2/20/2003)* of photography.

Mr. Buzzard announced that 5 or 6 seconds of data after LOS, then a 20 second gap, then 1 or 2 seconds of data had been recovered and was being analyzed. Expect to hear more on that tomorrow from Ralph Roe.

- Mr. O'Connor added that LOS means loss of normal signal and not necessarily loss of data.
- Admiral Gehman cautioned the Board to be careful with terminology and to not ever infer that Columbia operated normally for that 32 seconds.
- Mr. Hallock indicated it was approximately at the 4 second point when the 3rd and 4th yaw jest started firing and that is not good.

Mr. Wallace brought up the theory of a tire explosion.

Mr. O'Connor indicated that a tire explosion would have been heard and felt. He believes all instrumentation would be lost if a tire blows up. He witnessed main gear tire blowing at Wright-Patterson. Mr. Buzzard indicated multiple sensors would have reported if landing gear door had been blown off.

Mr. Hubbard believes there is a story in the dynamic pressure story that can shed light on how this failed.

Discussion of a water dump sensor located 30 to 40 feet forward that went out.

Gen Barry indicated that the debris that came off the orbiter on flight day 2 had a velocity of 10 meters/second. It has been determined it was not cloth which has been observed before.

Gen Barry asked if there were pressure sensors in the landing gear well.

Mr. Buzzard responded that the vehicles have vent doors to insure internal and external pressures are equalized and there is no ΔP. There are also many vent holes. There was a discussion of the functioning of vent doors and the vent holes that total approximately 140 sq inches in cumulative area. Mr. O'Connor indicated the vent doors open close to landing. Mr. Buzzard indicated by design and by test that the passive venting system performs as needed.

Group 1

General Barry indicated the group had had a briefing from Rand Corporation. It was a discussion on maintenance, structure, and loads.

There is a need to look at the Long Duration Exposure Facility (LDEF) reports particularly regarding orbital debris hits.

There was a discussion on I-Loads to keep orbiter within structural limits on launch. It was pointed out that NASA will commit to launch so long as they are within the limits even if the are "up against the stops". Limits were much less flexible during early launches but has been opened up today.

General Barry asked how many times Columbia was launched when conditions were against or close to (2 or 2.5 Sigma) the stops – this bears on the aging spacecraft issue.

Mr. Buzzard, who designed the I-Loads portion of the avionics, gave a chalk talk on day of launch winds and nominal, +3, and –3 Sigma bounds.

Gen Barry asked if anyone had ever done and examination of fatigue and structural overload.

Mr. Buzzard – Yes, we have examined design load to verify fatigue and structural overload is good for 100 missions.

Gen Barry wants to see data showing Columbia trajectories showing how close they were to the boundaries.

Bob Dougherty from Langley Research Center (LaRC), John Young of Johnson Space Center (JSC), and a Mr. Fishback were interviewed. Details of their interviews can be found in the transcripts of those interviews.

Discussion on tile repair system regarding repairing of cracked tiles and tracking of tile repair work. Repair of damaged tile is not considered an anomaly and is not tracked in their anomaly reporting system.

Admiral Gehman brought up his impression that when NASA has a problem or issue he has observed NASA has a tendency to quantify unknowns or probabilistic events to such a degree that the events stop being probabilistic events so they morph in known quantities. He keeps running into a culture of moving unknowns into knowns. He mentioned the repair of fractured tiles as an example. He is concerned about the totality of controlled risks. He believes the shuttle orbiters are essentially hand made vehicles where many variances can creep in. Mr. O'Connor observed how hard it has been to move NASA into using probabilistic risk assessment. Admiral Gehman is concerned that when the number of controlled risks gets very large the totality of all that is concerning. Also concerned is that we have an essentially hand made vehicle which is subject to many variances. General Barry offered the opinion that there is an issue of an aging spacecraft being utilized in an R&D environment.

Gen Barry distributed a handout that is reproduced below.

Group 1: Maintenance material & Management
Barry/Turcotte/Deal

Material/Maintenance: Design, modifications, refurbishment, processing, quality assurance, inspections, vendors, aging platforms, STS integration

Management: boards/committees, internal processes, decision levels, oversight, budget, contract management

MRT Working Groups:

- Debris sighting
- ET
- SSME
- RSRM
- SRB

Group 2

Gen Hess indicated his group has core mission parts divided up and was honing in on some factors that could be taken off the table.

There was then short break followed by a medical briefing and discussion with a limited audience.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
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Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Joe Hartman	Recorder	281-283-7591
Lisa Chu-Thielbar	CAIB Support	281-283-7583
Jim Bagian	CAIB Support	
Frank Buzzard	NASA	281-483-8412
Bill Sikora	CAIB Support	281-483-6624
Steven Schmidt	CAIB Support	
Rick Burgess	CAIB Support	281-283-7566
Don White	CAIB Support	281-283-7570
Bob Vallaster	Group 1	281-283-7578
Mike Francis	Group 1	281-283-7574
Steve Clark	Group 1	
Robert Cobb	NASA	202-744-5877
Laura Brown	CAIB Support	
Steve Nesbitt	NASA	

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 21, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 21 February 2003 **Time:** 1300 through 1440

Admiral Gehman introduced two new staff members from the National Transportation Safety Board (NTSB); John Clark and Jeff Guzzett.

Sid Gutierrez Presentation

Admiral Gehman introduced Sid Gutierrez who provided a presentation on flight crew safety. Mr. Gutierrez is a former test pilot and astronaut, currently works at Sandia, and is a member of the Aerospace Safety Advisory Panel (ASAP). Admiral Gehman explained the board will occasionally hear from guests with alternative views and the board should expect to hear about crew safety, crew escape, and on-orbit repairs.

Mr. Gutierrez provided hard copy handouts, which have been scanned and are available electronically in the PBMA folder containing these minutes.

Mr. Gutierrez' presentation focused on why we didn't get the flight crew back alive and did not address the vehicle survival.

Mr. Gutierrez opened his presentation by stating the saying the Shuttle is safe is a valueless statement. Empirical analysis proves that flying combat over North Vietnam was safer than flying a Shuttle.

Handout Page labeled 1:

- This chart is from a briefing by Michael Greenfield of NASA HQ, Code Q.
- It shows that NASA is getting better at doing Probabilistic Risk Assessment (PRA).
- Note that the chart only applies to ascent and entry and does not address orbital debris.
- The Air Force calculated Shuttle reliability at 0.96 a few months before the Challenger mishap; the 25th flight. The calculation was made because the Air Force was trying to justify additional Titan Expendable Launch Vehicles (ELV).
    - Mr. O'Connor asked if the Air Force calculation was of demonstrated reliability. ANS. It was an actual assessment using similar technologies used in ELVs.
- The probability of crew survival in the Shuttle is approximately 0.98 or 0.99. While this is better than ELV reliability is it not astronomically better.
- The question that must be answered is: What is acceptable reliability?

Handout page labeled 2:

- This page is from a human survivability document published by JSC in 1999 in which they came up with a .9999 requirement for crew survivability exclusive of the vehicle.

Handout pages labeled 3 and 4:

- These pages are from a NASA Headquarters procedures and guidelines document.

- The ASAP reviewed the draft of this document and determined the crew survivability requirements were stated in such a way that the requirements could be "gamed". These comments were given to NASA HQ who responded by removing all numerical crew survivability requirements.

Handout page labeled 5:

- This page contains the ASAP comments on the NASA HQ guidelines document and the total lack of crew survivability numbers.
- The question is: What does the public, Congress, and the Administration think is acceptable?
- If having a memorial service in Houston every 75 flights is not acceptable then what can be done about it?
    - The Space Shuttle has significant and inherent risks. Challenger was lost due to a problem with the Solid rocket Boosters (SRB). Columbia was probably lost due to a thermal event. We cannot due much about the probable causes of the Columbia mishap (spray-on foam and/or the Thermal Protection System) and still have a viable Shuttle program. These features are inherent in the design of the system.
    - Program insiders worry most about the Space Shuttle main Engines (SSME) that rotate at 44,000 RPM and are cooled with liquid oxygen and liquid hydrogen. They are incredible pieces of equipment that cannot be replaced with engines with less ISP because you won't be able to deliver anything to orbit.
    - Have spoken with Max Faget, generally considered to be the designer of the Space Shuttle, who believes the Auxiliary Power Unit (APU), is the highest risk system in the Shuttle. The Electrical APU program is delayed.
    - The bottom line for all of this is that we have lost 2 vehicles due to high risk systems and there are others out there.

Chart page labeled 10:

- The reliability numbers on these charts should be cut to one third or one fifth of their stated value in order to reflect demonstrated reliability.
- While the reliability improvement brought on by the upgrades are significant they do not approach the 2 orders of magnitude improvement that is needed. We seem to be reaching an area of diminishing returns.
- There is also a debate as to whether installing improvements will introduce other problems.
    - Mr. Buzzard observed that NASA is flying the Advanced Health Monitoring System (AHMS) without turning it on. Experience to date indicates AHMS would have shut down 2 perfectly good engines during ascent.
- The prevailing belief that ascent is the most dangerous flight phase is not necessarily correct especially with the upcoming upgrades. Entry is more dangerous.
    - Mr. O'Connor noted that many ascent problems may not show up until reentry, as may have been the case with the Columbia mishap.
- What is the solution? There are 2.
    - A new vehicle based on modern technology that tries to design out the inherent risks of the Shuttle.

- A crew escape system with a .95 reliability. This would add an order of magnitude to the crew survival number.

- The ASAP has asked the Administrator to do 4 things:
  - Identify a date to retire the Shuttle.
  - Develop a realistic plan for a replacement vehicle.
  - Evaluate Shuttle upgrades against these items.
  - Address crew escape.

Chart page labeled 6:

- This page is from an ASAP report regarding crew escape.
- The Administrator was not responsive to the 2000 ASAP report
- Last year Mr. O'Keefe was responsive.
  - The Shuttle will fly until 2020
  - There will be a Space Station Crew Escape vehicle by 2012.
  - There will be a new vehicle within the next decade.
  - Funding for the Shuttle Life Extension Program (SLEP) has been obtained.
  - NASA continues to study the crew escape issue.

Chart pages labeled 7 and 8:

- The Shuttle was supposed to be designed to fly like an airliner with the risks of an airliner. It was also supposed to be able to carry 60,000 pounds of cargo to orbit.
- These were diametrically opposed requirements the Shuttle designers were faced with.
  - Carrying people safely requires extra margins of redundancy and performance.
  - Carrying 60,000 pounds of payload to orbit required reducing those margins in order to achieve lift requirements.
- After Challenger, a B-17 like escape system was implemented. A study for a more advanced system was never implemented. NASA is currently studying crew escape.
  - Note on chart 8 the relatively small increase in crew survival using an escape system that relies on the crew wearing space suits and using ejection seats.
  - This is because the greatest risk occurs at speeds and flight regimes greater than that at which an ejection seat based system could save the crew.
- The 2002 ASAP report, which has not been released as yet, will recommend a crew escape system useful throughout powered flight including reentry that rules out the use of ejection seats.
- The chart on page 8 also shows the reentry risk to be almost as great as ascent risk. NASA will be asked to investigate an on-orbit repair system.
- Since the International Space Station (ISS) will be the primary destination of future Shuttle flights, many of the assumptions, which precluded a viable on-orbit repair system, are no longer valid.
  - There would be no up/down weight penalty since the repair system will be based permanently at the ISS
  - A platform for the repair crew to stand on will be available at ISS
  - The ISS has its own arm 9Remote Manipulator System).
- Tile repair kits have been designed since STS-1 and have been rejected because of weight penalties and difficulty of access to complete necessary repairs.

- Gen Barry observed that most of NASA's energies seem to be devoted to ascent and that once orbit is achieved there seems to be some relaxation.
    - Mr. Buzzard observed that of the 4 flight mishaps which have cost human life (2 Russian and 2 American), 3 of these mishaps have been on entry.
- NASA is looking at crew escape systems.
    - There is a concept whereby passengers would ride in a capsule in the payload bay while the pilot and commander would be taken care of separately.
        - There was discussion and alternate opinions as to whether this system would have worked for the Challenger and Columbia mishaps.
    - Ejection capsules have been designed with capabilities up to orbital velocities.
- The point is, that crew escape is possible without completely redesigning the Shuttle.
- There is a need to decide what is an acceptable level of risk. If 1 in 75 is not acceptable then a crew escape system and a new vehicle are necessary. An on-orbit TPS repair capability is also required.
    - Mr. Buzzard observed that there will still be inherent risks in a new vehicle because of the speeds and flight regimes in which that vehicle will operate.
- There was lengthy anecdotal discussion about the relative merits of various ejection systems including SR-71, B-58, and others.

Chart page labeled 9:

- Orbital Space Plane (OSP) requirements do not address these issues.
    - Mr. O'Connor indicated that while the OSP must be human rated, the human rating document is not complete.

There was a discussion on whether the purpose of a flight shouldn't be made part of the risk calculation. It was pointed out that what the Challenger crew was doing could have been done by a Titan. Admiral Gehman indicated the Shuttle shouldn't be used for delivering cargo to orbit.

There was a discussion regarding the categories of a space flight crew that was prompted by a question as to whether payload specialists (PS) are needed. Mr. O'Connor explained the various crew positions and indicated the PS is necessary and is a legitimate crew position.

- The Spaceflight Participant Program where journalists, congressmen, teachers, etc. were to be allowed to fly was cancelled after the Challenger mishap.
- Teachers in space is being considered for reactivation. Barbara Morgan, who was the Challenger backup, is now a trained NASA Astronaut who happens to be a teacher.

Group 1 – Gen Barry:

- NASA is doing probabilistic risk assessment (PRA). Dr. E. Mosley of the University of Maryland Reliability department is concerned that the Fault Tree Analysis NASA is performing in association with the Columbia mishap is not using basic PRA tenets. At this point Mr. O'Connor interjected that PRA is not normally used in accident investigations.
    - PRA is a predictive decision support tool that uses a scenario based approach.
    - NASA is currently using both techniques for decision support issues, scenarios and fault trees.

- Mr. Buzzard indicated that fault trees and PRA use different approaches that usually give approximately the same answer.
- Mr. Bradley indicated that NASA was doing a PRA to "backfit" the Shuttle Program.

- Admiral Gehman stated that NASA has processes to quantify and bound risk. We are operating a hand-made machine operating at the edge of the envelope with lots of risk. He wondered if there experts out there who would look critically at how NASA treats and manages risk. Given the same set of conditions would those experts come up with the same mathematical model? Would they say NASA is not applying the model correctly or would they say NASA is understating risk? Should the board review how NASA treats and manages risk? The board may need to hire an expert on risk.
  - Mr. O'Connor agreed that the board needs to examine how NASA manages risk. It was a big deal during the Challenger mishap investigation and should be a big deal during the Columbia mishap investigation.
- The Mission Evaluation Room (MER) visit was helpful.
- Interviews have been conducted with John Young, Ralph Roe, and Linda Ham. Information about those interviews may be found in the interview transcripts.

Group 3 – Mr. Tetrault:

- The video analysis working group believes 3 pieces of debris hit the shuttle. NASA believes the object that appears to be moving upwards was in fact not moving upwards. Radar data confirms the conclusion of no upward movement. A 3-D analysis will be performed.
- The group is having an overview of the landing gear area today in preparation of traveling to KSC. The Mission Operations Directorate (MOD) Mechanical Maintenance Are and Crew Systems Team (MMACS) team will also be there to answer questions regarding hydraulics.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are listed below:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Major General Hess	CAIB	281-283-7512
Mr. O'Connor	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mr. Bradley	CAIB Ex. Secretary	281-283-7525
Mr. Hartman	Recorder	281-283-7591
Frank Buzzard	NASA CTF	281-483-8412
Rick Burgess	CAIB Support	281-283-7566
Matt Granger	CAIB Support	281-283-7567
Don White	CAIB Support	281-283-7570
Pat Goodman	CAIB Support	
Doug Cooke	CAIB Support	202-329-8844
Dave Pyne	CAIB Support	281-283-7549
Johnny Wolfe	CAIB Support	281-283-7543
Dr. James Smiley	CAIB Support	281-283-7545
Dr. paul Wilde	CAIB Support	301-775-6797
Bill Sikora	CAIB Support	281-283-7564
Jim Bagian	CAIB Support	281-283-7563

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 24, 2003
These Minutes Contain No Sensitive Data

Purpose: Shuttle Tile and Risk Presentation
Elizabeth Pate-Cornell, Professor of Engineering @ Stanford Univ.

Date: 24 February 2003 **Time:** 0900

The list of attendees is appended to the end of this report.

Handouts provided at this meeting can be found on the CAIB PBMA website.

There were no action items or requests for information generated from this meeting.

Following the Challenger mishap, NASA Headquarters asked Prof. Pate-Cornell to perform risk assessments on several Shuttle systems and sub-systems. For various reasons the Thermal Protection System (TPS) was chosen and tile bonding was the focus. The study results presented at this meeting cover the first 33 flights of the Space Transportation System. The study was completed in 1990.

The main focus of the risk analysis performed on the TPS was to answer the question: How many cycles could the tile bonding take gracefully? The study was interested in loss of flight crew and vehicle due to tile failure.

It was determined there were 2 primary causes of tile failure:

- Poor bonding
- Debris strikes from objects on the pad, ice, or insulation from the External tank (ET) or Solid Rocket Boosters (SRB).

A map of debris strikes on the orbiter fleet from the first 33 flights was supplied by Rockwell Corp. There was a pattern of some concentration under each wing. The proximity of an ET fuel line seemed to be linked to the concentration of debris hits that was observed.

Not all of the 25,000 tiles on an orbiter are equally responsible for the risk of losing a shuttle. They are not equally subjected to dynamic forces nor are they equally subjected to the same heating loads. Additionally, all tiles do not protect the critical systems.

Admiral Gehman asked where incorrectly manufactured tile fits into the picture. ANS: This subject was not looked at because it was felt the bonding problem was more severe.

The following scenario was used:

- There would be a loss of 1 to 4 tiles because of a debris strike.
- Turbulence and heating causes the loss of adjacent tiles (zipper effect)
- There is the possibility of burn through the aluminum skin.
- There is the possibility of the loss of critical systems such as hydraulics, avionics, crew cabin, wheel wells.

The risk is the probability of the initiating event occurring and the probability of the remaining events in the scenario occurring.

As shown on Page 73 of the final report of the study, approximately 15% of the tiles account for 80% of the risk. Pages 67 and 68 of the report show trajectories and possibilities of foam debonding from the ET.

The models were extended to see how human and organizational factors could impact the technical reliability.

- Kennedy Space Center (KSC) was visited and technicians were interviewed who had discovered 12 poorly bonded tiles during inspections and tests covering approximately half of the tiles in the whole Shuttle fleet. There was no speculation or attempted extrapolation regarding an upper bound. From a purely statistical perspective, there were 12 more poorly bonded tiles in the fleet.
- There was in use at KSC a pull test which was designed to uncover poorly bonded tiles but since only 10 PSI was used in this test poorly bonded tiles were escaping detection. This was due to the desire to not damage the tiles being pull tested.
- NASA also has a few trained technicians who are trained to perform a wiggle test on random tiles to feel by hand to see if they are coming loose.
- It was learned that surface roughness of the tiles is also a concern because this condition causes laminar flow to turn into turbulent flow earlier.
- It was not possible to check the application of foam to the ET and SRB because there was no travel to MSFC.

The study also looked at management factors.

- The tile technicians were under tremendous pressure because they were deemed to be the long pole in turning around a Shuttle.
    - A daily quota was levied against their work that was checked every day by the CEO of the contractor. A suggestion was made that a weekly quota would provide some relief for unforeseen occurrences.
    - There were several contractors involved in the tile work. They were located on both coasts. They worked for different NASA centers. There was poor communications between them. And, there was much "trench warfare".
    - Management was spoken to and they were flabbergasted.

Approximately a year after the study was completed, a follow-up was made to KSC and it was obvious they appreciated the work and took the recommendations seriously. Second-hand reports indicated personnel at JSC were not happy with the work. There were also reports that MSFC was trying to improve the installation of insulation on the ET.

Admiral Gehman wanted to know from a statistical or generic Quality Assurance perspective that would be a statistically relevant number of tiles to pull to failure to gain 3 Sigma assurance.
ANS: A large number of tiles would have to be pulled. It is believed there are non-destructive testing (NDT) techniques such as ultra-sound that can be used to see the bond.

Admiral Gehman asked what kind of statistical methods could be applied to NDT? ANS: Very simple – determine how many fail the pull and wiggle tests to determine how many are poorly bonded out of the 75,000 tiles on the vehicles remaining in the fleet.

There was a question on whether the depth of tile damage was a factor in the study. ANS: It was very unsophisticated study; the assumption was made that there was at least a 1-inch layer left.

Admiral Gehman wanted to know the probability of tiles surviving a zipper test. Following a discussion about the test techniques it was indicated that NASA is preparing to conduct a zipper test.

The study did not look at the reinforced carbon-carbon (RCC), only the tiles.

Mr. Hubbard announced that Prof. Pate-Cornell would be available until 1430 hours for detailed discussions and the meeting adjourned.

These minutes are hereby submitted for the record.

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Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
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Mr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Mr. Tetrault	CAIB	281-283-7509
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Bill Sikora	CAIB Staff	281-283-7564
LtCol Don White	CAIB Staff	281-283-7570
Jim Arnold	CAIB Staff	
LtCol Thompson	CAIB Staff	281-283-7573
Dave Pyb	CAIB Staff	281-283-7549
Dr. Jim Smiley	CAIB Staff	281-283-7545
Bob Vallaster	CAIB Staff	281-283-7578
Lisa Chu-Thielbar	CAIB Staff	
Tony Griffith	CTF Support	281-244-5813
Robert Carvalho	CAIB Staff	281-283-7575
Alan Balusek	CTF Support	281-244-7392
Gordon Ducote	CTF Support	281-483-8557
Ron Gress	CAIB Staff	281-283-7532
Mike Francis	CAIB Staff	281-283-7574
Paul Wilde	CAIB Staff	301-775-6797
Jim Bagian	CAIB Staff	
Tom Haustian	NTSB	202-314-6302
John Clark	NTSB	202-257-0121

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 24, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

The list of attendees is appended to the end of this report.

There were no action items or requests for information generated from this meeting.

Admiral Gehman opened the meeting at 1300 hours by outlining the agenda: a demonstration of a reconstruction graphics tool to be followed by a short brainstorming session using the GroupSystems Meeting Support Software.

Reconstruction Graphics Tool:

Joshua Lane demonstrated the Reconstruction Graphics Tool following an introduction by General Barry who recommended the Admiral take this tool with him on a laptop to use while meeting with the various Congressmen during the forthcoming trip to Washington.

Three views of Columbia were shown: view from above and behind the orbiter followed by views of the left wing from above and below. This was followed by a map of the debris field showing actual plotted points where debris has been recovered. A 4th video sequence showing debris strikes during launch will be added. The video ran at 2 times the real time speed. For the wing views, a green sensor indicates normal readings, a yellow sensor indicates high readings, and a red sensor indicates a lost sensor.

Admiral Gehman noted that the altitude display indicated the Columbia was not descending very fast. Mr. Buzzard explained that this was normal because at this point in the flight the object was to get through the peak heating period by balancing the angle of attack.

Admiral Gehman expressed interest in knowing which wing sensors never showed anomalous readings. Mr. Buzzard indicated that the number is of the order of 7 to 10.

After completion of the demonstration, Admiral Gehman requested Mr. Lane make several adjustments to the video:

- Change those values with large decimal values to whole numbers
- Add the relevant temperature sensors that stayed within family to show section of the wing where there was no heating.
- Put some sort of an audio cue whenever a sensor is going to change color. Mr. Lane responded that he wasn't sure an audio cue was possible but a visual cue could easily be added.

Mr. Wallace asked if the debris database was available as yet. Mr. Bradley responded that KSC and Barksdale have put together elements of a debris database but these elements have not been integrated.

General Barry indicated that he believed that when the debris events and voice transmission data are superimposed over this video it will become quite clear that the flight crew were unaware that Columbia was shedding debris.

At this point a short break was called so the computers could be configured to support the brainstorming session.

Brainstorming Session:

Admiral Gehman explained that the purpose of this session was to supplement the investigatory themes previously agreed to for each working group.

The GroupSystems Meeting Support Software produces a report that is appended to these minutes.

Following the session, Admiral Gehman requested that for future sessions using this software the computers be prepared before the meeting commenced and that "time-out" parameters be adjusted so the machines did not time out.

Admiral Gehman then asked the board if they thought there was enough work identified in areas of policy, culture, rules of engagement (who and what should fly on the Shuttle), management, contracting strategy, outsourcing, and other non-technical topics to warrant establishing a 4th working group and expanding board membership by 1 or 2 members. There then followed a wide ranging discussion of these subjects. When General Barry cautioned against the board getting too involved in non-technical, non-mishap related areas Admiral Gehman indicated that his desire to not impact the current focus and momentum of the board was causing him to lean towards another working group and expanded board membership to address these issues. He indicated he was being pushed towards addressing these issues. Admiral Gehman asked for board concurrence to expand the board by a member or two and to add a 4th working group. There were no dissenting views.

At this point the board moved into executive session.

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Columbia Accident Investigation Board

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Rick Burgess	CAIB Staff	281-283-7566
Doug Cooke	CAIB Staff	202-329-8844
Tyrone Woodyard	CAIB Staff	281-283-7565
Laura Brown	CAIB Staff	281-283-7565
Pat Goodman	CAIB Staff	
Dave Pye	CAIB Staff	281-283-7549
Mark Worden	NASA	281-244-2941
Dave Lengyel	CAIB Staff	281-283-7581

BRAINSTORMING SESSION MINUTES:

Agenda - CAIB Organization Brainstorming

2/24/2003

1:00 PM **Introduction**
Brainstorm and Compile Additional Investigation Items

1:10 PM **Brainstorm items for Groups 1 - 3 (Categorizer)**
Brainstorm and Compile additional Investigation items

1:40 PM **Discussion**

Brainstorm items for Groups 1 - 3 (Categorizer)

Participant Instructions

Brainstorm and Compile additional Investigation items

Brainstorm items for Groups 1 - 3

Group 1: Material

1. Design
2. Modifications
how design assumptions chnaged with time

3. Vendors
4. Quality assurance
5. Inspections
6. Aging Platforms
7. STS Integration
8. management
9. Boards / Committees
10. Internal processes
11. Working group - Debris sighting
12. Working Group - ET
Do we have closeout photos of the heater and cap area?

13. Working Group - SSME
14. Working Group - Reusable Solid Rocket Motor
15. Working Group - SRB
16. contract oversight
17. relationships between NASA centers
18. wiring aging

19. How did KSC control Bolts?
20. How did KSC Document tile repairs?
What tiles on Columbia are the original tiles?

21. review all relevant previous top level outside program reviews looking for repeat items
22. Relationships between departments
23. What LESS stem disassembly occured prior to STS-107?
24. What would the ET look like if designed from a clean sheet of paper with today's technology?
25. What is the shielding on the wires that are used in the left wing?
26. Was the heater working at takeoff?
27. look at culture issues (work force, leadership)
how has the experience of the engineering staff changed with time

28. Maintenance

Group 2 : Operations

1. Crew Factors
2. Mission Control
3. Mission Planning
4. Payload
5. Training
6. Mission Management team
7. FRR
8. Boards and Committees relted to Flight Ops
9. Working Groups - MIT
10. Working Groups - EOC
11. Working Groups - Systems integration
12. Crew escape and survivability
13. Safety process integration
14. safety culture
15. The big debate-who should fly and why?
16. risk/gain/cost of manned flight vs unmanned
17. Conditions for return to flight.
18. assumption that shuttle is operational - consequences
19. Justification of payloads--what should fly and why.
20. Determine whether lawyers fold, wrap, or detach their dorsal fins in civilian clothes
21. how does assumption of "operational" status affect decisions?
22. attention to minority views in anomaly resolution
23. Impact of SFOC contract on operations
24. Review of go/no-go decisions
25. how are the experiences of the emeritus staff incorporated

26. how has the
27. organization: authority, clarity, responsibility
28. Connectivity between shuttle elements
29. How can the risks of spaceflight be best understood and explained to the public.
30. payload integration

Group 3 : Engineering and Technical Analysis

1. Flight Telemetry
2. Debris Analysis
3. Independence Testing and Analysis
4. Reconstruction
5. Photographic and Videographic Analysis
6. Working Groups - Orbiter
7. Working Groups - Data and Record Handling
8. Examining analysis of prior flight anomalies
9. Evaluating foam application on the shuttle side of the ET (versus slick/metal) and did anyone change the process?
10. Evaluating the change to ET foam in the late 90s, its testing, and design/mix changes, if any
11. Should there be improved recording/telemetry capability--what should be recorded that was not?
12. Examine STS-107 versus other Columbia ascent/entry
13. Evaluate previous tire failure mode testing and applicatioon of results to orbiter design/modification
14. What new investigative techniques were used in this investigation and how can they be enhanced
15. start directing independent studies
16. Evaluate prior testing of wheel well pyrotechnic failure modes and application to orbiter design/modification
17. determine debris testing procedures
18. take charge of requests for minor cleaning and testing at KSC
19. Propose making tracking of STS a routine/continuous tasking for DoD assets

Independent Analysis

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 27, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 27 February 2003 **Time:** 1300 - 1405

The list of attendees is appended to the end of this report.

There were no presentation materials used at this meeting.

There were 7 action items generated from this meeting that are listed at the end of this report.

Mr. Tetrault reported via telecon from KSC. He provided a number of gross-order preliminary observations related to recovered debris at KSC:

- He saw no piece of debris larger than a man of his stature.
- It was sad to see the scale of destruction on the shop floor.
- While much of the debris has not yet appeared on the reconstruction hanger floor one can begin to see things.
- It is going to be difficult to pinpoint where the heat and breach occurred because of the significant amount damage from reentry. He anticipates struggling with ballistic coefficients and being able to tell whether damage was caused by the incident or during the heat of reentry.
- All tires have reportedly been recovered. The 2 left tires are completely blown while the condition of the right tires is quite different. It is possible to tell where the tires were mounted because of the patches on the tire.
- Of the 35 tanks on Columbia, some 25 have been recovered intact.
- Engine pieces approximately 2.5 feet long were observed while Mr. Tetrault expected to see an engine. It is clear that the engine broke up upon reentry or upon hitting the ground.
- A large 4 inch by 2 inch hole was observed to have been burned into the hydraulic fluid reservoir from the left elevon. It is a good bet that the hydraulic fluid escaped through this hole.
- A piece of landing gear strut has been recovered. We cannot tell if it is from the left or right side but there is a very large hole burned into the upper portion.
- There is an 80% probability that landing gear recovered is the left landing gear. It contains a large burned area on the front end facing forward but we cannot tell if the burning was caused by the mishap or the reentry. No pieces of the left wheel well door have been recovered as of yet while almost the entire right wheel well door has been recovered.
- A number of tiles have been recovered and have been placed in 105 small plastic boxes. Virtually all are severely damaged. There is a coating of what appears to be soot covering the white part of the tile. This is unique in that the soot was not observed from tiles damaged on previous missions.
- Damaged tiles from previous missions were examined. Even for small holes it is obvious that things got very hot due to the presence of glass beads that indicate temperatures were

at the melting point. Even small holes show presence of turbulent air-flow. One tile from a previous mission contained a hole that was believed made by a piece of ice striking it at a 30-degree angle. The hole was 1 inch in diameter. It created a wormhole penetrating to the vehicle's metal skin. This shows that even small holes can spell disaster. Mr. Tetrault had not previously seen the wormhole effect.

- KSC has a labeling system only for tiles with damage greater than 1 inch. This does not seem to be an adequate system because by ignoring smaller areas of damage the system does not describe what is happening and a true assessment of the TPS cannot be made.
- Debris from 16 of 20 leading edge areas from the left side have been recovered. One piece of Reinforced Carbon-Carbon (RCC) from or near position 12 is covered with what looks like aluminum splatter. There is a piece on the shelf from position 9 which is also covered with what looks like aluminum splatter as well as some gold colored material which could be copper, inconel, or something else.
- There are many more questions than answers that will be difficult to get to the bottom of. We believe this will eventually be put together.
- Mr. Hubbard had a question as to whether there had been any proposals for conducting non-destructive testing (NDT)/non-destructive evaluation (NDE). ANS: We have seen some things such as the sprayed on aluminum/gold colored metal that should be pursued. NASA seems to be slow at initiating testing because their current priority is to get the debris into the system, catalogued, and onto the reconstruction floor. Suggested that some of this analysis could be done in parallel. Mr. Tetrault believed the strut area is on the critical path.
- Admiral Gehman asked if the Mishap Response Team (MRT) was the best way to energize metallurgy and testing activities. ANS: Correct; Mr. Tetrault believes that NASA/KSC is not yet organized to address testing issues . Most of the debris found so far has been late breakup; early breakup debris would be more telling.
- Admiral Gehman asked if KSC needed any more authority from the CAIB in order to help their progress. ANS: Do not think so. The CAIB now has a staff member resident at KSC. That staff member has been tasked with providing a total listing of all left wing items on the floor of the reconstruction hanger.
- There is a need to understand where debris landed so that an attempt to extrapolate where it might have been shed can be made. A map detailing this information has been requested and the National Transportation Safety Board (NTSB) has agreed to perform this analysis.
- Admiral Gehman requested an up to date picture of the floor of the reconstruction hanger. ANS: That is already in work.
- Dr. Widnall asked a question regarding whether a list of laboratories and other facilities that could help with NDE was available. ANS: There is a pretty good NDE laboratory at KSC; however, very sophisticated tests will have to be sent outside.

Group 1

- Maj. General Barry reported on his Palmdale trip.
    - A storyboard on the subject of tiles will be provided.
    - Palmdale still does some orbiter work; external tank valves (17 in. disconnects) and some cold plates.
    - When the Orbiter Modification and Maintenance (OMM) work moved from Palmdale to KSC, only three of 300 employees transferred. There was no

transition team. The decision was made quickly and implemented rather abruptly. The GAO report on that activity will be reviewed.
  - Of the 8 OMMs done at Palmdale, 4 of them were done on Columbia. Of interest, the last Columbia OMM was stretched from 10 to 17 months due to major problems discovered to the kapton wiring. Some 9500 wiring repairs were made.
  - A lot of masking-type tape was left in the left wing after the last Columbia OMM. It was discovered and removed.
  - An RCC lockout bolt was incorrectly installed during the last Columbia OMM. Its installation was reaccomplished in order to get the RCC correctly aligned. There is high confidence this was correctly performed since there was no problem on STS-109 (Columbia's last flight prior to STS-107).
- Rear Admiral Turcotte reported on his trip to Thiokol.
  - He was very impressed by the tool control, quality control, and overall thoroughness of the work.
  - While the buildings at the refurbishment facility are antiquated, the equipment first-rate, and operation is the finest depot operation he had seen.
  - At the assembly area there are 26,000 X-Rays taken of poured materials.
  - Thiokol performs thorough and complete ultrasound NDE after assembly of the entire Reusable Solid Rocket Motor (RSRM).
  - Rear Admiral Turcotte spoke with Thiokol supervisors and employees. There is high work force morale and a lot of enthusiasm. This is a well organized operation.
  - One issue was uncovered and paper is coming shortly: A 4 foot crack has been discovered in the main boot where it attaches to the phenolic bearing assembly. Thiokol is investigating what happened. Telemetry from the Columbia launch indicated the equipment performed nominally.
- Maj. General Barry then continued with the Group 1 Report.
  - Questions have been asked on the CRATER software tool. It is becoming clear that not too many people understand it.
  - The SRB/RSRM is a leading candidate for exclusion from the list of possible causes.
  - NASA will de-stack Atlantis and is looking at being able to launch on 6 weeks notice but not earlier than 7/21/2003.
  - A human factors expert is being brought in to look at management decisions and to try to understand why the E-mail traffic and decisions did not get any further up the management chain.
  - Paper process reviews are being conducted at both Palmdale and KSC.
    - Palmdale is looking at approximately 250,000 pieces of paper associated with critical areas of the left wing only and are about 28% finished.
      - Maj. Gen Barry was confident in the review process. There are at least 4 reviewers for each piece of paper, 1 each from NASA, USA, Boeing, and an independent person.
      - It should be noted that Palmdale is reviewing copies of their paper as the originals are kept at KSC.
      - There have been 2 findings to date. Both findings concern the RCC coming out of OMM and involve pinholes in the material

that were within specification. Maj. Gen Barry does not think these are a major mishap issue.

- The KSC paper review is also focusing on the left wing.
  - There have been 500 findings at KSC, however, the 2 locations use different definitions to determine findings. Maj. Gen Barry has asked for some commonality.
  - A vulnerability assessment has also been requested.
  - There have been 5 TPS findings for such things as corners.
- Both KSC and Palmdale have been striving to complete their paper reviews by April 1. Both have been asked to accelerate the review to the middle of March if physically possible.

- Mr. Hubbard indicated his group (Group 3) has requested a copy of CRATER and felt that both groups needed to coordinate. Gen Barry agreed and indicated his group (Group 1) was only looking at the management aspects.
- Maj. Gen Barry indicated most RCC inspections were visual. There is a new process called infrared thermography which offers promise and may be the subject of a CAIB recommendation for its adoption.
- Maj. Gen Barry has asked for an explanation of how debris field maps could be used for analysis, i.e. burn patterns.
- Maj. Gen Barry said he believes we can start thinking about theories about the mishap. He believes we know what happened but we don't know where the initiating event occurred or why it occurred: Hot superheated air entered through the rear of the left outboard landing gear door.

- Mr. Wallace reported on his trip.
  - He learned about differences in the handling qualities of the Orbiters. He spoke to Andy Allen, USA's Associate Program Manager (APM) for Ground Operations at KSC and a former astronaut, who indicated that he believes this phenomenon is more a function of how the Orbiters are loaded for each individual mission.
  - Mr. Wallace reported that he was informed about "unofficial mission procedures" which were used but not certified for use.
  - A meeting with the organization responsible for Certification of Flight Readiness (CoFR) revealed that the STS-107 process was mostly by the book with a few inconsequential waivers.
  - Mr. Wallace indicated there are areas of improvement that should be brought forward by the CAIB even though they were not a causal factor to the Columbia mishap. Such areas include the Checkout and Launch Control System (CLCS) at KSC and telemetry upgrades to increase the data that is downlinked. For example, 3 cameras film the ET during launch but that data is not downlinked because of bandwidth restrictions.
  - The launch day video review was determined to be normal. Ice debris from the umbilical occurs on all flights and is normal. The launch day Video Team will produce 4 categories of reports: significant anomaly, minor anomaly, funnies, and observations.

Group 3 – Mr. Hubbard

- Mr. Hubbard reported that the group requires approximately 6 persons to be deputized to formally represent the group.
- Group 3 has been following the ET foam debris and TPS damage thread. NASA seems to be making heavy reliance on math models without using actual video of things hitting the underside of orbiters in flight. There is a question as to how NASA has established a cause and effect relationship between hits and damage to the TPS.
- The 1999 tile impact study by Southwest Research Institute (SwRI) cannot be extrapolated to this mishap.
- Admiral Gehman asked whether the foam was designed to come off at launch. ANS: No; the fact that it comes off at launch is a continual system failure and the foam should not impact the orbiter at all. Admiral Gehman asked whether this system (ET Foam), which is not operating as designed, is sending a message to the CAIB. He indicated that the CAIB needs to examine how NASA treats this continuing failure.
- Admiral Gehman then asked whether the fact that the ET on the first two STS flights was painted essentially sealed the foam on those tanks. He charged the CAIB to look at whether there was foam shedding on the first 2 Shuttle flights (STS-1 and STS-2).
- The group is following up on NASA's thermal analysis which is getting more sophisticated every day. The NASA working group is not just doing static analysis but is looking at forming the formation of heat plumes and other dynamic phenomena.
- There is speculation that the soot observed on some items of the debris is pyrolized (burned) hydraulic fluid.
- Group 3 is attempting to find a way to find a way to explain the environment (the heat) to the public.

Dr. Widnall:

- Dr. Widnall is going to KSC on Monday (3/3/2003).
- She expects to receive a thorough aerodynamics briefing on Tuesday.
- Dr. Widnall believes there needs to be a credible space weather analysis including solar flares, shock waves, etc.
- She has requested an "after action" report on anomalies from STS-109.

Group 2 – Gen Hess:

- Group 2 works with training, Life Sciences, and payload organizations is moving forward.
- There is very little independent analysis to prove that basic assumptions made very early in the Shuttle Program are still valid.
- Group 2 is starting to look at Mission Management Team (MMT) post-launch operations.

Mr. O'Connor then offered the following observations:

- The CAIB should pursue whether both tires blew or one caused the other to blow. The chance of both tires blowing at once is very low. The CAIB really needs to try to piece together what really happened to the tires. He believes they are very important.
- Mr. Wallace indicated that the top Michelin people are in route to KSC to assist in the investigation.
- Admiral Gehman agreed that the tires are more important than some other pieces.

The meeting adjourned at 1405 hours.

Identified Actions

- Action from Mr. Tetrault to the NTSB to provide a map of where all debris from the left wing of Columbia landed.
- Action from Admiral Turcotte to Thiokol to provide a report on the investigation results of the crack in the STS-107 RSRM main boot.
- Action to Group 3 to deputize 6 persons to formally represent the group.
- Action from Admiral Gehman to the NASA Space Shuttle Program to provide an explanation as to how NASA deals with External Tank (ET) foam shedding at launch.
- Action from Admiral Gehman to the CAIB to investigate whether there was ET foam shedding on STS-1 and STS-2, when the ET foam was painted.
- Action from Dr. Widnall to the NASA Space Shuttle Program to provide an "after action" report on anomalies from STS-109.
- Request from Admiral Gehman to NASA KSC to provide a current photograph of the floor of the reconstruction hanger.

These minutes are hereby submitted for the record.

Approved
FOR
Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 27, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME		ORG.	PHONE
Admiral Gehman		CAIB	281-283-7537
Major General Barry	(Via Telecon)	CAIB	281-283-7526
Brigadier General Deal	(Via Telecon)	CAIB	281-283-7507
Mr. Hallock		CAIB	281-283-7518
Major General Hess		CAIB	281-283-7512
Mr. Hubbard		CAIB	281-283-7517
Mr. O'Connor	(Via Telecon)	CAIB	281-283-7511
Mr. Tetrault	(Via Telecon)	CAIB	281-283-7509
Rear Admiral Turcotte	(Via Telecon)	CAIB	281-283-7557
Mr. Wallace	(Via Telecon)	CAIB	281-283-7508
Dr. Widnall		CAIB	281-283-7579
Mr. Bradley		CAIB Exec. Secretary	281-283-7525
Joe Hartman		Recorder	281-283-7951
John Shannon		CTF	281-483-8408
LtC. Goodman		CAIB Staff	x7569
Jim Smiley		CAIB Staff	x7545
Dr. Jim Bagian		CAIB Staff	x7563
Don White		CAIB Staff	x7570
Lisa Chu-Thielbar		CAIB Staff	x7568
John Clark		NTSB	202-257-0121
Dave Lengyel		CAIB Staff	281-283-7581
Laura Brown		CAIB Staff	x7565
Woody Woodyard		CAIB Staff	x7520
Steve Schmidt		CAIB Staff	x7820
Elizabeth Fountain		CTF	281-483-5257

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 28, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 28 February 2003 **Time:** 1300

The list of attendees is appended to the end of this report.

There were no presentation materials used at this meeting.

There was one action item generated from this meeting.

Admiral Gehman introduced LCol Mike Bloomfield, USAF who will be taking Mr. O'Connor's place.

Admiral Gehman urged the board towards making greater efforts in testing. Mr. Hubbard identified 4 areas where testing could profitably be done quickly:

- The "sooty stuff" on the tiles which looks like pyrolized hydraulic fluid.
- Tiles that have significant impacts.
- Slag-like areas.
- Burn through areas on the RCC.

Mr. Hubbard felt this testing could be done quickly from a technical perspective however; there is an issue with getting the required paper through the MRT. He reported that Dr. Kovacs is very impressed with NASA's testing facilities. He believes an X-Ray fluorescence test could be done very quickly on the slag-like material.

Mr. Hallock reported he is still in the process of getting his arms around the fault tree issue. He is also spending some time on the space weather issue.

Admiral Gehman initiated a discussion concerning board progress to date. He indicated that by the end of the 4th week after the Challenger mishap the investigating team knew what happened and the CAIB still does not know what went wrong with Columbia. He asked the board if there were things that could be done more aggressively.

- Dr. Hallock responded that he is having trouble getting materials he has requested. It takes a week to 10 days.
- Dr. Hubbard suggested that getting closer to the lower-level NASA working groups would speed things up to a certain extent.
- Mr. Hubbard then offered an approach of concentrating on a few potentially high payoff scenarios. He cautioned that this approach goes against the grain of looking at everything that is on the table.
- Dr. Hallock then stated he was starting to write down scenarios. He indicated he needed additional staff in the areas of fault trees and sensors. Admiral Gehman urged the acquisition of additional staff.

Mr. Hubbard reported that he had received a briefing and full-blown demonstration of Investigator Organizer (IO) and he believes this software tool will be useful. He is also writing up a "follow the foam" scenario.

MGen Hess reported his team at KSC will be finished following discussions with the guidance and control team. Admiral Gehman said he is interested to get impressions of what was happening about the foam, etc.

MGen Barry reported from MSFC.

- MGen Barry suggested building a large schematic similar to a fault tree which would point to who said what and when and would also show who knew what and when. He recommended a similar approach to analyzing the photo request.
- MGen Barry reported MSFC had built their own fault trees that are not integrated with the JSC built fault trees. There is a meeting Monday *(March 3)* to accomplish that integration.
- MGen Barry suggested the closeout process on non-factors needs to be agreed upon. He believes the first candidate for closeout will be the Space Shuttle Main Engine (SSME) in about 1.5 weeks. He envisions the SSME team will appear before the CAIB with a briefing requesting closeout. He believes the closeout request will list recommendations such as acquisition of a wind radar to determine winds at altitude prior to I-Load selection.
- MGen Barry reported ET-93 was mated, demated, and mated again. This needs to be looked at.
- Post-launch analysis indicated a pretty significant wind shear at 32,000 feet. It caused the second highest left SRB Thrust Vector Control (TVC) maneuver ever. These maneuvers occurred on STS-90 and STS-107; both of which were Columbia flights. MGen Barry indicated this was a possible area to look into for stress and load conditions.
- MGen Barry reported that Southwest Research Incorporated (SRI) is looking into taking the wheel well door off the Shuttle Enterprise to use as a target for their impact testing. Mr. Hubbard indicated he is aware of this approach and will visit SRI on Tuesday *(March 4)* to assess their test planning and evaluate their facilities.
    - Mr. Hubbard then asked MGen Barry to try to run down an allegation regarding the use of the wrong glue on the ablative material.
- MGen Barry then reported that MSFC requires a more comprehensive computer model for assessing debris impacts. MSFC believes they need a more physics based model which utilizes more empirical data.
    - Admiral Gehman observed that sooner or later we were going to have to do a "frozen chicken test" on a representation of the underside of the wing and the main landing gear door. Mr. Hubbard agreed and added that a test of the Reinforced Carbon-Carbon (RCC) and its associated support structure is also required. He suggested this would not just be about hitting tiles and measuring craters.
- MGen Barry then responded to Admiral Gehman's earlier question on suggestions to pick up the pace of the investigation. He suggested that the board needed to get going on writing the report, interviews could be speeded up, and scenarios should be built so they can be discussed and analyzed. He indicated it was not too early to talk about findings,

causes, and recommendations. MGen Barry said he has added people to accelerate things in human factors and materials stress analysis.

RAdm Turcotte then reported:

- That there is a very significant amount of paper generated for a Shuttle flight. Thus far, reviews of this paper has not revealed any major findings; just a lot of little things such as missing or wrong dates, etc.
- RAdm Turcotte believes the debris field pattern is important and recommended a plot of where left wing pieces have been found. There have been many pieces found to date and such a plot would facilitate directing searchers where to look for the rest of the pieces. This technique has worked in many past accidents.
- RAdm Turcotte reported the results of Non-Destructive Evaluation (NDE) related discussions:
    - No NDE is done as a matter of course during either the orbiter flow for a flight nor during the Orbiter Maintenance and Modification (OMM) period.
    - Some recent thermography tests have revealed pockets of delamination with the RCC.
    - Columbia had none of this experimental NDE done to it.
- RAdm Turcotte recommended that if the board looked at RCC consideration should be given to examining samples that were as old as Columbia.

BGen Deal reported from Patrick AFB (PAFB), FL:

- A Quality Assurance person, name and organization not identified, approached BGen Deal while he was at KSC and this person may have something to say. That person is considering whether to come forward officially and provide a statement.
- Security at KSC and Cape Canaveral Air Force Station (CCAFS) has been looked at and BGen Deal believes this item may be able to be closed out very soon.
    - NASA has an interim approval for active air defense and a permanent approval is needed.
- PAFB has impounded a pretty significant amount of data from range cameras, radars, etc. BGen Deal will examine this data with the PAFB Commanding Officer (CO) for disposition.
- BGen Deal reported that the United Space Alliance (USA) manager at KSC is concerned that ground processing is being implicated as a factor in the mishap. He assured the USA person that this was not true.

The meeting adjourned at 1335 for an executive session to discuss potential new board members.

Identified Actions

- CTF/CAIB require an agreed to closeout process for major elements (e.g. SSME) which may include a formal presentation to the Board and closeout form.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
February 28, 2003
These Minutes Contain No Sensitive Data

Attendees were as follows:

NAME		ORG.	PHONE
Admiral Gehman		CAIB	281-283-7537
Major General Barry	(Via Telecon)	CAIB	281-283-7526
Brigadier General Deal	(Via Telecon)	CAIB	281-283-7507
Dr. Hallock		CAIB	281-283-7518
Major General Hess		CAIB	281-283-7512
Mr. Hubbard		CAIB	281-283-7517
Mr. O'Connor	(Via Telecon)	CAIB	281-283-7511
Rear Admiral Turcotte	(Via Telecon)	CAIB	281-283-7557
Joe Hartman		Recorder	281-283-7951
Dave Lengyel		CAIB Staff	7581
LtC. Mike Bloomfield		CAIB	281-244-2233
Steven Schmidt		CAIB Staff	202-494-9162
John Clark		NTSB	202-257-0121
Don White		CAIB Staff	7570
Dave Pye		CAIB Staff	7549
Jim Mosquera		CAIB Staff	7549
Wade Thompson		CAIB Staff	7573
Tyrone Woodyard		CAIB Staff	7565
Laura Brown		CAIB Staff	7565
Ron Gress		CAIB Staff	7532
Moose Cobb	(Via telecon)	NASA IG	202-358-1220

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 3, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 3 March 2003 **Time:** 1230

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA web site.

There were 2 action items generated from this meeting that are listed at the end of this report.

Admiral Gehman announced he had spoken to all 3 top candidates for CAIB expansion and all 3 had said maybe; no one said no.

The first item of business was a GroupSystems session on how to pick up the pace of the investigation. Admiral Gehman indicated he believes the CAIB can either focus on promising areas of investigation or go on as they are and hire more people. The purpose of this first GroupSystems session for the day was concerned with capturing all possible initiating events. The record of the session produced by the GroupSystems software is appended to the end of this report.

- The CAIB captured too many items to effectively deal with. All bullets were captured and will be turned into hypothetical statements.
- Admiral Gehman asked the CAIB if they felt comfortable in focusing on trying to develop 4 to 6 hypothetical statements. There was no dissenting opinion.
    - Mr. Pye indicated he believed it is clear that the Thermal Protection System (TPS) failed to protect the Shuttle because it was hit by ice, a piece of TPS fell off, it was designed incorrectly or some other reason. Admiral Gehman responded that he not sure of this externally induced scenario. The failure could have started internally and the TPS worked perfectly. Possible internal initiating events could include a squib going off, leak in the hydraulic system, wiring burned through, or other failures.

Dr. Hallock then gave a presentation on a hypothesis he is working on which has nothing to do with TPS failure.

- Dr. Hallock indicated that the NASA lower level working group meetings he is attending are extremely valuable.
- He then gave a talk dealing with the Vehicle Data Mapping (VDM) Team and an updated timeline.
    - Dr. Hallock's theory is that the breach occurred on the top of the wing and he is in the process of coming to a conclusion that the entire fuselage heated up, not just the underwing and wheel well.
    - He pointed out that no blankets or white tiles have been found. The blankets would have low ballistic coefficients and could have drifted out of the search areas.
    - Dr. Hallock indicated he had learned about a closeout panel forward of the left wing which had to be installed several times.

- Maj. General Barry then indicated he believed the orbiter could be shedding things and the crew would never be aware of it due to low dynamic pressure.
    - Mr. Bloomfield then indicated that except for the kick of the reaction control jets (RCS), the entry is a pretty benign ride.
    - Admiral Gehman offered some insight into telemetry analysis that is now reporting early Columbia control system activity that had not been seen on previous flights. While these observations indicate a very low level of control system activity, this is not in family.
- Mr. Hubbard then indicated that except for schedules, integration is not happening within the Mishap Response Team (MRT). For example, nobody doing thermal analysis at JSC has been to KSC to view the debris. RAdm. Turcotte added that nobody at KSC responsible for the debris has been talking to anybody at JSC. There needs to be a systems engineering /fault analysis team organized to integrate information across the whole effort.
    - Admiral Gehman then indicated he wants to identify specific tests or truth points to prove or disprove Mr. Hallock's and other hypothesis. A really big one of these tests/truth points is the thermal analysis to see if sufficient heat can get into the wheel well.

Maj. General Barry then distributed a preliminary failure scenario that hypothesizes that foam hit the bottom of the orbiter and punched a hole in the underside of the wing aft of the main landing gear door. He said External Tank (ET) debris strike tests are necessary. During his presentation he made points about the mate-demate-mate of ET-93, damage to the foam at the bipod interface, and that only visual inspections were accomplished with the exclusion of Non-Destructive Evaluation (NDE) techniques. Rear Admiral Turcotte then indicated he had uncovered some things which will "curl your hair" as regards older Reinforced Carbon-Carbon (RCC) segments.

Rear Admiral Turcotte then reported on his recent visit to the reconstruction facility at KSC. Admiral Gehman asked for help in understanding the daily KSC report; 22,000 pieces of debris at KSC, 15,000 identified, 14,300 in storage, and 700 on the grid. Rear Admiral Turcotte indicated many parts, especially internal parts, are not being placed on the grid and that he thought everything should be there. He also believes that the tanks, many of which have been recovered, should be placed on the grid. He indicated the orbiter is being reconstructed in 2 dimensions and upside down so the underside is facing a viewer standing above the grid.

- Rear Admiral Turcotte reported he had spent some 8 hours in the debris hanger and observed lots of questions from those working at the KSC facility about where certain items were found in relation to other items. He said this triggered an alarm bell within himself that integration of the debris databases needed to be done.
- Admiral Gehman then asked the board to ponder whether the CAIB should direct the MRT to initiate a 3 dimensional reconstruction of portions of the left side of the fuselage and the left wing in its entirety.
- It was revealed that scenarios are being developed showing that the breach started in many areas.
- Mr. Hubbard had a question relating to the KSC personnel. RAdm. Turcotte indicated that KSC is still in organizational mode and had not moved into analysis and testing. They have done a great job laying out the debris and need to align the debris along the fuselage so the metal starts talking to us.

- There then ensued a long discussion about the left wheel well pictures.
- Admiral Gehman proposed a theory that the data seems to be pointing towards an idea that the entry point of the heat is closer to the point where the left wing attaches to the fuselage than may have been previously thought. RCC sections 12 to 15 show a little bit of slag, but not much, and are pretty much intact. Also of concern is the fact we have sections RCC panels 12 – 15, with nothing on 9 – 12, and nothing on 4/5 – 9. Where are they?
- The left tires were blown completely inside out. Rear Admiral Turcotte said he had never seen anything like that. The right tire which has been recovered shows a standard breach pattern.
- Rear Admiral Turcotte reported that the full right wheel well door has been recovered but none of the left wheel well door has been recovered. He wondered if the left door was lost early. Rear Admiral Turcotte indicated he is developing a theory that the wheel well somehow got hot enough to cook off a pyro.
- Rear Admiral Turcotte then introduced a briefing on thermography test results that were obtained under witness privilege. He distributed a short handout all of which were returned to him at the conclusion of the briefing. No minutes of this portion of the CAIB meeting were taken.
- Rear Admiral Turcotte then discussed the paper review being conducted at KSC. Over 1 million pages of documentation are being reviewed. The Rear Admiral is concentrating on some 200 Work Authorization Documents (WADs). He said KSC has an awesome system with many fail-safes built in no matter who performs the QA function. The KSC review team is being very critical and he saw nothing that was alarming, just 3 or 4 concerns.

Maj. General Barry then showed the CAIB two animated videos that are being developed. One showed the heat buildup in the period before the breakup and the other was of the launch sequence. He indicated that Josh Lane, who is doing these for Group 1, is available to the other groups to animate other potential scenarios.

At this point Admiral Gehman directed the members back to the GroupSystems scenario development. The purpose was to identify a half dozen more plausible scenarios that can the CAIB can focus upon. The following 6 scenarios were agreed to:

- Launch debris
- Shuttle shedding
- Orbital debris
- Internal anomaly
- TPS failure other than debris strike
- Aging Orbiter unique attributes caused premature transition to turbulent airflow.

Maj. General Barry than added that he is starting to deal with closeouts and expects Space Shuttle Main Engine, Solid Rocket Booster, and Redesigned Solid Rocket Motor to be among the first items proposed for elimination from further consideration.

Admiral Gehman again directed the Board to the GroupSystems computers for a brainstorming session to identify facts that are currently indisputably known. The CAIB identified 43 items of

which 22 were agreed to be facts and 21 either were not factual or still need more work to be certified as factual.

Identified Actions

- Action from Admiral Gehman to the NASA Space Shuttle Program to organize an intercenter systems engineering /fault analysis team to integrate information across the entire debris collection effort.

- Action from Admiral Gehman to the NASA Space Shuttle Program to integrate the debris collection databases.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

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Mr. O'Connor (Via Telecon From NASA HQ)	CAIB	281-283-7511
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mr. Hartman	Recorder	281-283-7951
Mr. Buzzard	CTF	281-483-8412
Mr. Lengyel	CAIB Staff	281-283-7581
Mr. Cobb (Via telecon from NASA HQ)	NASA IG	202-358-1220
John Clark	NTSB	202-257-0121
Bill Sikora	CAIB Staff	281-283-7564
Paul Wilde	CAIB Staff	301-775-6797
Jim Arnold	CAIB Staff	281-283-7572
Doug Cooke	CAIB Staff	202-329-8844
Woody Woodyard	CAIB Staff	281-283-7520
Laura Brown	CAIB Staff	281-283-7565
Christopher Kirchhoff	CAIB Staff	281-283-7821
Ron Gress	CAIB Staff	281-283-7532
Lisa Chu-Thielbar	CAIB Staff	281-283-7568
Dave Pye	CAIB Staff	281-283-7549
Steven Schmidt	CAIB Staff	281-283-7577
LtC. Mike Bloomberg	CAIB Staff	281-244-2233

GROUPSYSTEMS SESSION ON HOW TO PICK UP THE PACE

Facts (Group Outliner)

1. Initiating event originated from pre-launch activities
- **1.1 Maintenance (High)**
  - **1.1.1 TPS Maintenance**
- **1.2 Design**
- **1.3 Modifications**
- **1.4 Vendors**
- **1.5 Suppliers**
- **1.6 Quality Assurance and inspections**
- **1.7 Aging platform (High)**
- **1.8 STS Integration and Payload Planning**
- **1.9 Willful damage**
- **1.10 Environment**
- **1.11 Columiba Unique (High)**
  - **1.11.1 Wing roughness (step and gap)**

2. Initiating event originated from launch phase activities (main engine start to OMS2 Burn)
- **2.1 Crew factors (flight and ground)**
- **2.2 Mission Control**
- **2.3 Mission Planning**
- **2.4 I Loads**
  - **2.4.1 Wind Shear**
- **2.5 Weather**
- **2.6 Debris (High)**
  - **2.6.1 Ice**
  - **2.6.2 Foam**
  - **2.6.3 SLA**
  - **2.6.4 Scres / Nuts / Bolts / Etc.**

3. Initiating event originated during orbit
- **3.1 Space Debris (High)**
  - **3.1.1 MMOD**
- **3.2 Crew Factors**
- **3.3 Payload**
- **3.4 Wiring**
- **3.5 System anomaly**
- **3.6 Shuttle sheds part (TFOA) (High)**

4. Initiating event originatd during entry phase (begins with deorbit burn and ends with wheel stop at KSC)
- **4.1 Space Debris**
- **4.2 Internal system anomaly (High)**
  - **4.2.1 TPS Failture**
  - **4.2.2 Hydraulic Leak**
  - **4.2.3 Wiring**
  - **4.2.4 Structural Failure**
  - **4.2.5 Pryo Burning**

4.3 Payload
4.4 Space weather
4.5 Crew Factors
4.6 Entry profile
4.6.1 Early Transition to Turbulent Flow
4.6.2 Asymmetric Transition to Turbulent Flow

Suggested Facts (03-MAR-03) (Categorizer)
Suggested Facts (03-MAR-03) (Categorizer)

1. Potential Facts

The columbia is x years old {#3}
Columbia took a debris hit at 81 Seconds {#4}
anomalous temperatures in the left wheel well {#5}
the columbia has flown y previous shuttle missions. {#6}
Columbia was on it's 28th flight and was the oldest orbter {#7}
14 debris shedding events have been observed {#8}
Columbia launched on Jan 16th 2003 {#9}
The columbia is the oldest orbiter {#10}
The Pre Launch Certification process was followed properly iaw NASA regs. {#11}
A review of crew member medical records was accomplished and nothing remarkable was noted. {#12}
The flight crew was properly appointed. {#13}
at the final LOS all hydraulic fluid was gone {#14}
The flight crew was properly trained. {#15}
Columbia was the first to fly with Block II engines {#16}
Columbia broke up over Texas about Mach 18 at 200,000 feet. {#17}
The space debris following Columbia came from Columbia. {#18}
Experimental payloads were carried in the Spacehab Double Module, on the Freestar platform, and on the middeck. {#19}
The FRR was conducted IAW NASA guidelined {#20}
Columbia experience an off nominal Absolute Angle at 62 seconds {#21}
At 81 seconds a photographic event took place. {#22}
Multiple debris shedding events are apparent as Columbia approached the coast of California thru structural breakup over Texas. {#23}
The Columbia broke up in a flight regime in which, given the design of the orbiter, there was no possibility of crew survival. {#24}
Columbia had the most OMMs of any orbiter {#25}
The orbiter was damaged prior to EI. {#26}
Shuttle crew was medically cleared/ready for flight {#27}
The "stick bump" had nothing to do with the accident. {#28}
There was no possibility of on-orbit repair to the TPS, nor was there a possibility of reaching the ISS after Columbia entered orbit. {#29}
many observers, both professional and amateur, took pictures of the orbiter during the entry phase {#30}
Columbia had damage to the bipod foam area on mating/demating/remating but determined to be in acceptable range {#31}
Request for DoD imagry was turned off {#32}
The columbia had a different leading edge than the other orbiters. {#33}

The same teams of two persons for a total of three teams worked on the bipod foam area for the last 12 years {#34}
The columbia sat out in the wx for x days prior to launch. {#35}
Elevon trim, telemetry data, and yaw jet firing just before vehicle breakup confirm a problem on the left wing. {#36}
External tank foam has been observed shedding on several previous flights {#37}
Tiles can absorb moisture. {#38}
Foam can absorb moisture. {#39}
The Columbia weighed more than the other orbiters. {#40}
Columbia had a different internal configuration than the other orbiters...docking via the mid-deck {#41}
Columbia shed something on orbit on the second day after launch {#42}
an object was observed trailing the orbiter on the secoind day of flight {#43}
Three cameras film ET separation from the orbiter, but these are all film cameras which require return of the film to earth; there is no telemetry of this information. {#44}
Cryopumping was the reason the bipod foam flew off {#45}

Fact Vote (Vote)

Voting Results

Yes/No (Allow bypass)
Number of ballot items: 43
Total number of voters (N): 1

Yes %	
100.00	1. Shuttle crew was medically cleared/ready for flight
100.00	2. Columbia took a debris hit at 81 Seconds
100.00	3. anomalous temperatures in the left wheel well
100.00	4. the columbia has flown y previous shuttle missions.
100.00	5. Columbia was on it's 28th flight and was the oldest orbter
100.00	6. Columbia launched on Jan 16th 2003
100.00	7. The columbia is the oldest orbiter
100.00	8. A review of crew member medical records was accomplished and nothing remarkable was noted.
100.00	9. an object was observed trailing the orbiter on the secoind day of flight
100.00	10. Columbia had a different internal configuration than the other orbiters...docking via the mid-deck
100.00	11. The Columbia weighed more than the other orbiters.
100.00	12. Foam can absorb moisture.
100.00	13. Experimental payloads were carried in the Spacehab Double Module, on the Freestar platform, and on the middeck.
100.00	14. Tiles can absorb moisture.
100.00	15. External tank foam has been observed shedding on several previous flights
100.00	16. At 81 seconds a photographic event took place.
100.00	17. Elevon trim, telemetry data, and yaw jet firing just before vehicle breakup confirm a problem on the left wing.

100.00 18. Columbia had damage to the bipod foam area on mating/demating/remating but determined to be in acceptable range
100.00 19. many observers, both professional and amateur, took pictures of the orbiter during the entry phase
100.00 20. The "stick bump" had nothing to do with the accident.
100.00 21. The flight crew was properly appointed.
100.00 22. Columbia had the most OMMs of any orbiter
0.00 23. Cryopumping was the reason the bipod foam flew off
0.00 24. Three cameras film ET separation from the orbiter, but these are all film cameras which require return of the film to earth; there is no telemetry of this information.
0.00 25. The columbia is x years old
0.00 26. Columbia shed something on orbit on the second day after launch
0.00 27. The orbiter was damaged prior to EI.
0.00 28. There was no possibility of on-orbit repair to the TPS, nor was there a possibility of reaching the ISS after Columbia entered orbit.
0.00 29. The Columbia broke up in a flight regime in which, given the design of the orbiter, there was no possibility of crew survival.
0.00 30. Request for DoD imagry was turned off
0.00 31. The columbia had a different leading edge than the other orbiters.
0.00 32. The same teams of two persons for a total of three teams worked on the bipod foam area for the last 12 years
0.00 33. The columbia sat out in the wx for x days prior to launch.
0.00 34. Multiple debris shedding events are apparent as Columbia approached the coast of California thru structural breakup over Texas.
0.00 35. Columbia experience an off nominal Absolute Angle at 62 seconds
0.00 36. The FRR was conducted IAW NASA guidelined
0.00 37. The space debris following Columbia came from Columbia.
0.00 38. Columbia broke up over Texas about Mach 18 at 200,000 feet.
0.00 39. Columbia was the first to fly with Block II engines
0.00 40. The flight crew was properly trained.
0.00 41. at the final LOS all hydraulic fluid was gone
0.00 42. The Pre Launch Certification process was followed properly iaw NASA regs.
0.00 43. 14 debris shedding events have been observed

Number of Votes in Each Rating

	Yes %	No %	n
1. Shuttle crew was medically cleared/ready for flight	100.00	0.00	1
2. Columbia took a debris hit at 81 Seconds 100.00	0.00	1	
3. anomalous temperatures in the left wheel well	100.00	0.00	1

4. the columbia has flown y previous shuttle missions. 100.00 0.00 1
5. Columbia was on it's 28th flight and was the oldest orbter 100.00 0.00 1
6. Columbia launched on Jan 16th 2003 100.00 0.00 1
7. The columbia is the oldest orbiter 100.00 0.00 1
8. A review of crew member medical records was accomplished and 100.00 0.00 1
9. an object was observed trailing the orbiter on the secoind d 100.00 0.00 1
10. Columbia had a different internal configuration than the oth 100.00 0.00 1
11. The Columbia weighed more than the other orbiters. 100.00 0.00 1
12. Foam can absorb moisture. 100.00 0.00 1
13. Experimental payloads were carried in the Spacehab Double Mo 100.00 0.00 1
14. Tiles can absorb moisture. 100.00 0.00 1
15. External tank foam has been observed shedding on several pre 100.00 0.00 1
16. At 81 seconds a photographic event took place. 100.00 0.00 1
17. Elevon trim, telemetry data, and yaw jet firing just before 100.00 0.00 1
18. Columbia had damage to the bipod foam area on mating/dematin 100.00 0.00 1
19. many observers, both professional and amateur, took pictures 100.00 0.00 1
20. The "stick bump" had nothing to do with the accident. 100.00 0.00 1
21. The flight crew was properly appointed. 100.00 0.00 1
22. Columbia had the most OMMs of any orbiter 100.00 0.00 1
23. Cryopumping was the reason the bipod foam flew off 0.00 100.00 1
24. Three cameras film ET separation from the orbiter, but these 0.00 100.00 1
25. The columbia is x years old 0.00 100.00 1
26. Columbia shed something on orbit on the second day after lau 0.00 100.00 1
27. The orbiter was damaged prior to EI. 0.00 100.00 1
28. There was no possibility of on-orbit repair to the TPS, nor 0.00 100.00 1
29. The Columbia broke up in a flight regime in which, given the 0.00 100.00 1
30. Request for DoD imagry was turned off 0.00 100.00 1
31. The columbia had a different leading edge than the other orb 0.00 100.00 1
32. The same teams of two persons for a total of three teams wor 0.00 100.00 1
33. The columbia sat out in the wx for x days prior to launch. 0.00 100.00 1
34. Multiple debris shedding events are apparent as Columbia app 0.00 100.00 1

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36. The FRR was conducted IAW NASA guidelined 0.00 100.00 1
37. The space debris following Columbia came from Columbia. 0.00 100.00 1
38. Columbia broke up over Texas about Mach 18 at 200,000 feet. 0.00 100.00 1
39. Columbia was the first to fly with Block II engines 0.00 100.00 1
40. The flight crew was properly trained. 0.00 100.00 1
41. at the final LOS all hydraulic fluid was gone 0.00 100.00 1
42. The Pre Launch Certification process was followed properly i 0.00 100.00 1
43. 14 debris shedding events have been observed 0.00 100.00 1

Ballot Items in Original Order

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3. anomalous temperatures in the left wheel well
4. the columbia has flown y previous shuttle missions.
5. Columbia was on it's 28th flight and was the oldest orbter
6. 14 debris shedding events have been observed
7. Columbia launched on Jan 16th 2003
8. The columbia is the oldest orbiter
9. The Pre Launch Certification process was followed properly iaw NASA regs.
10. A review of crew member medical records was accomplished and nothing remarkable was noted.
11. The flight crew was properly appointed.
12. at the final LOS all hydraulic fluid was gone
13. The flight crew was properly trained.
14. Columbia was the first to fly with Block II engines
15. Columbia broke up over Texas about Mach 18 at 200,000 feet.
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36. Tiles can absorb moisture.
37. Foam can absorb moisture.
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39. Columbia had a different internal configuration than the other orbiters...docking via the mid-deck
40. Columbia shed something on orbit on the second day after launch
41. an object was observed trailing the orbiter on the secoind day of flight
42. Three cameras film ET separation from the orbiter, but these are all film cameras which require return of the film to earth; there is no telemetry of this information.
43. Cryopumping was the reason the bipod foam flew off

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 5, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 5 March 2003 **Time:** 1230 - 1430

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA web site.

There were two requests for information generated from this meeting that are listed at the end of this report.

A CNN cameraman was admitted to the board meeting room and allowed to shoot a few minutes of the CAIB meeting. The sound was off.

Admiral Gehman announced the addition of three new CAIB members:

- Dr. Sally Ride will appear as early as Friday (*3/7/03*).
- Dr. Doug Osheroff, Chair of Physics Dept. at Stanford and a Nobel Prize winner in 1996.
- Dr. John Logsdon will chair the 4th CAIB Sub-Group looking into management, cultural, contractor oversight, privatization and other programmatic matters.

A press announcement will be made on the evening of 5 March.

Shuttle Independent Assessment Team (SIAT) Report Briefing

Dr. Tina L. Panontin, the Chief Engineer for NASA Ames Research Center (ARC) and deputy for the Shuttle Independent Assessment Study in 1999 gave the board an overview of the results of that study and discussed the recommendations made in the final report.

- Admiral Gehman asked if the study covered the Thermal Protection System (TPS). ANS: Yes, the TPS was covered under structures. The independent assessment (IA) was conducted under a broad charter and the IA team was not limited to looking at mishaps. The IA was focused primarily on the Orbiter element.
- Admiral Gehman asked if the SIAT considered the Orbiter to be a hand-made vehicle. ANS: There was a sense, especially from the DoD members that the Orbiter is not a production line vehicle. One cannot look at one and see them all. These types of issues came up especially during wiring inspections.
- Admiral Gehman asked what is meant by "assuming risk". ANS: This is associated with authorizing standard repairs on criticality 1 systems where there is a presumption that because there is an authorized standard repair there is no additional risk.
- Maj. General Hess asked who suspended flight operations after the STS-93 pin ejection incident. ANS: The Administrator (Dan Goldin) and Associate Administrator for Human Spaceflight (Joe Rothenberg) made that decision.
    - Mr. Buzzard added that the initial recommendation was made by the program office and endorsed by higher management.
- Dr. Widnall asked to what extent was the SIAT driven by other agendas – an organization essentially investigating itself. ANS: The SIAT was committed to making a difference

in the Space Shuttle Program. NASA members of the SIAT were not part of the Shuttle Program (SSP).

- Mr. Buzzard asked how the number (~330) of Critical items List (CIL) waivers in place for STS-93 compared with the previous flight. ANS: Mr. O'Connor indicated that most of the waivers are generic and carry from flight to flight.
- Maj. General Barry asked for an explanation of the difference between a waiver and an exception. ANS: Mr. O'Connor replied that a waiver is granted whenever the vehicle doesn't meet redundancy requirements and there are many areas which do not meet these requirements; for example, the tires. Mr. O'Connor does not know what an exception is.
    - RADM Turcotte indicated his team had seen many one time exceptions in the examination of the maintenance records.
- Admiral Gehman asked if the SIAT encountered any problems having risks addressed. ANS: Yes, some were found. Also, process changes and lax problem reporting were causing things to be repaired without adequate assessment of risk.
- Mr. Buzzard asked whether the SIAT investigated the process used for approving standard repairs. ANS: Yes, it was found to be flawed.
    - Admiral Gehman commented that he thought the standard repair process unknowingly added risk to the system.
- Maj. General Hess asked about insight versus oversight and the impact of 3rd party inspections. ANS: This is all geared toward the movement from government to contractor control.
    - Maj. General Barry then indicated he was acquiring a copy of Shuttle Program Manager Ron Ditttemore's paper on turning control of the program over to the private sector. Mr. O'Connor indicated this was all part of the President's agenda and the move towards privatization was NASA's response to this agenda. He said NASA is moving to be a customer of the service much like NASA buys launch services for robotic spacecraft.
- Rear Admiral Turcotte indicated that his team was finding many instances where necessary repairs are not made due to the certification of standard repairs.
- Mr. O'Connor stated that the requirements for maintainability, survivability, and some other "ilities" were very poorly specified for the Orbiter.
- Maj. General Barry then observed that the Shuttle Independent Assessment Team report is one of the better reports he has read.

Southwest Research Institute (SwRI) Trip Presentation

Mr. Hubbard then reported on a trip he and several members of his team made to SwRI to assess impact tests planned by SwRI and to assess their capabilities to support further CAIB sponsored testing.

- Chart 3 - For 57 years SwRI has been in the business of determining what happens when things hit other things.
- Chart 5 – Maj. General Barry asked if the currently planned set of tests were concerned with empirical data only. ANS: They are only planning to perform a set of "cookbook" tests to a detailed plan provided by JSC.
- Chart 7 – Mr. Hubbard indicated SwRI has the analytic tools to look at ceramics, etc. which aren't being examined in the currently planned set of tests.
- Chart 15 – Mr. Hubbard indicated he had identified approximately 10 sequences for which to acquire high resolution versions of photos.

- Chart 16 – Mr. Hubbard will ask the CAIB Independent Analysis and Support Team (CIAST) to replot the data since this chart is so hard to read.
- Chart 17 – Admiral Gehman asked what kind of speeds were being worked with. ANS: 700 to 800 feet per second.
    - At this point Mr. Hubbard announced he had determined what he considered to be a fact: That foam off the External Tank (ET) hit the wing leading edge between positions 5 and 8.
- Chart 22 – The target will not be as depicted in the picture but will be panels populated with multiple shuttle tiles.
    - Maj. General Barry asked when the tests would be done. ANS: We do not have that information as yet.
- Chart 28 – Dr. Widnall asked when the test on the Reinforced Carbon-Carbon (RCC) would be performed. ANS: At the end of March or early in April.
- Chart 29 – Mr. Hubbard believes the CAIB should exercise SwRI expertise.
    - Admiral Gehman indicated the CAIB would adopt all Mr. Hubbard's recommendations. He said his inclination is for the CAIB to get its own contract with SwRI and to have SwRI propose detailed tests to be performed in response to high level CAIB requirements.

GroupSystems Session on Facts and Scenarios
The GroupSystems report on this session is appended at the end of this report.

The purpose of this session was to more narrowly focus the investigation.

Identified Requests for Information

- Request from Major General Barry to the NASA Space Shuttle Program to provide the definition of a waiver versus an exception.

- Request from Major General Barry to the NASA Space Shuttle Program to provide a copy of Ron Dittemore's paper on turning control of the program over to the private sector.

The meeting adjourned at 1430.

These minutes are hereby submitted for the record.

Approved
Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Mr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Mr. Bloomfield	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. O'Connor	CAIB	281-283-7511
Mr. Bradley	CAIB Exec. Secretary	281-283-7525
Joe Hartman	Recorder	281-283-7951
Mr. Buzzard	CTF	281-483-8412
Steven Schmidt	CAIB Staff	281-283-7577
Doug Cooke	CAIB Staff	202-329-8844
Tyrone Woodyard	CAIB Staff	281-283-7520
Bob Vallaster	CAIB Staff	281-283-7578
Wade Thompson	CAIB Staff	281-283-7573
Greg Phillips	CAIB Staff	281-283-7618
Paul Wilde	CAIB Staff	301-775-6797
Michael Miller	CAIB Staff	281-283-7807
Vern Ellingston	NTSB	202-262-5111
John Clark	NTSB	202-257-0121
Lester Reingold	CAIB Staff	281-283-7539
Christopher Kirchoff	CAIB Staff	281-283-7821
Laura Brown	CAIB Staff	281-283-7565
Dave Lengyel	CAIB Staff	281-283-7581
Mike Bloomberg	CAIB Staff	281-244-2233
Tina Panontin	NASA ARC	

Hypothesis 1 (Group Outliner)

1. The orbiter and crew were lost because of structural damage to the left wing. Entry aero forces, combined with the weakened wing damage to the wing beyond the orbiter's control system's ability to maintain controlled flight. The left wing structural weakness originated:

1.1 In loss of TPS under the wing

1.1.1 Due to maintenance turn around work

1.1.2 Due to ascent debris strike

1.1.3 Due to orbital debris strike

1.1.4 Poor design / manufacture

1.2 In loss of TPS (other than under the wing)

1.2.1 Due to maintenance turn around work

1.2.2 Due to ascent debris strike

1.2.3 Due to orbital debris strike

1.2.4 Poor design / manufacture

1.3 From compromise to RCC

1.3.1 maintenance / turnaround escape

1.3.2 ascent debris strike

1.3.3 on orbit debris strike

1.3.4 Poor design / manufacture

1.4 From a structural issue

1.4.1 caused by maintenance / turnaround escape

1.4.2 ascent debris strike

1.4.3 on orbit debris strike

1.4.4 Rough wing

1.4.5 Poor design / manufacture

1.5 In off-nominal entry configuration / flow field

1.5.1 due to maintenance / turnaround escape

1.5.2 ascent debris strike

1.5.3 on orbit debris strike

1.6 internal hazards

1.6.1 fire (pyro, hydraulic fluid, etc.)

1.6.2 explosion (tires, pyro, etc.)

1.6.3 other

1.7 Willful Damage

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 7, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 7 March 2003 **Time:** 1230 - 1330

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA web site.

There were no action items or requests for information generated from this meeting.

BGen Deal Trip to Michoud Assembly Facility (MAF)

- The team spent a lot of time examining non-destructive evaluation (NDE) capabilities. Design of the bipod was also discussed.
- There are plans to remove the ablator materials from the bipod ramp area.
- Admiral Gehman asked if the CAIB has a history of the ET. ANS: Yes, but the history is from MSFC and not Michoud.
    - Mr. O'Connor added that the ET is next on NASA's list to be transitioned to non-government furnished equipment. NASA will not be buying ETs from a private contractor but will transition from an oversight role to one of insight. The ET is considered to be one of the least risky elements in the Shuttle Program.
- It was learned that a large section of foam on ET-118 had debonded from the feed line area. This was a first time failure and indicates a need to use laser shearography as an NDE tool.
- Currently only visual inspections are performed on the ET.
- The probable cause has been identified and a fix will be implemented on the production line.
    - Admiral Gehman asked if this meant that 8 or 9 ETs would potentially suffer the same issue. ANS: Yes, this was not considered a safety of flight issue.
    - Dr. Ride asked what analysis was done to back up the decision that this was not a flight safety issue. ANS: The CAIB has requested that data.
    - Admiral Gehman indicated he would like to reverse the question to NASA and ask why it wasn't a safety of flight issue instead of asking someone to demonstrate it was a safety of flight issue.
    - Mr. Wallace asked where the process for making this determination takes place. ANS: Not at the Flight Readiness Review (FRR).
        - Mr. O'Connor indicated it would have been addressed as if it were a post flight anomaly in the program environment at the Program Requirements Control Board (PRCB). While there are many reasons topics go before the FRR this would not show up at an FRR because it was not deemed to be a safety of flight issue and would have been handled at the project and program level.
- BGen Deal is convinced NDE is required for the ET foam prior to return to flight.
- There is also a need to remove the ablator material before flight.

- Upon return to Michoud the group will be looking at the contractors as well as their contracts.
- BGen Deal then briefed the CAIB on the capability of DoD assets which were available to support NASA.

Group 3 – Dr. Hallock

- The group has been working on space weather. Numerous inputs have been received from many universities. There are 2 or 3 experts visiting on 3/12/03 or 3/13/03 to finish the topic and take space weather off the table.
- Admiral Gehman explained that there was a space weather event (solar flare) at issue during entry of Columbia. There were high energy shock waves observed during the deorbit burn but this is not believed to be an issue since Columbia was shielded by the mass of the planet from these waves.
- Dr. Hallock then discussed fault trees.
    - Scenarios are part of the fault tree work and he urged the CAIB to keep developing scenarios.
    - The NASA fault tree keeps growing and version three was due out the day of this meeting.
    - Although fault trees have been developed for the ET and the Solid Rocket Boosters most scenarios that have been developed concern the Orbiter.
    - Scenario development is causing the fault trees to expand.
    - NASA is hoping to start closing items next week and the group will require assistance to assess the closures.
    - Admiral Gehman asked about the future of the fault analysis group which NASA is forming. ANS: There are really 2 independent groups, one for fault tree analysis and the other for scenario development. They have had their first meeting and have observed that the CAIB is seeing things which NASA was not addressing.
    - Dr. Hallock expressed that he was nervous that the Orbiter fault tree was being developed due to the mishap and that NASA didn't already have one.

Group 1 – MGen Barry

- Debris event #6 is approximately 1.5 seconds in length and it appears to be the size of a golf ball. Several members expressed surprise at the small estimated size. It came down within a 100 nautical mile area around Caliente, NV. Search efforts are hampered by snow on the ground. However the debris went through the plasma and shockwave so it must have substance to it.
- Debris event #14 is lighter but bigger than #6. It occurred over Flagstaff, AZ and entered around Albuquerque, NM.
- Several items are being shipped to Wright-Patterson AFB, OH to see if radar comparisons can be made.
    - Dr. Ride asked if ice had been eliminated. ANS: Nothing has been eliminated as yet but it is believed that ice should be easy to eliminate.
- Hyperspectral radar will be used for debris searching although Defense Intelligence Agency is attempting to pull back the aircraft with this capability.
- With regard to the Kirtland photo – not much faith is being placed in it although NASA Ames Research Center is performing spectroscopic analysis.

- MGen Barry then asked Col Fraser to report on the task forces on internal NASA communications and the DoD photo request.
    - The objective of each task force is to determine how information flowed between areas of responsibility.
    - Flow charts will be developed depicting the flow of information to various NASA levels.
    - The task forces are investigating the possibility of collecting larger amounts of data beyond that which is subject to FOIA.
    - Mr. Wallace then pointed out that this is a joint effort between groups 1 and 2. Controls are also being put into place to insure that privacy is not being violated.
    - MGen Barry then pointed out that the task force is trying to answer the question of why the information did not get to management.
    - Admiral Gehman asked if NASA regulations address how E-mail is to be used. ANS: The staff has been unable to uncover anything that describes how E-mail is to be used or any official status for E-Mail. Mr. O'Connor confirmed that E-Mails have no official standing within the agency except as another means of communication.

Admiral Gehman then said the CAIB had to decide whether to pursue the E-mail issue publicly or under privilege. The board cannot obtain information under privilege and then ask the same questions in public. If approached under privilege then detailed data cannot be made public.

- Laura Brown then indicated that she believes NASA will make the E-mail authors available for a press teleconference on Monday *(3/10/03)*.
- Admiral Gehman offered an opinion that since the E-Mail issue was being completely aired in the press there was no reason to offer the authors privilege.
    - Mr. O'Connor disagreed and stated that he thought privilege was necessary if one wanted to get to the bottom of an investigatory line of thought.
    - MGen Barry then indicated that he had received previously unpublished E-Mails during a privileged interview and did not believe he would have gotten them if they weren't under privilege. He is really worried that public hearings are going to be counterproductive to getting to a high quality final report.
    - Admiral Gehman then offered the suggestion of offering the E-Mail authors privilege if it would mean being able to get into their heads. He believes the CAIB should be able to question a person in public who has held a press conference. The CAIB should then be able to grant privilege to hear anything else the subject may want to relate.
- Admiral Gehman then indicated he would build a public hearing roadmap describing what will be done in public to guide the rest of the CAIB on when to offer privilege.
- Dr. Ride then observed that even though everything that is relevant will make it into the press the easiest way to get to the bottom of things and to a stellar final report is via privilege.
- Admiral Gehman indicated that certain parts of the investigation will be done under privilege and others will be done in the open. In the meantime Admiral Gehman directed that privilege not be offered to the E-Mail authors.
- MGen Barry believes the CAIB can either grant privilege or not for individual witnesses; it can't be both ways. Once a person is granted privilege he/she should not be called before a public hearing.

  - Admiral Gehman replied that he believed this was a fair approach but he's not sure it can be accommodated in all cases.
- Admiral Gehman then stated that since the E-mail issue was going to be aired out in the press he could make an argument that the CAIB should only address the issue under privilege.

MGen Barry then finished his Group 1 report.

- The NASA-DoD photo request will be put to bed soon.
- Dr. Ride asked who was assessing launch photos. ANS: Group 3 although the original tape is at Wright-Patterson AFB being looked at by Dr. Fugati. Dr. Ride indicated she may know someone who could bring innovative techniques to this issue.

Group 3 – Mr. Tetrault

- OV-102 wiring bundles are completely different from the other orbiters. He believes many wires did not go anywhere in Columbia while many others went to an internal operations recorder. He is interested in 2 sensors that went off-line very late but cannot figure out how they were wired. He reported that the CAIB storyboards are incorrect and has suspicions that the wiring diagrams need to be updated.
- Mr. Tetrault then led a discussion of the left inboard forward wheel well tile. He believes a channel was made with the door on and the corner of the hatch door was lifted and the seal separated sufficiently so that an air stream blew out the corner of the door. This is believed to have occurred very late and was not part of the original problem.

Admiral Gehman then asked the CAIB if they thought a 3 dimensional reconstruction of the left wing debris was required. Mr. Tetrault indicated that he has requested a 3-D CAD reconstruction.

- The board agreed some sort of 3-D reconstruction was necessary.
- Admiral Gehman indicated he would put NASA on notice that any computer reconstruction of the left wing must be very high fidelity or a physical 3-D model will be required. The CAIB desires to have actual parts scanned into the model.

Admiral Gehman asked if anyone had requested debris patterns of the left wing. Mr. Tetrault responded he had already asked for a debris map and ballistic coefficients for every piece.

Admiral Gehman then thanked Mr. O'Connor for his valuable service to the board and wished him well as he returned to his "day job". Mr. O'Connor made a final statement where he requested the CAIB to take special pains to be certain that the recommendations which are put forward are backed up by good solid analysis and data since NASA will treat this report like the Bible for many years to come.

The meeting adjourned at 1330.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 7, 2003
These Minutes Contain No Sensitive Data

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. for
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

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Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Logsdon	CAIB	202-994-7292
Dr. Osheroff	CAIB	281-283-7511
Dr. Ride	CAIB	281-283-7503
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Bradley	CAIB Ex. Secretary	281-283-7525
Mr. Hartman	Recorder	281-283-7591
Mr. Buzzard	CTF	281-483-8412
LtC. Bloomfield	CAIB	281-244-2233

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 10, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 10 March 2003 **Time:** 1230 – 1540

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA web site.

There was one action item generated from this meeting and listed at the end of this report.

Dave Pye presented the results of his study of Reinforced Carbon-Carbon (RCC)

- Mr. Pye recommended the removal of RCC from existing Orbiters in order that all RCC and supporting structure can be directly inspected.
- The data is based on "secondary" NASA paper rather than primary paper.
- Mr. Pye stated that some information comes from privileged testimony from witness interviews.
- The CAIB continued with this topic into executive session without recording.

Maj. General Barry reported the following:

- The transcripts of 11 taped interviews have been completed.
- The report from the External Tank (ET) Technical Interchange Forum @ MSFC on 3/3-4/03 is out, with a number of recommendations
    - Redesign the ET bipod and take ablative foam out before return to flight.
    - Investigate Non-Destructive Evaluation (NDE) and waterproofing.
- Boeing continues to move employees to JSC and KSC from Huntington Beach, and the impact to critical skills will continue to be assessed.
- Expect the Space Shuttle Main Engine (SSME) fault tree to be complete in 1.5 weeks, followed thereafter by the SRB and RSRM fault trees. There are a couple of issues, but they are not controversial.
- The big controversy regards the ET and Orbiter
    - Change in blowing agent
    - Mate-demate-remate
    - Left hand nozzle vector
    - Cryo pumping of ablative material
    - Oxidation of RCC
- There are 14 working groups involved with the ET fault tree and 3200 blocks
- Regarding day 2 debris, Wright Patterson AFB is looking at calibration of radar signatures.
- The debris assessment team discussed CRATER.
    - Dr. Ride suggested that the CRATER briefing on March 13 be followed by interviews. A list of interviewers has been developed.
- Maj. General Barry's bottom line regarding CRATER:

  - Lots of miscommunication
  - Dependence on E-mail
  - Informality
  - Things might have been done differently
  - CRATER is 20 years old and does not have as strong an algorithm as is available today.
  - Lack of management pursuit
  - Lack of convictions from analysts to pursue results
- Maj. General Barry then made the following recommendations (not time critical):
  - NASA should assign classified cleared personnel by job, not persons, as some key decision-making persons are not cleared.
  - DoD should give yearly briefings to NASA on what data is possible for NASA to receive.
  - Admiral Gehman commented that there was clearly miscommunication and those people making decisions did not know what they could get from DoD. He also reinforced that the DoD briefing is a good example of a recommendation that the CAIB could make right now.
- Good public inputs have been received via the 1-800 phone number.
- A previous statement regarding the launch of block 2 engines needs to be clarified: This flight was actually the first time the block 2 engines flew with a lightweight ET; previously they had only flown with a super lightweight ET. Any other peculiarities, even those seemingly minor, should be identified.

Dr. Hallock discussed the following:

- Dr. Hallock showed a picture from a Navy airship possibly showing debris during ascent.
- Dr. Hallock stated that the board was about to be inundated with fault tree analysis results.
  - Dr. Hallock distributed a flow chart for the proposed processing scheme.
  - Admiral Gehman asked how many times this will happen. Maj. General Barry responded that it is being done for each major system.
  - Mr. Schmidt asked if this represents only JSC fault trees or all NASA fault trees. The board resolved that it represented a comprehensive MRT fault tree.

Mr. Hubbard and Mr. Tetrault opened the following discussion:

- A collection of interesting RCC pieces have been identified, but KSC personnel have not had time to address these pieces.
  - Mr. Tetrault stated that there is only one person who is an expert on RCC and he cannot devote a lot of his time to the shop floor.
  - Admiral Gehman stated that the CAIB can rearrange KSC priorities, and he hesitates to authorize the CAIB staff to perform independent analysis or debris collection.
- Mr. Tetrault stated that new theory twists are beginning to emerge.
  - A piece in the bottom edge glove area was found with a 6 square inch hole. This is not consistent with entry damage. The hole is between two tiles, and may have burned through the skin. Although it may not be large enough to be the

fundamental breech, but might help answer how the forward water dump valve temperature rose.
  - If the breech is on the leading edge, support structures could be blown into the wing and dragged along until breakup.
  - Event heating and breakup heating need to be differentiated.
  - The floor population of debris is growing.
  - The hole is in RCC panel #9, not #3 as reported in the press.
- Mr. Hubbard stated that it looks like the area around the left wing leading edge has more damage than other areas. It would be advantageous to devise a more quantitative means to describe damage. Mr. Hubbard expects to talk to NASA representatives about this tomorrow. Admiral Gehman added that a good CAD reconstruction of the left wing with a damage label might help – the key is good reconstruction.
- It was stated that Dr. Ride has suggested bringing in the JASONS to review the effort to date. Admiral Gehman added that the JASONS could provide a peer review of selected items, such as the NASA model for heat transfer inside the Orbiter, particularly examining the predictions at 300,000 feet. Admiral Gehman stated the independent analysis team needs to identify a short list of specific questions for the JASONS and generate a statement of work (SOW).
- Brig. General Deal stated that he is well along the way to recommending that procedures be built for on-orbit interviews. The willful damage work is going well. Brig. General Deal visited Spacehab and is investigating whether random checks are done on secured blankets; in addition, the wheel well and leading edge closeouts are being examined. Brig. General Deal is concerned that information from privileged testimony statements is appearing in working documents and he will take measures to stop this.
- Major General Hess stated he has been shown spectral analysis of two flash events that thus far may not have surfaced in the investigation.

After a short break the CAIB members began a working session on the information and charts that the board is putting together.

- Admiral Gehman stated that the board must try to answer if all parts of the hypotheses are being worked and what testing is needed to test the hypotheses. The hypotheses have been reviewed with possible contributing factors, and matrix has been built.
- Admiral Gehman has three different scenarios from Mr. Hubbard, Dr. Hallock, and Mr. Tetrault, and considered opened up discussion as to whether the board was closer to determining the initial event for the mishap. Brig. General Deal said he now believes that there is a 60% chance the initiating event occurred in the RCC and a 40% chance in the under belly – quite different than he initially believed. Admiral Gehman stated that a LaRC report indicates one completely missing RCC panel would not cause yaw disturbances by itself. Mr. Buzzard discussed the scenario that sequential series of events may have started with the shedding of an RCC panel followed by the loss of additional pieces, thereby changing the wing geometry and inducing yaw disturbance.
- Discussion continued with regard to the aerodynamic forces at an altitude of 236,000 feet and whether there was sufficient heat to initiate an event prior to the severe dynamic pressure regime. A pre-existing condition is implied, as there is a breach, followed by high heat, followed by substantial dynamic pressure.

- Mr. Buzzard stated that the sequential shedding hypothesis depends on the existence of a pre-existing condition before re-entry, and the shedding likely began under relatively low dynamic forces.
- Admiral Gehman asked the board members to ponder what happens if the radar cross section of the carrier panel matches the day 2 debris. Panel discussion and speculation ensued about the possibility of a portion of the Orbiter staying on under high ascent forces only to separate under low on-orbit forces.
- Admiral Gehman then initiated further discussion on the rewording of the board hypothesis statement, concentrating on the interplay of an anomalous condition, entry heating, and aerodynamic forces. Mr. Wallace suggested that the statement emphasize that there was a catastrophic breakup and there was nothing that the control systems could have done about it. Admiral Gehman encouraged the board members to provide further comments and revise the hypothesis statement. Mr. Buzzard stressed that the cause and effect sequence is valuable to help build criteria to test the hypothesis; also, something came off on flight day 2 and it must be explained why it did not come off at ascent.

The meeting was adjourned at 1540.

Identified Actions

- Admiral Gehman stated the Independent Analysis and Support Team (IAST) needs to identify a short list of specific questions for the JASONS and generate a statement of work (SOW). Actionee: Jim Mosquera

These minutes are hereby submitted for the record.

Approved
FOR
Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 10, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal (via telecon @ KSC)	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard (via telecon @ KSC)	CAIB	281-283-7517
Dr. Logsdon	CAIB	202-994-7292
Dr. Osheroff	CAIB	281-283-7511
Dr. Ride	CAIB	281-283-7503
Mr. Tetrault (via telecon @ KSC)	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Hartman	Recorder	281-283-7951
Mr. Buzzard	CTF	281-483-8412
LtC. Bloomfield	CAIB Staff	281-244-2233
Dave Lengyel	CAIB Staff	281-283-7581
Lt. Colonel Goodman (via telecon @ KSC)	CAIB Staff	281-283-7569
Steven Schmidt	CAIB Staff	281-283-7577
Bill Sikora	CAIB Staff	281-283-7564
Patrick Garrett	CAIB Staff	281-283-7593
Col.Jack Anthony	DoD Rep	281-283-7588
Mr. Cobb (via telecon @ NASA HQ)	NASA IG	202-358-1220

Hypothesis 1 (Group Outliner)

1. The orbiter and crew were lost because of structural damage to the left wing. Entry aero forces, combined with the weakened wing damage to the wing beyond the orbiter's control system's ability to maintain controlled flight. The left wing structural weakness originated:

1.1 In loss of TPS under the wing

1.1.1 Due to maintenance turn around work

1.1.2 Due to ascent debris strike

1.1.3 Due to orbital debris strike

1.1.4 Poor design / manufacture

1.2 In loss of TPS (other than under the wing)

1.2.1 Due to maintenance turn around work

1.2.2 Due to ascent debris strike

1.2.3 Due to orbital debris strike

1.2.4 Poor design / manufacture

1.3 From compromise to RCC

1.3.1 maintenance / turnaround escape

1.3.2 ascent debris strike

1.3.3 on orbit debris strike

1.3.4 Poor design / manufacture

1.4 From a structural issue

1.4.1 caused by maintenance / turnaround escape

1.4.2 ascent debris strike

1.4.3 on orbit debris strike

1.4.4 Rough wing

1.4.5 Poor design / manufacture

1.5 In off-nominal entry configuration / flow field

1.5.1 due to maintenance / turnaround escape

1.5.2 ascent debris strike

1.5.3 on orbit debris strike

1.6 internal hazards

1.6.1 fire (pyro, hydraulic fluid, etc.)

1.6.2 explosion (tires, pyro, etc.)

1.6.3 other

1.7 Willful Damage

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 12, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 12 March 2003 **Time:** 1230 – 14:10

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting consisted of computer-generated graphics, handheld digital camera video, Orbiter payload bay camera footage, and a presentation of "Thermal Conditions Preceding Columbia Breakup" and can be found on the CAIB PBMA web site.

There were 6 action items generated from this meeting.

Admiral Gehman has been attempting to contact former Astronaut Maj. Gen. (retired) Charlie Bolden to see about hiring him to take the place of Theron Bradley who must leave the CAIB.

Maj. Gen. Barry presented a computer animation of the Orbiter's actions in the last 32 seconds.

This animation consisted of a video pictorial of the Columbia with attitudes and Reaction Control System (RCS) jet firings matching known data. There was high confidence in the first 5 seconds of data, but not in the last 2 seconds utilized in the modeling.

- The video began with the first 5 seconds of the extra 32 seconds of data that was recovered, and demonstrates the Shuttle beginning to tip over in roll and yaw. The RCS jet firings are depicted as well as directional arrows to both TDRS West (signal source) and TDRS East.
- Admiral Gehman questioned if the Orbiter was "falling out of the sky leftward, left wing down" (orientation in animation) that it would seem to exacerbate the problem. LtCol. Bloomfield responded that this is an effort to keep Beta with a sideslip of zero.
- Mr. Buzzard offered that they are seeing some evidence of a bit more yaw trim required than expected, but not outside of the normal bound until very late in the trajectory. In the last 5 seconds we are clearly seeing huge yaw disturbances. We (NASA) are blending yaw jets and aerodynamic controls. We are actually using elevons for trim functions, and only asking the RCS jets to fire for large commanded maneuvers like a role reversal or, in this case, we are getting uncommanded motion and trying to correct. Typically, one jet is all you need; two if you need it for roll reversal. There is a small translation in toward the vertical that would reduce your altitude, but really we are using bank angle to control cross range. We are not really trying to use bank angle to maintain altitude. Mr. Buzzard then pointed out that utilizing 4 RCS jets is extremely unusual. We would never fire 4, because we have plenty of control authority, so that is why that is completely out of family.

The rendition of the data in the computer generated graphic starts with 2 RCS jets firing then 3, and finally 4.

- Mr. Buzzard volunteered a comment on the presentation that the yaw disturbance is larger than the elevon trim can accommodate. The situation is totally unusual to have two jets firing continuously that is not at the initiation or completion of a bank maneuver.
- LtCol. Bloomfield offered that the crew used to have a schedule that they flew religiously when the use of RCS jets were applied which was basically a look up table to augment the aerodynamic surfaces if the required attitude rates were not attained.

The same initial 5 seconds of the computer-generated animation were shown appended with a linear interpolation to the last data points.

- Dr. Widnall commented on the severity of the Orbiter movement toward the end of the animation (the Orbiter appeared to spin violently). The modeling performed a linear interpolation of the data through a 20 sec gap to the last two data points, which appeared as a very severe maneuver.
- Dr. Widnall questioned if there was a dynamic model for the Orbiter vehicle that could be used in this analysis. Mr. Buzzard stated that because they did not know the actual configuration of the wing, the dynamic model would not be valid for use with any confidence.
- Adm. Gehman was uncomfortable with the severity of the movement of the Orbiter and suggested the interpolation of the data should be reviewed. The Admiral stated that he knew that the Orbiter was yawing to the left at more than 20 degrees per second. There was some concern when the model rates were identified to be 6 degrees per second.
- Mr. Wallace suggested that this computer animation should not be used for a press release at the present time and Adm. Gehman agreed.

Dr. Hallock provided two video presentations to the board.

The first video was from a hand held digital camera through the Orbiter overhead window used by the STS-107 crew to film the External Tank (ET) separation. The ET was rotated slightly in the view presented so as to make the bi-pod area unavailable for inspection. This video showed large pieces of material that appeared to be ice exiting from the ET. According to Mr. Buzzard this was seen many times before and was considered a "normal" event.

The second video consisted of camera footage from one of the rear Orbiter payload bay cameras which filmed the left wing, the right wing, then the left wing concentrating on the elevon cove area.

- Dr. Hallock plans to calculate how far forward you can actually see in the video of the left wing. He also plans to examine the film frame by frame for points of interest and have a Quicktime version developed.
- Adm. Gehman questioned why this video had not surfaced previously to which there was no informative response.

Group 3 - Dr. Hallock

Dr. Hallock met with representatives from Hanscom and NOAA and was briefed on the space weather during the Columbia reentry timeframe. During this timeframe there was a solar event which resulted in a glancing shock front (high speed particles) which occurred at approximately the time the orbiter performed its de-orbit burn (raised some concern) followed by a Coronal Mass Ejection (heavy particles) hours later. The area that still remains somewhat in question is that there is a very strong density shear (density of air changing rapidly).

- Dr. Hallock does not believe that the density shear is of major consequence and the space weather representatives were going to write a short paper which will dismiss the item as a concern. Dr. Hallock assumed the density is part of the equations that deal with guidance of the Orbiter.
- Mr. Buzzard stated that NASA does not model the density shear, although they are aware of it. NASA treats it as a disturbance and address it by modulating the drag and heat profile. It is considered to be a 2nd or 3rd order effect.

Dr. Hallock is continuing to work the fault tree area. He is working closely with NASA to see how their fault trees reflect their current reported 12 scenarios. He is starting to define the CAIB scenarios along the same lines as NASA.

Mr. James Smiley Presentation on " Thermal Conditions Preceding Columbia Breakup"

Mr. Smiley provided a presentation on the thermal conditions of the Orbiter environment utilizing data from Dr. Bertin's book. During the presentation, Mr. Smiley questioned whether traditional Computational Fluid Dynamics (CFD) tools would be appropriate. It appears that there is a large amount of activity occuring very early during reentry in a low density environment.

- Adm. Gehman offered for discussion whether the heating phenomenon caused "un-zippering" of material, or did "un-zippering" of material cause the heating phenomenon. The discussion lead one to believe that there could be pre existing conditions of heating occurred followed by aerodynamic shedding of material.
- Mr. Buzzard offered some test information from Langley arc jet facilities (pre STS-1). When more than 2 RCC panels were removed, NASA started seeing evidence, of being able to strip material away which supports the board hypothesis discussed.
- Maj. Gen. Barry questioned whether it is more dynamic at the leading edge (8 or 9) on ascent or entry and whether the ET shields during ascent.
- Mr. Smiley provided that the regime in question was very difficult to test in these ranges because wind tunnels can test Mach 5-6 maximum.
- Mr. Buzzard offered that during ascent that aerodynamics are the primary concern with heating secondary. Whereas during decent heating is the primary concern and the aerodynamics are secondary.
- Maj. Gen. Barry suggested that the thermal area maybe a good subject for the JASONS since the aerodynamics are well understood, but the heat flow is not.

- LtCol. Bloomfield suggested that the board look into infrared data from a sensor that was flown on previous Columbia flights for additional insight into the environment. Mr. Buzzard will pursue the data for Group 3.

Dr. Widnall

Dr. Widnall is continuing to investigate the aero/thermal dynamic environment and backing out guidance control equations. Dr. Widnall also highlighted some early NASA testing of Carbon-Carbon testing in which an arc jet was directed into a hole and it increase the size five fold. This provided more information on the fragility of the RCC material.

Group 3- RAdm. Turcotte

Continuing RCC Activities. Interviewing contractors.

Group 3 - Maj. Gen. Deal

Travel to Michoud

Group 3 - Maj. Gen. Barry

- Continuing investigation of foam and following the issue of mate-demate-mate implications.

- Team is investigating mobile thermography equipment with regard to RCC NDE testing, and planning trip to Lockheed Martin – Dallas with experts to talk to 4 individuals, one of which was recalled from retirement about the RCC process.

Admiral Gehman stated that the board should perform an audit concerning the foam. At one time this might have been an In flight Anomaly (IFA) and he would like to see how it got cleared. The Admiral then mentioned that the board has spent significant time and effort looking at the initiating cause of the accident and that he planned for the board to look at management and human factor issues in the future.

The Admiral requested anyone interested in providing inputs to the statement of work for the Jasons contact Dr. Hallock. He received no feedback so he will generate a letter to initiate the activity.

Admiral Gehman provided the following information:

- He was going to write a letter to the Chairman of ASAP (Shirley McCarty) and invite her to send a delegation to the Board for a discussion
- He wanted to organize one of the 12:30 meetings to have Astronaut John Young to talk to the board.
- He would like for Dr. Hallock's group to task NASA to remove private video to allow for a debris shedding video that is releasable. If this video is the same as previously seen (two loops) then disregard the request.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 12, 2003
These Minutes Contain No Sensitive Data

Identified Actions

- Adm. Gehman to write a letter to the Chairman of ASAP (Shirley McCarty) and invite her to send a delegation to the Board for a discussion. Action: CPO Fitzgibbon

- Adm. Gehman wanted to organize one of the 12:30 meetings to have Astronaut John Young to talk to the board. Action: Executive Secretary

- Maj. Gen. Barry suggested that the thermal area maybe a good subject for the JASONS since the aerodynamics are well understood, but the heat flow is not. Action: IAST

- LtCol. Bloomfield suggested that the board look into infrared data from a sensor that was flown on previous Columbia flights for additional insight into the environment. Mr. Buzzard will pursue the data for Group 3.

- Admiral Gehman stated that the board should perform an audit concerning the foam. At one time this might have been an In flight Anomaly (IFA) and he would like to see how it got cleared. Action: Group 1

- Admiral Gehman would like for Dr. Hallock's group to task NASA to remove private video to allow for a debris shedding video that is releasable. If this video is the same as previously seen (two loops) then disregard the request.

The meeting was adjourned at 1410.

These minutes are hereby submitted for the record.

Approved
Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Rear Admiral Turcotte via telecon	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Schmidt	CAIB	281-283-7577
Mr. Lengyel	CAIB	281-283-7581

Mr. Choban	Recorder	281-283-7591
Mr. Buzzard	CTF	281-483-8412
LtCol. Bloomfield	CAIB	281-244-2233
Mr. Smiley	CAIB	281-283-7545

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 14, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 14 March 2003 **Time:** 1300 - 1515

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

There were 4 action items generated from this meeting and listed later in this report.

Mr. Roger Tetrault provided an update on where they are going with debris:

Reached following agreements with NASA regarding debris:

- 3D models of the debris will be developed. The debris will be color coded to indicate attributes, such as whether or not the debris had any evidence of slag. The debris will also be sized.
- Each piece of debris will be identified, along with the lat and long where it was found, estimate of ballistic coefficient, unique attributes, testing performed, and numbers of samples taken from it.
- Reached agreement on database and how data can be manipulated. For instance, want to be able to take patterns from left wing and compare with patterns from right wing.

NASA was asked to reconsider the way debris is laid out at KSC. In the current configuration, debris from the sides of the fuselage is laid out between debris from the center of the fuselage and debris from the corresponding wing. As a result, debris from the wings is separated from the corresponding attach points on the underside of the body by 15-20 ft of side fuselage debris, making pattern recognition extremely difficult. The team prefers to see a layout that would allow them to put the entire underside of the craft together, thus making pattern recognition easier to accomplish.

Near term activity will focus on analysis of slag deposits. Slag consists of anything that is deposited, such as carbon, hydraulic fluids, molten stainless steel, titanium, or copper wire. Twenty-two different colors of slag have been identified thus far. The current plan is to test nine different slags, with 9-27 samples taken from each. The purpose is to identify constituents—what's in the slag, is there any layering? This information will allow them to identify what's being splattered, particularly forward on the leading edge of the wing, with the heaviest deposits on the backside of the RCC panels (no slag found on the front side of the RCCs). Qualitative assessment indicates that there is some sort of pattern to the RCC deposits.

A comprehensive tile analysis is also planned, with a mutually agreed-to tile test plan expected in the near future. Meanwhile, the Littlefield tile (the furthest west tile) was sent off for analysis to determine if the paint-like surface is actually painted. This could be significant because only tiles from the chine area are painted.

Mr. Tetrault next reported that one out of four uplock rollers from the Left Main Landing Gear (LMLG) door was found among the debris (see attachment). They know that this came from the left side because the door from the right side wheel well was found with all four uplocks still attached.

Findings and observations relative to the uplock are summarized as follows:

- The end of the uplock that is inserted into a hole in the aluminum door skin and secured is still "silvery shiny". From this one can surmise that it stayed attached to the aluminum structure for a long time into the event.

- The end of the uplock that is exposed in the wheel well appears to be plated with a chrome-like substance. This can be important if it is chrome because the only thing in the vicinity that is chrome plated is the wheel strut. This would suggest that hot gas blew the chrome of the wheel strut and on to the uplock.

- The uplock is plated differentially from side-to-side. This would help characterize behavior of the heat source.

- The close-up showing the roller and its relationship to the grid marks on the shim indicates that it is off center. By comparing this against closeout photos they hope to determine the exact location of the uplock in the wheel well

- The roller pin nut always points to the wall of the wheel well, whether the uplock is in the forward position or the side position. If the closeout photos are inconclusive they can still determine the position relative to the wall.

- One corner (near the roller nut) appears to be burned off. Since the uplocks are made of titanium, this suggests that the heat in the wheel well was intense (melting point of titanium is approximately 3000 deg F).

Mr. Tetrault then referred to a chart depicting the relative positions of the uplocks, hinges, two pieces of tile debris that were determined to have come from the areas immediately adjacent to the forward corners of the wheel well edge, and one piece of tile debris determined to have come from the front, outboard corner of the LMLG door. The following findings/observations were made:

Debris on the outboard side of the wheel well appears to have a vent hole indicating that hot gas was escaping from the wheel well outward and blowing across the body of the orbiter. Existence of the vent hole leads them to assume that the door had been closed.

The piece from the opposite side shows similar effects but to a lesser extent.

The ceramic coating on the tile from the door itself appears to be bubbled back (from heat).

Mr. Tetrault then postulated the following scenario: The uplock roller in the front position was blasted by an intense heat source. Heat was transferred from the uplock to the aluminum door

structure. The aluminum begins to melt or decay, allowing the uplock to pull out, thus providing a mechanism for the front corners of the door to come up/down and blow the vent holes out.

There is still a lot of analysis to be performed. The bottom line is that there were high temperatures and pressures in the wheel well caused by some sort of jet entering from the forward end.

Mr. Tetrault then concluded by saying something to the effect that if it turns out that the roller pin comes from the aft end then all the theories go out the window and they'll start again.

A group discussion related to modeling the characteristics or behavior of the heat source followed. It was noted that some debris from the wheel area is coated, other items weren't. Some items were aluminum and simply vaporized. Others survived the entry. It was noted that KSC was directed to determine what material was deposited on the uplock roller. Where they go next depends on the results of this test and others, such as performing chemical analysis on the tires to determine if any constituents are imbedded in it.

Mr. Scott Hubbard reported that he is working on getting three questions answered:

1. What is the difference between foam impact and ice impact and how to you know?
2. What is the change in a tile pre-mission and post mission after you've had an impact and how do you know?
3. Changing contrasts

Mr. Hubbard brought back from KSC three pieces of tile from STS-73 that were struck by ET insulation debris. Impact areas are easily observed due to differences in contrast. The nature of the tile damage leads them to believe that it is very unlikely that there was a big area under Columbia that was raked off by ET debris—would have seen very high contrast in the video. The connection between ET debris and tile gouges was done analytically—little direct visual evidence. But if you look at the flow fields and Southwest test it is a highly plausible case. A request is in the system to obtain video of known shedding events. Could validate conclusions.

Question: Since these were all low angle impacts—why would you conclude that these were harmless events regardless of where they struck? That is not his personal conclusion; however, there is no evidence that any of these impact events resulted in loss of structural integrity. No evidence that any of the "wounds" from foam impacts during launch grew during re-entry. The same cannot be said about wormholes

Question regarding use of CRATER--CRATER analysis previously always performed after the fact at KSC. Not predictive since you are doing after the fact fit of the data. Nonetheless this is how analysts obtain their level of confidence. STS-107 was the first time CRATER was used in flight.

CRATER database is not repopulated with new data. They simply compare as flown data with CRATER (not updated since 1985). Don't repopulate because they don't know the cause of the impacts. Do a "gut-check" comparison—look at the number of divots above and below 1 inch and compare against CRATER.

This led to a question—how do you know what kind of damage comes from what kind of impact? They feel they are able to differentiate between insulation impacts and ice impacts. Foam impacts create divots. Ice impacts create holes that grow over time—thus the name wormholes. The wormhole evident in the third tile from STS-73 was probably caused by a piece of ice about the size of the tip of a finger and weighing ~1 gram. Wormholes are not only caused by ice. During STS-1 a bolt or nut that got picked up at launch impacted the body flap—resulting in a sizeable wormhole.

There is speculation that some of the wormholes evident in Columbia debris were caused by impacts from other debris during reentry.

In theory, as a wormhole in a tile hits the aluminum plate underneath, the aluminum heats up and results in possible delamination of that tile and subsequent delamination of adjacent tiles.

Throughout Shuttle history—average of 75 divots per flight, with about 200 being the max (all sizes)

Question about statistical analysis of impacts—lots of variables: 1) where does it strike; 2) how big is impact; and 3) what is the density at that location? Each contributes differently to the analysis. Agreed that they must review any statistical analysis performed by NASA.

Independent analysis by Dr. Peter of Cornell in '94 concluded that there is significant, clustered damage related to these events, and that they probably had a problem that would manifest itself on the right side before the left side (assumes that oxygen feed line on right side provides extra debris). Also concluded that significant follow-up is required in terms of how the tiles were bonded and what their impact resistance was.

This led to a question about impact testing performed by NASA. Response was that some tests were performed, but never a full-up array of tests covering the range of impact resistance.

Follow-on work - Tile debris evaluation test plan is currently being developed. Also following up on video of STS-73 debris hits. Also considering looking at all ascent video to determine if any changes to tiles can be found, regardless or whether or not debris can be seen

Debris Field Chart Discussion – Debris is coded to indicate high-predicted ballistic coefficients vs. low coefficients. While the pattern indicates that left wing debris fell first and in greater quantities—cannot draw any real conclusions because: 1) pickup of pieces depends on how many people live in the area and how many roads are in the area; 2) people were focusing on left wing debris; and 3) assume that tile debris was from the left wing unless you can conclude that it wasn't. The chart nevertheless indicates that the problem originated in the left wing and clearly shows that the crew module came out last

Brainstorming the Hypothesis

Problem started in the left wing, eventually resulting in structural weakness. Orbiter could not withstand aero forces and came apart. Investigation roadmap says that this structural weakness originated in the "fill in the blank".

Question: What testing or investigatory activities need to be performed that would lead us to prove/disprove or accept or reject any of the identified potential problem issues?

Maj.Gen. Barry reported that the team is looking at maintenance turnaround issues. The subteam is looking at OMM process at KSC. Already looked at the Palmdale records, flow process, tools, procedures and signoff, QA & QC. Still working waivers.

Adm. Gehman: Since we don't know the initiating event or direct cause—kind of Easter egging looking around maintenance records?

Maj.Gen. Barry: Took the SIAT report as an example and told the subteam to look there again. Maintenance team went out to the pad to look around. FOD is big issue—really strict when Orbiter moving to the pad. However, lots of FOD when there's no Orbiter on the pad. Question—could any of this stuff get away? Example--nut/bolt from a scaffold popped off. People heard the noise it made and knew something happened. Debris wasn't not found until after launch.

Question re: Aging – Does NASA perform stress tests on the wings? Measure deflections over time? Response: Don't believe so. Aging usually addressed by mods. However, some mods are made to save weight.

Aging is difficult to identify because you don't know it is taking place. If you did know it would be considered "modification" or "repair".

Adm. Gehman: add a .5 to each of the categories where it makes sense—"detection of aging events". Applies to tiles—some tiles still original.

Question: As the role or function of the orbiter changed over time have any weaknesses crept in? For example, tiles were never designed with impacts in mind—nothing in the specs that could be found. No one thought that launch environment would be so "dirty".

Question: Is NASA using modern or updated NDE techniques and testing? Our team is bringing in their own experts--has NASA kept up to date and spending the money to be current? Pandora Box opened. Visual inspection not good enough in an aging space force.

RCC spec'ed for 61 flights (downgrade from 100). Is this something to follow-up on?

Question: Is it possible to test structural integrity of RCC panels that have flown? Can do same tests done originally. Lockheed Martin to provide some destructively tested as flown panels.

Question: How to determine residual ability of tiles to stay on unless you take a sample and pull? Currently they only do a visual inspection and "wiggle" test. Pull tests are performed only on newly installed tiles (10 lb test).

Question: What about tiles that are still original? Only tested when first installed, and then only to determine if the tile will fall off. Never tested to failure. Therefore there won't be any baseline to compare upcoming results to.

Pull test on recently installed tile was once witnessed at KSC. Literally pulled the face off the tile. Rather than replace it NASA glued the tile back together (repair)

Speculate that repairing tile on-orbit with RTV is OK. Developing procedures makes it complicated.

If we were projecting lateral stresses you'd think we'd know how strong the bond is. NASA should know! Lot of debris where RTV and everything else like core bond is all-intact and half a tile is missing. Hit at high speed and bond is still there. Lose a lot of tiles where there's a lot of heat. Lots of tile structurally intact

Action to group 3 to check literature and determine the adhesiveness of the tiles?
What do you compare against?

Adm. Gehman – if end up with a complex failure where a number of things had to go wrong in series, weakened tile bonding certainly must be considered.

Adm. Gehman – what are effects of rough wing? RAdm. Turcotte is working this issue. Don't have any kind of roughness coefficient.

Data from STS-109 indicates Columbia on average is a rough ship.

Adm. Gehman believes he heard somewhere that even though Columbia spent no greater time in the transition periods—she did indeed experience higher temperatures than the other three. If true, we would expect that higher temps would affect RTV, etc.

Since Columbia is heavier, does that result in higher temps? Need to compare to STS-109 trajectory.

Adm. Gehman - Two questions to be answered: 1) rough wing analysis, and 2) does heavier necessarily equal hotter and faster?

Design Compromises – example ET paint vs. foaming. Table design business until fault mechanism better understood.

The meeting was adjourned at 1515.

Identified Actions

- Question about statistical analysis of impacts—lots of variables: 1) where does it strike; 2) how big is impact; and 3) what is density at that location? Each contributes differently to the analysis. Agreed that they must review any statistical analysis performed by NASA. Action: Group 1

- RCC spec'd for 61 flights (downgraded from 100). Should be followed up on. Action: Group 1

- Action to Group 3 to check literature and determine the adhesiveness of the tiles? What do you compare against? Action: Group 3.
- Adm. Gehman - Two questions to be answered: 1) rough wing analysis, and 2) does heavier necessarily equal hotter and faster? Need to compare to STS-109 trajectory. Action: Group 1.

These minutes are hereby submitted for the record.

Approved
Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff	CAIB	281-283-7571
Mr. Tetrault	CAIB	281-283-7509
Mr. Wallace	CAIB	281-283-7508
Mr. Choban	Recorder	281-283-7591
Mr. Shannon	CTF	281-483-8412
LtC. Bloomfield	CAIB	281-244-2233
Mr. Kirchhoff	CAIB	281-283-7821
Mr. D Pye	CAIB	281-283-7549
LtC. Goodman	CAIB	281-283-7569
James Arnold	CAIB	281-283-7572
Laura Brown	CAIB	281-283-7565
Doug Cooke	CAIB	202-329-8844
Paul Wilde	CAIB	301-775-6797
Bill Sikora	CAIB	281-283-7564
Jeff Guzzetti	CAIB (NTSB)	202-297-8880
Steve Schmidt	CAIB	281-283-7577

Hypothesis 1 as revised 03/14 (Group Outliner)

1. The orbiter and crew were lost because of structural damage to the left wing. Damage caused by entry aero forces, combined with the weakened wing previously damaged by thermo dynamic forces, were beyond the orbiter's control system's ability to maintain controlled flight. The left wing structural weakness originated:

- **1.1 In loss of TPS under the wing**
  - **1.1.1 Due to maintenance turn around work**
  - **1.1.2 Due to ascent debris strike**
  - **1.1.3 Due to orbital debris strike**
  - **1.1.4 Poor design / manufacture / modifications**
  - **1.1.5 Due to aging (Loss of performance over time)**
- **1.2 In loss of Tiles (other than under the wing)**
  - **1.2.1 Due to maintenance turn around work**
  - **1.2.2 Due to ascent debris strike**
  - **1.2.3 Due to orbital debris strike**
  - **1.2.4 Poor design / manufacture / modifications**
  - **1.2.5 Due to aging (Loss of performance over time)**
- **1.3 From compromise to RCC**
  - **1.3.1 maintenance / turnaround escape**
  - **1.3.2 ascent debris strike**
  - **1.3.3 on orbit debris strike**
  - **1.3.4 Poor design / manufacture / modifications**
  - **1.3.5 Due to aging (Loss of performance over time)**
- **1.4 From a structural issue**
  - **1.4.1 caused by maintenance / turnaround escape**
  - **1.4.2 ascent debris strike**
  - **1.4.3 on orbit debris strike**
  - **1.4.4 Rough wing**
  - **1.4.5 Poor design / manufacture / modifications**
  - **1.4.6 Due to aging (Loss of performance over time)**

- 1.5 In off-nominal entry configuration / flow field
  - 1.5.1 due to maintenance / turnaround escape
  - 1.5.2 ascent debris strike
  - 1.5.3 on orbit debris strike
  - 1.5.4 Space weather
- 1.6 internal hazard
  - 1.6.1 fire (pyro, hydraulic fluid, etc.)
  - 1.6.2 explosion (tires, pyro, etc.)
  - 1.6.3 other
- 1.7 Willful Damage

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 19, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 19 March 2003 **Time:** 1300 - 1715

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

Admiral Gehman opened the meeting at 1300 hours by outlining the agenda: a discussion of the format and structure of the final report to be followed by a discussion of interim recommendations facilitated by the Group Systems Meeting Support Software.

There were 3 action items generated from this meeting and listed later in this report.

Final Report Structure and Format

Admiral Gehman set the stage for the discussion by stating the goal of the meeting. This goal was clarification of what was needed for the final report in order that he would know what to ask from the sub groups. He wanted to define format and structure. Admiral Gehman stated that whatever the Board is comfortable with would be fine, but suspected compromise would be required since the CAIB represented many communities. Admiral Gehman then introduced Mr. Lester Reingold, Lead Editor for the report.

Mr. Reingold presented information on potential audiences, writing style, some formats, formatting issues, and the current outline.

Admiral Gehman opened the discussion with the question of identifying the target audience for the final report. Before that question was answered, several other key points were made. Dr. Ride pointed out that report had to be written so that it was actionable. Dr. Widnall suggested that the report should be considered a layered document that would address the various backgrounds of the audience. Dr. Ride discussed several aspects of the Rogers Commission report.

Admiral Gehman stated that all recommendations must be supported by facts and findings, findings equate to conclusions. The order of precedence should be facts, analysis, findings then recommendations. Another output the CAIB will generate are significant observations to capture those items that may not be appropriate for a recommendation.

Mr. Hubbard raised the concern that all members have the same understanding of "facts" and "data". Admiral Gehman stated that facts equals data, discussion equals analysis. Admiral Gehman suggested that analysis is a way getting to the conclusions and that there are four steps to go through:

a. Have facts and data
b. Discussion and Analysis
c. Findings

d. Recommendations from one or more findings.

Getting back to his opening question, Admiral Gehman suggested that the target audience be the public policy audience and that the report could be a single document. Mr. Wallace pointed out that the public, which influences policy makers, and policy makers will view the report with different perspectives.

Mr. Schmidt suggested that care be taken relative to technical discussions that might lead to disclosure of proprietary or ITAR data. Admiral Gehman emphasized the report must be written in English, not technical jargon, and that the report writers must not assume some level of technical knowledge. The Report should be comprehensive, items must be described elsewhere.

Admiral Gehman stated that the Board would defer the discussion of chapter titles to another meeting.

Admiral Gehman summarized the structure agreed to during discussion. The report would contain:

a. Preface & Signature page (combined)
b. Memoriam Page
b. Executive Summary
c. Topically Oriented Chapters
d. Footnotes and references would go at the end of each Chapter

Dr. Logsdon made the point that the Summary should be capable of standing alone. Dr. Ride suggested that the recommendations of the report follow the Summary. Ms. Brown suggested that the press release could also act as a two page summary.

Mr. Hubbard recommended definition of terms like "analysis" since some terms may be subject to interpretation.

Admiral Gehman suggested each chapter should be organized about the same. Each chapter may be able to stand alone. Summarized somewhere else.

1. Start off with facts
2. Discussion or analysis
3. Findings
4. Conclusions
5. Recommendations

Admiral Gehman stated the consensus reached by the Board:

a. Lessons learned in administration (separate annex, defer specific content.)
b. Chapters must stand alone
c. Electronic and paper copy (everyone walks out with an electronic and hardcopy version of a brief)
d. Interim report (e.g. interim recommendations)
e. Media (use of CD-ROM is a good idea)
f. Graphics (there should be liberal use of)

Dr. Ride made the point that issuing an interim report facilitating Return To Flight is good as soon as the root cause of the accident has been determined. Admiral Gehman stated that an interim report could deal with specific technical issues, while the final report will include those things plus all the managerial issues.

Dr. Logsdon pointed out some of the reasons for the length of time it took for the Return To Flight on Challenger (e.g. recommendations for oversight and recertification on the SRM/SRB). If there is an interim report that specifies certain actions, then that puts the CAIB and NASA in the role of validating the findings.

Mr. Schmidt stated that another complicating concern is the manning of the ISS. Waiting too long to issue a finding may impact the manning of the facility.

Admiral Gehman observed that the CAIB would appear more timely and relevant if findings were provided, as they were ready. The CAIB could issue advisories and the sum of the advisories could equal an interim report. NASA is not waiting for the CAIB to issue findings.

Dr. Widnall stated that for the final report Time zero equals Feb 1st. The CAIB should issue a report that addresses the "as was" situation, changes post accident are O.K. but not necessarily relevant to the content of this report.

Dr. Logsdon observed that the perception is that recommendations for fixes are going to come from the CAIB. The report should indicate whether there is agreement on the fixes. Dr. Logsdon also stated the need to understand the power of public and political legitimization of the CAIB recommendations.

Admiral Gehman summarized by saying recommendations have to be phrased very adroitly. The recommendations should proscribe NASA's approach, not the fix. NASA's path to Return To Flight should not drive the CAIB report. Can have interim reports and advisories.

Mr. Lengyel asked the Board if the understanding was that groups would be writing factuals and analytical reports based on the NTSB format for specific topics. These reports based on fact finding visits etc. by the Groups. Admiral Gehman responded that he was not ready to decide. The board will go back later to decide what kind of raw materials are needed. Groups will be tasked to submit material to support the report, specifics will be determined later. Admiral Gehman stated that the Board primaries will meet with each group to determine specifics.

Mr. Lengyel then suggested the use of the list of Group topics published in week 2 as a starting point. Admiral Gehman agreed but believes the list needs to be updated before being used. Admiral Gehman commented that the investigation road map is closer and may be a better tool. The Board will capture what has been decided at this meeting and see how it translates Group by Group.

Moved to the executive session.

Identified Actions

- Update the Group Topics List from week 2. Action: Ad Hoc Report Writing Working Group
- Set meetings with each Group to identify required inputs for the final report. Action: Executive Secretary
- Obtain copy of Office of Technology Assessment (OTA) reports as a template. Action: Dr. Logston stated he would get a copy.

The meeting adjourned at 1715.

These minutes are hereby submitted for the record.

Approved
FOR
Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 19, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG	PHONE
Admiral Gehman	CAIB	281-283-7537
Mr. Hubbard	CAIB	281-283-7517
Dr. Ride	CAIB	281-283-7503
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283--7579
Dr. Logsdon	CAIB	202-994-7292
Mr. Choban	Recorder	281-283-7591
Mr. Buzzard	CTF	281-483-8412
LtC. Bloomfield	CAIB	281-244-2233
Mr. Kirchhoff	Editor	281-283-7821
Mr. Reingold	Lead Editor	281-283-7539
Mr. D Lengyel	CAIB Staff	281-283-7581
Lisa Chu-Thielbar	CAIB Staff	281-283-7568
Dave Pye	CAIB	281-283-7549
Laura Brown	CAIB	x7565
Dan Diggins	CAIB	x7814
Ron Gress	CAIB (IAST)	x7532
Lindy Fortenberry	CTF	281-483-8433
R. John Primbs	CAIB	281-283-7838
Cpt. Anne-Marie Contreras	CAIB	281-283-7838

CAIB Recommendation Process (Group Outliner)

1. Recommendations should identify a safety issue, but generally should not specify the solution, beyond stating the safety objective.

2. The best minds in the world are available to use, and we should use them in vetting recommendations.

3. We might consider raising safety issues and making recommendations on three levels.

   3.1 Identify safety issues brought to NASA's attention (or elsewhere) for consideration / discussion.

   3.2 Recommendations which cannot wait for the final report.

   3.3 Final report recommendations.

Recommendation 1 (Group Outliner)

1. Form a working group to define processes that ensure imaging of the orbiter via DoD assets is accomplished near the beginning of each mission and near the end of the same mission. As a minimum, the group should include representatives of USSTRATCOM, AF Space Command, NRO,NIMA, and NASA (specifically, MMT, FDO, and FCO members). Items for the working group to delineate include the following:

   1.1 Consider all assets available, from ground-based optical and radar imaging, to space-based assets.

   1.2 Address who will need to be cleared to the Secret and/or Top Secret / SCI levels to address and view classified products, but ensuring the right management levels affecting on-orbit decisions have proper access.

   1.3 Plan initial and (recommended) annual recurring training and orientation to the types of products available and the processes used to obtain the products. This training includes, but is not limited to:

      1.3.1 RF tracking and imaging systems

      1.3.2 Optical tracking and imaging systems

      1.3.3 Debris discovery capability and limitations

1.3.4 Emerging technologies with relevant contingency capability

1.3.5 Other sensors

1.3.6 Process / procedures / guidelines to request DoD / other agency support

1.3.7 Security guidance and procedures

1.4 Upgrade NASA security communications equipment to ensure expeditious and secure communication with the appropriate agency or asset organization. These should be installed in close proximity to Space Shuttle management and operations centers in JSC. Include capability such as SIPRNET and other agencies' computer network capability as applicable.

Admiral Gehman opened this part of the session by stating the need to identify format or style and criteria for writing the recommendations. Recommendation should identify a safety issue but not a solution. Need to state what is trying to be fixed. Don't keep it secret but vet it widely to ensure it is not a mistake, don't surprise anyone.

Mr. Schmidt asked two questions: Does it have to be a safety recommendation? Is a hardware fix a safety issue? Admiral Gehman responded by saying that a recommendation must be related to the charter. If it affects redundancy or margin of safety then it is a safety issue. The must adopt a very broad definition. The CAIB needs to comment on the three gradations of recommendations.

Admiral Gehman stated that the CAIB has to issue an advisory or significant observation saying the issue must be addressed.

Mr. Buzzard raised a caution on the level of formality that the advisory may take on. Mr. Wallace observed that phrasing of these types of recommendation must be carefully chosen.

Dr. Ride agreed with Mr. Hubbard's idea of an action form so that it provides a focus. Its visible. It helps NASA focus on specific items. Helps people that may want to talk in privilege.

Admiral Gehman asked the question is: Is there something between an action form and a recommendation? Another example is playing around with a finding and a recommendation. Using Inconel bolts, they have been shown to be susceptible to corrosion in the salt air and lose ½ their strength over time. CAIB thinks NASA should do something about it. If CAIB tables the recommendation to determine what is known and unknown and pursues further study of something like "Can foam knock off a carrier panel", more study is needed, but if CAIB is suspicious, should the CAIB notify NASA they have a concern about Inconel bolts? Should there be something between a 564 and a recommendation? Is utilization of the 564 form appropriate.

Mr. Buzzard stated that there two principles to be considered

a. CAIB has vetted issue enough to consider it important will be part of report
b. Issue needs more time and can't wait for report.

Admiral Gehman stated that he was leaning to make a recommendation on the use of imagery.

Mr. Lengyel asked if positive findings were candidates for interim recommendations? Admiral Gehman answered, No. A recommendation is based on findings. Admiral Gehman then stated that interim recommendations should follow the same rules.

The Board recommended that utilization of on-orbit photography goes to 3.1 but requires witness testimony.

Dr. Ride stated that the Shuttle needs to be inspected on orbit twice.

Admiral Gehman summarized the discussion by saying that 3.2 and 3.3 items are recommendations going into the final report. A 3.1 may or may not be a recommendation, when issued it is not. When a 3.1 is issued supporting rationale is not required.

Recommendation 2 (Group Outliner)

1. Facts

1.1 The RCC system is one of the principle components of the Thermal Protection System (TPS) and has a Critically Rating of 1/1 (loss of crew - loss of vehicle).

1.2 The composite used in the shuttle TPS system is a complex material system. It consists of a reinforced carbon-carbon (RCC) substrate that carries the structural loads, a silicon carbide coating that protects the carbon from oxidation, and tetraethyl orthosilicate (TEOS) impregnation and a sealant coating that provides additional oxidation protection.

1.3 During initial manufacturing acceptance, the integrity of production composites used in the RCC system are checked at various points in production by physical tap, ultrasonic, radiographic, eddy current, weight gain, and visual tests. In addition, a flat plate control panel made in parallel with the production piece is destructively tested at various points in the production process.

1.4 A projected design mission life has been established for each RCC component. These range from one flight, for certain LESS/RCC system fasteners, to over 100 flights for some RCC panels. These projections are based on simulated flight load testing and/or analysis and assumed the presence of a sound composite structure.

1.5 NASA Calculates that a 1" diameter hole in the silicon carbide coating on the upper surface of the wing leading edge panel would not lead to a breach of the thermal protective system on reentry. For the hotter lower panels (Panels 7-12), a circular flaw of 0.25 inches has been calculated as being acceptable. The remaining lower surface panels are calculated to be able to survive reentry with a 1" circular hole in the silicon carbide coating.

1.6 During service, RCC components are only inspected visually between flights unless an unusual surface condition is found.

1.7 The planned interval for removing RCC components for inspection is typically many flight unless their removal is dictated by an observed surface condition or necessitated by the requirement to provide access for other operations. For example the interval for the wing leading edge panel is 16 missions.

1.8 Post flight material flaws have been observed on some shuttle wing leading edge RCC components. This experience is summarized in Table 1 and illustrated in Figures 2 - 8.

1.9 Destructive testing of some post-flight RCC components and the use of Thermography, Computer Tomography (CA), and Shearography have shown indications of RCC flaws not previously identified by specified shuttle inspection methods. Results of these inspections are summarized in Table 2 and illustrated in Figures 9 - 13.

2. Discussion

2.1 The composite material used in the LESS/RCC system is both complex and not fully understood. As the summary of post flight RCC system material damage shows, NASA is still learning about the performance of this material in a service environment.

2.2 Indications of subsurface flaws in RCC components have been found using advanced inspection methods. Despite the incomplete state of qualification for some of these methods, these results strongly suggest that currently specified inspections of composite RCC structures are not sufficient to ensure their material integrity is consistent with the assumptions inherent in the NASA analyses of the RCC capability and mission life.

2.3 To determine the most effective method of non-destructive testing methods to apply to the LESS/RCC System, the Independent Analysis and Support Team has initiated discussions with recognized composite

experts from the NTSB, FAA, USAF, USN and NASA. This work is ongoing and results will position the CAIB to specify the inspections necessary to ensure the material integrity of the LESS/RCC system.

2.4 Visual inspection is currently the primary means to verify the continuing integrity of the LESS/RCC system metallic support structure and fasteners. Satisfactory performance of these parts is critical to the overall performance of the Thermal Protective System. To verify the adequacy of these metallic parts and the specified inspections, it is judged that these parts should also receive inspections by methods more robust methods than simply visual inspections.

3. Recommendation

3.1 Based on reviews completed to date, the Columbia Accident Investigation Board (CAIB) has concluded the Leading Edge Structural Support System (LESS) should be removed from all shuttles and inspected. The scope of this inspection includes the reinforced carbon-carbon (RCC) components, internal insulation, attachment structure, and hardware.

3.2 NASA is directed to expeditiously develop, and submit for CAIB approval a comprehensive inspection plan for all LESS system components.

3.3 Upon plan approval, NASA is requested to perform these inspections in a timely manner. Results should be provided to the CAIB as they become available. Any parts exhibiting unacceptable or unusual condition should not be dispositioned without CAIB approval.

RADM Turcotte discussed his confidence level on the state of knowledge regarding the processes surrounding the RCC panels. At he was 80% sure, now he is only 65% sure. Recent events have shown what is not known about the RCC.

Only two panels were replaced on OV-102.
Pieces reviewed (samples viewed by the Board) were replaced after 19 flights.
Don't know the actual status of what was on OV-102.
Last time the entire system (RCC, spanner beams, inconel bolts) was when it was built using 25 year-old methods.
No clue about what was underneath the surface.
The Inconel spanner beams has not undergone NDE since manufacture.
Don't know specifics about repairs other than there have been a lot of repairs.
Bottom line is "we don't know".

Mr. Pye stated that there is an advantage to asking NASA to start putting together their thought on an NDE plan.

Admiral Gehman posed the question on how should the issue be framed: to state "prove to me that we have a flaw" or "prove to me it is safe to fly". Admiral Gehman stated his position that someone needs to prove that something that has not been inspected in 25 years is safe to fly. If you want to prove that something is safe then you must periodically certify it sooner than every 20 years.

Mr. Buzzard observed that there is a body of experience that suggests we are pushing our knowledge base of re-useable spacecraft with these materials and there ought to be concentrated effort to improve the NDE. The Board should make an observation that doesn't prejudge current practices.

Admiral Gehman summarized by saying that this recommendation was close to measuring up to a 3.1.

Recommendation 3 (Group Outliner)

1. Recommendation: The Shuttle should be inspected each mission, both at the beginning and the end of the mission. This can be done in whatever way is most convenient to the particular mission flight plan. To develop a plan for on-orbit tile inspection, NASA should:

1.1 Form a working group to determine the viability of inspecting the Shuttle from the ISS.

1.2 Form a working group to define processes that enable imaging of the orbiter via DoD assets. As a minimum, the group should include representatives of USSTRATCOM, AF Space Command, NRO, NIMA, and NASA (specifically, MMT, FDO, and FCO members). Items for the working group to delineate include the following:

1.2.1 Consider all assets available, from ground-based optical and radar imaging, to space-based assets.

1.2.2 Address which positions will need to be cleared to the Secret and/or Top Secret/SCI levels to address and view classified products, but ensuring the right management levels affecting on-orbit decisions have proper access.

1.2.3 Plan initial and (recommended) annual recurring training and orientation to the types of products available and the processes used to obtain the products. This training includes, but is not limited to:

1.2.3.1 RF tracking and imaging systems

1.2.3.2 Optical tracking and imaging systems

1.2.3.3 Debris discovery capability and limitations

1.2.3.4 Emerging technologies with relevant contingency capability

1.2.3.5 Other sensors

1.2.3.6 Process/procedures/guidelines to request DoD/other agency support

1.2.3.7 Security guidance and procedures

1.2.4 Upgrade NASA security communications equipment to ensure expeditious and secure communication with the appropriate agency or asset organization. These should be installed in close proximity to Space Shuttle management and operations centers at JSC. Include capability such as SIPRNET and other agencies' computer network capability as applicable.

1.2.5 Consider requirements to images the ISS imaging (would need to include ISS representatives for this aspect).

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
27 March, 2003
These Minutes Contain No Sensitive Data

Purpose: CAIB Daily Investigation Meeting

Date: 27 March 2003 **Time:** 12:30 - 1545

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA web site.

There were 3 action items generated from this meeting. These are listed at the end of this report.

Scotty Sparks and Steve Holmes from Marshall Space Flight Center (MSFC) briefed the CAIB on the subject of External tank (ET) foam. Mr. Sparks began the briefing. Questions, comments, and clarifications from each chart are provided below as necessary.

- Chart 3 -
  - MGen Barry requested comments about effects of temperature and humidity on the ET foam. ANS: These topics will be covered.
  - Foam is sprayed on with the use of robotic machines in most areas of the ET with the exception of the bipod area and closeout panels.
- Chart 4 –
  - Gaps in foam cells are filled with the foam propellant plus whatever is in the ambient air. Currently the foam propellant is CFC-11.
  - Voids are being found during the dissection of ET-120.
- Chart 5 –
  - The list of topics on the left side of this chart enumerates phenomena experienced during launch.
  - The primary driver for using foam is the prevention of ice forming on most of the acreage. There are a few areas where heating is the reason; bipod, bottom dome, close-out panels, cable trays.
- Chart 10 –
  - Chart 1contents were amended with a pen and ink change by adding "BX-265" in the middle of the upper right-hand box in the matrix.
  - Conversion from CFC to HCFC as propellant spray a couple of years ago caused reduced bonding strength but it is still well within specification. The flight requirement is 19 PSI; the specification requirement is 30 PSI, and the observed strength of the bond was reduced from 54 PSI to 44 PSI as the result of the change.
  - There is generally approximately 4500 pounds of foam on an ET.
- Chart 11 –
  - Mr. Hubbard asked about the moisture absorption characteristics as temperatures approached zero degrees. ANS: MSFC will examine. There is already a Request For Information (RFI) in the system requesting this data so an action item need not be generated.
  - MGen Barry asked which is the better propellant material, freon or the new material. ANS: The new material is good and meets requirements.
  - The ET-93 spray agent was freon.

  - Generally, ice is not observed except in small areas which are waivered.
  - The weight test to determine how much weight was added due to absorption of moisture was conducted over a 30 day period but the weight shown on the chart leveled off after 7 days. Water actually sat on some of the panels under test.
- Chart 14 – Mr. Holmes now briefing.
  - Mr. Holmes was not sure if the profiles were taken from actual flight data or were taken from design parameters.
- Chart 16 –
  - History of "plug Pulls" on ET foam shows a random mixture of low strength bonds among high strength bonds.
- Chart 17 –
  - Mr. Hubbard asked why BX-250 is the material of choice for the bipod area. ANS: Primarily because of substrate temperature and it can be hand sprayed. It also has better cryogenic properties than the average foam.
  - MGen Barry indicated he had in his possession a chart which showed different temperature and humidity data for STS-107 than was presented. ANS: The charts portray data for different locations; the bipod versus the inter-tank.
  - BX-265 has exhibited lower bonding strength at lower temperatures.
- Chart 18 –
  - The legend on this chart is incorrect; it has been reversed.
  - There has never been a flight without foam striking the orbiter. The average is 100 strikes of 1 inch or less material and 20 strikes of material greater than 1 inch.
  - MGen Barry asked if foam could be designed so there would be no hits on the orbiter. ANS: No. This would require increasing the strength and therefore the weight. Also, there is too much variability in the foam.
  - Dr. Widnall asked how bond integrity was verified and whether the quality of the bond makes any difference. ANS: Bond integrity is verified by plug pulls. There is also a dependence on rigidly keeping within the process as the primary quality control mechanism. There can be "kissing bonds" which cannot be detected.
  - Dr. Widnall asked if the acreage foam was less of a problem than attach points and closeout panels. ANS: Yes except for the inter-tank.
  - Admiral Gehman asked how ET shrinkage during fueling was accommodated. ANS: The foam shrinks more than the tank shrinks.
- Chart 19 –
  - The most likely places from which to lose foam are the bipod area and the flange area.
  - MGen Hess asked if foam was a criticality 1 item. ANS: I suppose so.
  - MGen Hess asked how the fact that foam comes off and strikes the orbiter on every flight is handled. ANS: Requirements are levied by the program to preclude debris strikes from being a safety of flight issue or affect turn-around time. The ET project does not define what constitutes a safety of flight issue. When such issues are identified they get fixed.
  - MGen Barry has a question on the redesign of the bipod and flange areas. ANS: The flange blowout problem will be addressed by process changes. The bipod will be resolved by placing an inconel shield over the bipod.

- There was a question as to whether there was a 100% check on chemicals. ANS: Yes, via a receiving inspection and test.
- MGen Barry suggested improved humidity control to provide more margin. He also suggested better NDE techniques are needed.
- There was a question as to whether there were any thoughts to moving to robotically spraying the bipod area. ANS: That would really be difficult. MSFC is trying to redesign the bipod to eliminate the ramp with an inconel fairing. Which would fully enclose it and be equipped with heaters. They expect to proceed to wind tunnel testing at Arnold Air Development Center very soon.
- MGen Hess asked if any other product, such as Japanese foam, had been considered. ANS: They have no experience with it. Boeing may have tried to use it some.
- Mr. Cooke asked if there had been any ultraviolet degradation. ANS. No, the ET is fully qualified for a 6 month pad stay and a 6 year storage life.

The presentation concluded at this point.

Admiral Gehman then advised the CAIB that he has been appraised of comments indicating the CAIB has no authority in the areas of determining the length of the debris search and influencing mishap related testing and test procedures. The CAIB does have say-so over both issues. Mr. Buzzard accepted an action item to clarify CAIB authority in these areas. It was noted that Mr. Dave Whittle will brief the CAIB next Wednesday (2 April 2003) on the debris search. Mr. Tetrault observed that there is only so much test hardware and it is imperative that we get it right the first time.

Dr. Hallock –

- Has been working in 5 areas
  - Has been receiving a lot of space weather suggestions, most of which have already been covered.
  - Orbital debris and micrometeoroid damage (1 in 200) is considered the largest mission limiting risk factor depending on the orbit. There have been missions delayed because of this. Mr. Buzzard indicated there is a large uncertainty in this number, on the order of $\pm$ 200.
  - The modeling being done regarding heat flows is being tracked.
  - The fault tree analysis groups want to bring approximately 30 items forward to close. There will be detailed briefings to the CAIB Sub-Groups followed by a summary briefing o the CAIB.
  - Mr. Buzzard indicated he believed the Orbiter, ET, and their overlap deserve most of the attention.
  - The main issue Dr. Hallock is concerned with is OEX data. CAIB staff will observe OEX data analysis over the weekend. The combination of OEX and telemetry data will be referred to by the board as "flight data".

Mr. Hubbard –

- Visual analysis has produced 3D plots of data records whereby the foam debris footprint can be located on the leading edge. This work will be used to guide testing at SRI.

- The NAIT test plan for SRI testing is required so CAIB can review and comment. Use of the testing at SRI to validate CRATER performance should not be a first order issue. The best solution is to develop a simulation which recreates what actually happened.
    - Admiral Gehman questioned the purpose of the SRI testing. ANS: Tile tests will be done at various angles and speeds for the purpose of building a visual database of impact measurements. There are 2 types of RCC available; old but pristine material from Enterprise plus 1 old piece with 28 flights on it.
    - An extensive list of spare hardware has also been recently uncovered.
    - There was a question as to the size of the leading edge test structure to be constructed. ANS: The entire leading edge sub-system.
    - Mr. Tetrault indicated that buckling of the RCC could cause gaps at either end of the panel
    - Admiral Gehman added that the foam hit occurred when loads on the wing were nearly at maximum and Mr. Hubbard added that these forces will have to be included analytically.

Admiral Gehman reported on the NIMA briefing from the previous day.

- NIMA has been working to enhance the launch photography on their own and have succeeded in greatly enhancing the ascent launch video which clearly shows multiple pieces of foam being shed. There were several smaller pieces but 1 large piece struck the orbiter.
- NIMA believes they also see a boomerang shaped, 2 ½ foot piece of structure. It requires a lot of imagination to see this.
- This NIMA video may confirm impact on underside of the leading edge, the closeout panels, and wing acreage.
- Double clarity still images were also shown which show no damage to the underside of the wing.

Dr. Widnall –

- Concerned about the catalytic reaction of aluminum.
- NASA is addressing the issue and has put together a team to examine it. This team seems to be contacting the correct people.
- Dr. Widnall produced a chart showing when aerodynamics parameters went off-nominal. She has placed these on a timeline in an attempt to show when structural damage occurred and started having an effect. This happened off the coast of California.
    - Admiral Gehman indicated that he believed the OEX data will direct the investigation earlier in time.
    - Mr. Tetrault indicated he believes this information, plus debris analysis on the left main landing gear will cause one of the current prevailing theories to come off the table. Based on his debris analysis, Mr. Tetrault does not believe the landing gear ever deployed as postulated by aerodynamics analysis at NASA. This belief is based on the scorching of the equipment and the belief that had the gear deployed over CA or NV it would have been torn off and never reached East TX. He believes Dr. Widnall's theory of burning aluminum accounts for the observed lift on the left wing.

- Mr. Tetrault also reported a rumor out of KSC that OEX temperature sensors between RCC panels 9 and 10 indicate a 1000 degree (F) temperature on a wing spar over the Pacific Ocean.

MGen Barry –

- ET testing is on-going
  - Admiral Gehman questioned the relevance of ET foam bonding testing. ANS: It could be a causal effect.
  - MGen Hess indicated the results could bear on the issue of the risk management approach during manufacturing processes.
  - Before commencing cutting into ET-94, the CAIB will be consulted.
  - Mr. Hubbard indicated there will be tests using the small gun at Glenn Research Center to fire small pieces of cold foam.
- RCC
  - The group is trying to determine the specified design life of the RCC. Many numbers have surfaced with the latest being 50 flights.
    - On average there are 50 to 100 pinholes in every RCC panel for each flight. The acceptable size before repair is required is 0.004 inches. There are visual inspections only.
    - Many reasons for these holes have been identified: corrosion, debris impacts, atmospheric aero hearting, atomic oxygen contamination in orbit.
    - RAdm Turcotte is following up to determine if the Type-A sealant used may be causing problems.
    - There was a discussion as to how often this sealant was applied. RAdm Turcotte will investigate to find out whether this sealant is applied after every flight.
    - Admiral Gehman observed that the number of pinholes brings the RCC strength into question.
- MGen Barry reported his group had had a wide ranging discussion with a number of astronauts over a large number of topics ranging from management to engineering to NASA's vision for the future. MGen Barry indicated he was surprised to hear the sentiment expressed by the astronauts that they favored concluding the Shuttle Program and going back to capsules since this was deemed the best way to get out past low earth orbit.

MGen Hess –

- The CAIB needs to recommend to NASA that they specify criteria for retiring one of the Shuttle vehicles as a different way to look at the longevity of the program.
  - Mr. Cooke interjected that it was difficult to separate a Shuttle life discussion from one for the International Space Station (ISS) which is designed to extract most out of the shuttle at every shuttle visit.
  - Admiral Gehman observed that getting to the next step of the human space flight program might require ending the Shuttle and Space Station programs at the same time.

- Group 2 is very close to taking such things off the table as payload, training, crew certification and life science issues. Examining the OEX data might delay closing the life sciences topic.
- Remaining work for Group 2 includes such things as DoD imagery request, CRATER, a foam audit from STS-112 onward, MER/MMT relationships, and SR&QA chain of command and how it reacted. This last topic includes FRR and CoFR.
- The CAIB needs to do a "what could have been done if" exercise on scenarios if certain decisions were or were not made. Admiral Gehman agreed this will have to be addressed in the report.

Mr. Wallace –

- His group is starting to see a picture of top-level meetings that are run by contractor senior executives with NASA GS-13 safety representative sitting in the 3rd row. This phenomenon is repeating itself.

Mr. Hallock –

- NASA has created a fact database and it is available to the CAIB.

The meeting adjourned at 1545 hours.

Action items generated from this meeting are listed below:

1. Mr. Buzzard to correct any impressions that the CAIB has no authority over length of debris search, test requirements and procedures, and other pertinent matters.
2. RAdm Turcotte to ascertain how often Type A sealant is applied to the RCC panels on the wing leading edge.
3. Each group to develop storyboards depicting what they've done and where they are going.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte via Telecon from KSC	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Lengyel	CAIB Ex. Secretary	281-283-7581
Mr. Hartman	Recorder	281-283-7591
Mr. Buzzard	CTF	281-483-8412
LtCol. Bloomfield		281-244-2233
LtCol Larry Butkus	CAIB Staff	281-283-7839
Doug Cooke	CAIB Staff	202-329-8844
Jim Arnold	CAIB Staff	281-684-2587
Laura Brown	CAIB Staff	281-283-7565
Bill Sikora	CAIB Staff	281-283-7564
Tom Haueter	NTSB	281-283-7808
Steven Schmidt	CAIB Staff	281-283-7577
Les Reingold	CAIB Staff	281-283-7539
Chris Kirchhoff	CAIB Staff	281-283-7821
Jim Smiley	CAIB Staff	281-283-7545
Jim Mosquera	CAIB Staff	281-283-7546
Tom Carter	CAIB Staff	703-416-3461

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 28, 2003
These Minutes Contain No Sensitive Data

Purpose: CAIB Daily Investigation

Date: 28 March 2003 **Time:** 1230 to 1415

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA web site.

There were no action items or requests for information generated from this meeting.

Admiral Gehman introduced Mr. R.L. Gibson who provided a presentation and discussion on in-flight anomalies (IFA) for STS-28 and STS-27. Admiral Gehman expressed the CAIB interest in learning how NASA handles in-flight anomalies. He observed that they "just seem to go away".

- STS-28 Chart 1 –
  - Boundary layer transitions are normally determined by increases in temperature.
  - The early boundary layer transition was not seen in real time by either the flight crew or ground crew. It was only noticed during post-flight data analysis.
  - Mr. Gibson was not part of the STS-28 flight crew, he was Chief of Safety for the Astronaut Office.
  - Admiral Gehman noted that the early boundary layer transition had larger implications than just in the area of time; it also has thermal implications.
- STS-28 Chart 2 –
  - Mr. Gibson offered a rough wing as an alternative to protruding gap fillers as the cause to the early boundary layer transition. He indicated that blaming the anomaly on protruding gap fillers might have been an easy answer so that flights could resume quickly. A determination that a rough wing caused the anomaly would have caused a big problem because the fix would have substantially delayed return to flight.
  - Mr. Gibson never had much success in having his alternative causes of the IFA considered.
- STS-28 Chart 3 –
  - There were questions on the definition of Keq and how it was measured. ANS: Not sure.
  - Mr. Gibson believes the Keq requirement is less than or equal to 0.110. The chart labeled Figure 8 shows a mapping of Keq for Columbia for STS-28.
  - MGen Barry commented that these types of incidents contribute to the aging vehicle issue. He also noted that the Type A sealant which is currently used to seal the pinholes in the RCC was not used on the 1st 5 flights of Columbia.
  - The atmosphere is not evenly distributed around the planet. It extends further into space at the equator than at the poles. As a result entries made on the descending node or from a high inclination angle cause more stressful thermal conditions than entries made from lower inclinations or from an ascending node. It was noted that STS-107 was entering from a relatively high inclination and on a descending node.

- This IFA occurred on the 8th flight of Columbia.
- STS-73 also had an early boundary layer transition on the left side and this also was a Columbia flight.

- Chart labeled STS-27 (1 chart plus a series of photographs)
  - STS-27 was a classified DoD flight that was struck by ablative coating shed from the nose cone of the right hand solid rocket booster (SRB). That the Orbiter was impacted by launch debris was noticed by the ground and the flight crew was notified on flight day 2 and asked to use the remote manipulator system (RMS) to conduct an inspection of the vehicle. The inspection revealed a right wing which "looked like it had been blasted by a shotgun".
  - While the in-flight inspection did not reveal any missing tiles, a post-flight inspection showed 1 tile was missing and there would have been a burn through of the orbiters metallic skin were it not for a steel plate associated with a communications antenna. Because the surrounding tiles were not noticeably damaged a theory was put forth that a wormhole in the tile allowed heat to melt the bonding and the tile debonded. Although high quality pictures of the tile damage were available to the flight crew they could only transmit very low quality pictures over the secure TV system because of the classified nature of the mission. The ground crew determined the damage was "nothing that hadn't been seen before" and the mission proceeded as though nothing was wrong.
  - Mr. Osheroff observed that he could not believe there was no corporate memory of this incident and the same kinds of mistakes were made on STS-107.
  - Mr. Gibson indicated that he asked during the de-briefing if anything could have been done to mitigate the thermal effects of the damaged tile. He was told that nobody knew if anything could have been done. MGen Barry indicated NASA had been asked the same question by the CAIB and while several steps that could have been taken were provided by NASA these steps would have only mitigated approximately 100 degrees of the 3000 degrees of heating. Dr. Hallock observed that reducing weight by dumping the Spacehab could have helped but that could not be accomplished on orbit.
  - Dr. Osheroff suggested that NASA consider replacing some of the tiles with heavier tiles and increasing the number of flights per year in order carry the same weight to orbit.
- General Discussion –
  - Admiral Gehman asked Mr. Gibson for his feelings about going on an extravehicular activity (EVA) to repair tile problems. Mr. Gibson replied that he would want to do that. He indicated NASA was working on developing an on-orbit tile repair kit but the project was cancelled before STS-1.
  - Admiral Gehman asked if Mr. Gibson has any suggestions or general observations.
    - NASA has lost much of its corporate memory over the past 10 years. Because of budget restrictions they are encouraging their older employees to leave.
    - Mr. Gibson indicated he believes the budget environment over the past 10 years has influenced turn around (tasks no longer done) and caused a spares shortage.

That concluded Mr. Gibson's presentation.

Admiral Gehman reported he had prepared a storyboard for the final report which will be used in the Group 1 focus meeting and subsequent focus meetings for groups 2 and 3.

Mr. Tetrault –

- Future changes to the mishap timeline are probable. There have been timing errors in some of the sensor readings.
- Two pieces of unusual debris have been noted at KSC; pieces of RCC with tile material fused to it. No conclusions about how this happened have been made.

MGen Barry –

- MSFC is considering 3 options for bipod redesign:
  - Smaller version of the same design
  - Exposing the top of the bipod to the air stream
  - The "mailbox"
- Group 1 has learned there are 3 kinds of maintenance associated with the RCC:
  - RCC panels are replaced. Three Columbia panels, 2 on left wing and 1 on right wing, have been replaced.
  - Panels are refurbished by removing them and shipping them to the original equipment manufacturer (OEM) in Dallas, TX. This has been done 11 times to panels from each wing.
  - RCC panels on all Shuttles are repaired by applying more Type-A ablative material.
- United Space Alliance (USA) has told Group 1 that they count at least 50 new pinholes per RCC panel per flight. Boeing reports the number is closer to 2 dozen. It is believed that the source of these pinholes is corrosion from the zinc oxide paint. Holes less than 0.004 inches do not get repaired. There was no repair or refurbishment on Columbia prior to STS-107. Mr. Hubbard observed the CAIB needs an RCC briefing from somebody who knows.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

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Dr. Osheroff (Via Teleconference)	CAIB	
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Lengyel	CAIB Ex. Secretary	281-283-7581
Mr. Hartman	Recorder	281-283-7591
Mr. Shannon	CTF	281-483-8412
LtCol. Bloomfield	CAIB Staff	281-283-7809
Mr. Cobb (Via Teleconference)	NASA HQ	202-358-1220

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 31, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 31 March 2003 **Time:** 1230 - 1400

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

There was one action item generated from this meeting and listed at the end of this report.

Impact Testing
Mr. Hubbard reported that the NASA proposed foam impact test plan includes validation of the CRATER program using the pieces that were evaluated during the mission. Group Three believes that including CRATER in the testing is a conflict of interest, and that the testing should be based on facts, observations, and plausible calculations. Also, NASA is making unsubstantiated assumptions that would allow them to reduce the sample size and hence the mass of the debris that would potentially be used in the testing. Group Three will be participating in a Test Readiness Review with NASA later this week. NASA understands that testing will not be performed without concurrence from the CAIB.

Hypothesis
Mr. Tetrault reported that on Thursday they would be presenting a new hypothesis of what happened based on analysis of the debris. Amongst other things, the data allows them to postulate one of the following three events: 1) the vehicle went into flat spin (there is data showing flow from the rear of the vehicle forward); 2) the wing broke off leaving behind the chine and the wheel well; or 3) when some RCC panels on the left wing fractured only the lower half came off, resulting in additional lift on the left wing.

Debris Field
Admiral Gehman noted that the current focus is footwalking the areas with the highest probability of picking up the most debris. This high probability debris tends to be from late in the breakup. After the high probability sites have been picked over, the team would be significantly downsized. However, more interesting debris tends to be further West, where the debris team plans on performing aerial surveillance on case-by-case basis and no footwalking. Since early debris shedding was high on the Board's list as of last week, the Admiral was prepared to push for greater emphasis on western debris than is currently planned. Given that the new timeline indicates early debris shedding occurred over water, increased emphasis on Western debris may not be warranted. Topic for discussion on Wednesday during session with Mr. Dave Whittle of the Mishap Investigation Team.

Level of confidence

Admiral Gehman asked that Group 3 start considering terminology to use to express the level of confidence that the direct/most probable cause has been identified. The verbiage used must be carefully chosen to minimize chances that findings will be misinterpreted--these are the words everyone will be scrutinizing first. During the ensuing discussion it became clear that the words they use, i.e. "likely" or "probably" will be dependent upon the strength of the evidence and supporting analysis.

Return to Flight (RTF)

Mr. Wallace described the roles and responsibilities of the NASA Program Requirements Control Board (PRCB) and discussed RTF issues that the PRCB is currently addressing (Attachment). He provided a copy of a memo dated March 12, 2003 from Bill Readdy to Gen. Kostelnik directing the General to establish a formal "Return to Flight" team (Attachment) that will, amongst other things, determine the actions necessary to comply with the formal recommendations of the CAIB.

Board subsequently identified RTF issues that need to worked in the future, such as

- The level of the Board's involvement in the RTF decision,
- How to handle findings/recommendations not directly affecting RTF,
- Board's role in fixing problems with in the NASA management system,
- Using independent panel(s) outside of NASA (and the Board) to oversee implementation of TBD specific recommendations affecting RTF,
- NASA taking responsibility for go no-go

Safety

Admiral Gehman pointed out that the Board had not consulted with any experts in safety theory. If any recommendations need to be made in the area of safety, he wants to be sure they have a solid foundation or basis for doing so. General Hess stated that he has had discussions along those lines with the head of safety for Dupont, who is also a member of the National Safety Council. The General will seek guidance from her on this matter. The Board also needs a better understanding of the principles and structure of NASA's many cross-looking safety organizations. Concerns were expressed about the effectiveness of NASA's oversight role.

Identified Actions

Team 2 is to secure the services of a recognized expert in safety theory to brief the Board on the tenets of safety and serve as a consultant on an as-needed basis.

This meeting was adjourned at 1400.

These minutes are hereby submitted for the record.

Approved FOR
Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
March 31, 2003
These Minutes Contain No Sensitive Data

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Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Mr. Wallace	CAIB	281-283-7508
Mr. Buzzard	CTF	281-483-8412
Mr. Choban	Audio	281-283-7591
Mike Boulavsky	Recorder	281-280-8062
Tom Hausten	NTSB	202-314-6300
Dave Lengyel	CAIB	202-283-7581
Mr. Kirchhoff	CAIB	281-283-7821
Mr. D Pye	CAIB	281-283-7549
Doug Cooke	CAIB	202-329-8844
Paul Wilde	CAIB	301-775-6797
Bill Sikora	CAIB	281-283-7564
John Primbs	CAIB	281-283-3837
Steve Schmidt	CAIB	202-283-7577
Les Reingold	CAIB	281-283-7539
Robert Cobb (via telecon)	NASA IG	202-358-1220

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 02, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 02 April 2003 **Time:** 1230 - 1400

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

There were three action items generated from this meeting and listed at the end of this report.

MISHAP INVESTIGATION TEAM EXIT STRATEGY

Mr. David Whittle, Chairman, Mishap Investigation Team (MIT), provided a briefing on the debris search effort. The briefing included a description of the search assets and the status of search efforts in Louisiana, bodies of water, the Lufkin corridor, Corsicana to Granbury, and west of Granbury to California. Mr. John Casper and Mr. Dominic Gorie assisted him. Hardcopy of the briefing is provided as an attachment to this report. The body of this report is limited to providing information that supplements or clarifies the content of the briefing package.

Search Assets

Of all the remote sensing vehicles or technologies that were used, the DC-3 Compass, which was a platform for a hyper spectral scanner, was the most useful. With the DC-3 they have found pieces of metal approximately 1.5 inches in diameter. However, the government agency that "owns" the plane has reclaimed it to make modifications. Depending on its scheduled use in other places, the MIT may or may not get it back. Other technologies such as Forward Looking Infrared (FLIR), satellite imagery, and ER-2 imagery were not useful. The bottom line is that people on the ground and in Forest Service helicopters provided the best support.

Application of manpower on the ground was coordinated with the Forest Service. A 75% Probability of Detection (POD) factor was used to determine the numbers and positioning of searchers on the ground. With a 75% POD, the searchers are about 10-15 ft. apart. With a 95% POD, the searchers would essentially be walking shoulder to shoulder. This would not be feasible due to limitations in manpower and time.

The Forest Service Currently has four camps operating: Corsicana, Nacogdoches, Palestine, and Hemphill, Texas.

Louisiana

The State Police and National Guard brought in most of the debris collected early on. Some high ballistic coefficient debris was found at Ft. Polk, but the search there was limited because the range was in use. The MIT was recently given March 31 and April 01 to search the range. After the search and recovery effort there is complete search efforts in LA will be terminated.

Water Operations

The Navy led a significant effort to map and identify potential targets in the Toledo Bend Reservoir, Lake Nacogdoches and various ponds using various underwater imaging devices. However, the lake bottoms are covered with trees and stumps, making target discrimination a "challenge". This was compounded by poor diving conditions (low water temperatures, extremely poor visibility)

Mr. Whittle was asked if any high priority items were thought to be in the water or Louisiana. He responded that the high priority items tend to be much lighter than the engine parts they have found in these areas; therefore they would be further west. For example debris such as the "salad bowls" (Orb/ET aft attach shell liner assemblies) was found in the Hemphill area, which is northwest of the Toledo Bend area.

Lufkin Corridor

The Lufkin Corridor runs from Toledo Bend west to Corsicana. The search areas are divided into numbered 2nm x 2nm grids. Detailed records are kept on each grid. For example, the MIT can tell who searched each grid, when and how each grid was searched, and what was found.

Search methodology - a line of Forest Service searchers is trailed by NASA/EPA personnel. Items they find that are smaller than a fist are put in a bag. When they get about a dozen items in the bag they will set it on the ground. The location of larger items is marked immediately. The NASA/EPA personnel that follow document lat/long of the bags and larger items so that investigators will know where the pieces came from.

The search of this corridor will be considered completed when they have finished all the planned searches of the grids and they are confident that there are not any bulges of debris on either side of the corridor. Recognizing that debris will still remain in the wooded areas, hunters will be advised (as part of the license renewal process) to continue looking for debris during hunting season.

Corsicana to Granbury

Tiles or pieces of tiles that can be identified by part number or location on the Orbiter are considered "identifiable". On many of the tiles that were found the part numbers were burned off.

Each grid (2nm by 2nm) contains approximately 2880 acres. Ground crews are clearing about 12,000 acres a day. It follows that the ground crews are clearing 3-4 grids per day. Helicopters clear about a grid each per day. If the debris is small enough to pick up and the landing area meets safety criteria then the helicopter crew can go ahead and make the pick up. Otherwise they would mark the location and perhaps even drive out and pick up the debris themselves after their search day was complete—taking "ownership" of debris they have found.

Granbury to California

NTSB search boxes are developed using radar tracks plus any available video or JSC-provided trajectory information. The boxes represent areas most likely to contain debris. Mr. Whittle is confident that there is something in Box 1 (near Granbury), based on the number of radar tracks and returns and the fact there was an eyewitness. The box is about a 1.5 grids in size and will receive a standard 75% POD search. Box 4 (Mineral Wells) is not searchable by helicopter—nothing but bushes. It would take several weeks and $800,000 to have a ground team search just the higher probability areas within the box. He would consider sending out the DC-3 to look at this box if it becomes available. Helicopter searches were performed in the other two boxes in Texas without success. He does not intend to spend any more time in those.

Utah Boxes (6&9) – Box 6 is in very rugged country. They do not plan on spending much effort on this one. Box 9 is less rugged but difficult nonetheless. Volunteers are currently searching it on weekends only.

The Nevada Boxes (7, 7-1, 7-2, 7-3 &8) have a higher probability of locating something. They have completed searching box 7 and have moved on to box 7-3.

Albuquerque Box (5) –Also considered a higher probability box. Preliminary searches were conducted by helicopter and by some personnel on the ground. However, this box is not small, and the feasibility of a 75% POD search by the Forest Service is questionable.

The boxes generated by strings of videos are hundreds of square miles. There is no intention to search these.

Several cases or observations may possibly be attributed to small globules of aluminum. There is an extremely small chance of finding any of these globules. However, if people are seeing globules, and the globules are from the Orbiter—that says something about what happened to the structure.

Discussion and Q&A

Admiral Gehman began by asking about the search from I-45 west to Granbury. The MIT plan is to move towards Granbury until they get a debris density less than one piece per two grids. One reason that they have not found much debris west of I-45 is that they really have not searched there yet. Initial searches were based on call-ins. The Board would like the search to continue because they are most interested in left wing debris and the debris west of I-45 is predominantly left wing.

Mr. Gorie noted that they recently plotted the location of tiles and RCC that were identifiable by x and y location on the Orbiter and found that everything is scattered. He speculated that a search to Granbury would result in a find of 20-30 randomly distributed tiles located at a high cost, and asked how significant might that data be. For that is a key for determining how far to go west. Admiral Gehman followed by stating that the fact that the distribution of left wing tiles is random suggests that the initiating event occurred way up stream and that these tiles are not contributing to our knowledge any more.

Mr. Tetrault pointed out that, while tiles may not contribute much knowledge, pieces of RCC, carrier panels, or LES structure are useful for defining exactly where the location (initiating event) is. The debris is not pointing to sections 5, 6, and 7 as the photograph shows. It is pointing to 7, 8, 9 or maybe 8, 9, and

10. In any case, they are not matching up. If you searched 26 miles and came up with a piece of carrier panel it might be worth it. Types of debris may be more significant than quantity, and that should be part of the criteria for stopping.

Mr. Buzzard – Another significant tile is the Littlefield tile, which they believe came from the chine area and they are pretty well convinced that the chine area made it all the way with the body to breakup. What is interesting is that it looks like it has been attacked and burned off from the backside. That could mean an entry point well forward of panel one.

Admiral Gehman – We need everything we can get off the left wing for hangar reconstruction purposes even if it isn't from one of the initiating events.

Summary

The Board concurs with the MIT plans for Louisiana, water searches, the Lufkin Corridor, California, and the NTSB boxes. However, the plans for the search west from I-45 must be kept open, because if the searchers march west 5 miles and only find one piece of debris—but that piece is a "Rosetta Stone", the Board will insist that the search continue.

The Board would like to be kept informed on the progress of the search west of I-45. They are particularly interested in RCC pieces and tiles from the carrier panel and chine. Mr. Gorie noted that anything from the left wing would continue to show up on the Significant Recovered Items List (SRIL). Any RCC will be treated as special.

Admiral Gehman noted that the CAIB intends give something commemorative to all that assisted the search efforts, and requested Mr. Whittle provide a list of those who should be singled out as being particularly helpful.

Identified Actions

MIT/Dave Whittle received the following actions:
1. Continue searching west of Interstate 45 until the CAIB is satisfied that the costs outweigh the potential benefits
2. Propose a schedule and method to report what is found west of I-45 to the CAIB.
3. Provide a list of individuals/organizations deserving special recognition for their efforts to assist the MIT searches.

This meeting was adjourned at 1400.

These minutes are hereby submitted for the record.

Approved FOR
Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff via telecon	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Mr. Wallace	CAIB	281-283-7508
Mr. Buzzard	CTF	281-483-8412
Dr. Widnall	CAIB	281-283-7579
Rear Admiral Turcotte	CAIB	281-283-7557
Colonel Bloomfield	CAIB	281-283-9809
Mr. Choban	Audio	281-283-7591
Mike Boulavsky	Recorder	281-280-8062
Rick Burgess	CAIB	281-283-7566
Dave Lengyel	CAIB	281-283-7581
Mr. Kirchhoff	CAIB	281-283-7821
Mr. D Pye	CAIB	281-283-7549
Doug Cooke	CAIB	202-329-8844
Paul Wilde	CAIB	301-775-6797
Bill Sikora	CAIB	281-283-7564
John Primbs	CAIB	281-283-3837
Steve Schmidt	CAIB	202-283-7577
Les Reingold	CAIB	281-283-7539
Robert Cobb (via telecon)	NASA IG	202-358-1220
Dave Whittle	MIT	281-483-4282
John Casper	MIT	281-483-3191
Dom Gorie	MIT	281-244-2223

Facts Vote 1 & 2 ; Brainstorm Of Facts 3

Wednesday, April 02, 2003

Fact Vote (Vote)

Voting Results

Yes/No (Allow bypass)

Number of ballot items: 43

Total number of voters (N): 1

Yes %

100.00	1. Shuttle crew was medically cleared/ready for flight
100.00	2. Columbia took a debris hit at 81 Seconds
100.00	3. anomalous temperatures in the left wheel well
100.00	4. the columbia has flown y previous shuttle missions.
100.00	5. Columbia was on it's 28th flight and was the oldest orbter
100.00	6. Columbia launched on Jan 16th 2003
100.00	7. The columbia is the oldest orbiter
100.00	8. A review of crew member medical records was accomplished and nothing remarkable was noted.
100.00	9. an object was observed trailing the orbiter on the secoind day of flight
100.00	10. Columbia had a different internal configuration than the other orbiters...docking via the mid-deck
100.00	11. The Columbia weighed more than the other orbiters.
100.00	12. Foam can absorb moisture.
100.00	13. Experimental payloads were carried in the Spacehab Double Module, on the Freestar platform, and on the middeck.
100.00	14. Tiles can absorb moisture.
100.00	15. External tank foam has been observed shedding on several previous flights
100.00	16. At 81 seconds a photographic event took place.
100.00	17. Elevon trim, telemetry data, and yaw jet firing just before vehicle breakup confirm a problem on the left wing.
100.00	18. Columbia had damage to the bipod foam area on mating/demating/remating but determined to be in acceptable range
100.00	19. many observers, both professional and amateur, took pictures of the orbiter during the entry phase
100.00	20. The "stick bump" had nothing to do with the accident.
100.00	21. The flight crew was properly appointed.
100.00	22. Columbia had the most OMMs of any orbiter

100.00	1. Shuttle crew was medically cleared/ready for flight
0.00	23. Cryopumping was the reason the bipod foam flew off
0.00	24. Three cameras film ET separation from the orbiter, but these are all film cameras which require return of the film to earth; there is no telemetry of this information.
0.00	25. The columbia is x years old
0.00	26. Columbia shed something on orbit on the second day after launch
0.00	27. The orbiter was damaged prior to EI.
0.00	28. There was no possibility of on-orbit repair to the TPS, nor was there a possibility of reaching the ISS after Columbia entered orbit.
0.00	29. The Columbia broke up in a flight regime in which, given the design of the orbiter, there was no possibility of crew survival.
0.00	30. Request for DoD imagry was turned off
0.00	31. The columbia had a different leading edge than the other orbiters.
0.00	32. The same teams of two persons for a total of three teams worked on the bipod foam area for the last 12 years
0.00	33. The columbia sat out in the wx for x days prior to launch.
0.00	34. Multiple debris shedding events are apparent as Columbia approached the coast of California thru structural breakup over Texas.
0.00	35. Columbia experience an off nominal Absolute Angle at 62 seconds
0.00	36. The FRR was conducted IAW NASA guidelined
0.00	37. The space debris following Columbia came from Columbia.
0.00	38. Columbia broke up over Texas about Mach 18 at 200,000 feet.
0.00	39. Columbia was the first to fly with Block II engines
0.00	40. The flight crew was properly trained.
0.00	41. at the final LOS all hydraulic fluid was gone
0.00	42. The Pre Launch Certification process was followed properly iaw NASA regs.
0.00	43. 14 debris shedding events have been observed

Fact Vote 2 (Vote)

Voting Results

Yes/No (Allow bypass)

Number of ballot items: 21

Total number of voters (N): 11

Yes %

100.00	1. The columbia's first flight was April 12 1981
100.00	2. Something separated from Columbia on orbit on the second day after launch
100.00	3. The columbia had a different leading edge substructure than the other orbiters.
100.00	4. Multiple debris shedding events are observed as Columbia passed from California thru structural breakup over Texas.
100.00	5. Columbia broke up over Texas about Mach 18 at 200,000 feet.
90.91	6. The Columbia broke up in a flight regime in which, given the design of the orbiter, there was no possibility of crew survival.
90.91	7. The Columbia sat on the launch pad for 28 days prior to launch.
90.91	8. At the final LOS all hydraulic fluid telemetered pressure and quantity indicated zero
81.82	9. Two cameras film ET separation from the orbiter umbilical well, but these are all film cameras which require return of the film to earth; there is no telemetry of this information.
81.82	10. There was no possibility of reaching the ISS after Columbia launched.
45.45	11. The orbiter was damaged prior to EI.
45.45	12. The flight crew was properly trained.
45.45	13. Pre LOS, 14 debris shedding events had been observed
27.27	14. There was no possibility of on-orbit repair to the TPS
18.18	15. Request for on-orbit imagery was turned off
9.09	16. The same teams of two persons for a total of three teams worked on the bipod foam area for the last 12 years
9.09	17. Columbia experienced an off nominal absolute angle at 62 seconds on ascent.
0.00	18. Cryopumping was the reason the bipod foam flew off
0.00	19. The FRR was conducted IAW NASA guidelines
0.00	20. Columbia was the first to fly with Block II engines
0.00	21. The Pre Launch Certification process was followed properly iaw NASA regs.

Number of Votes in Each Rating

	Yes %	No %	n
1. The columbia's first flight was April 12 1981	100.00	0.00	11
2. Something separated from Columbia on orbit on the second day	100.00	0.00	11
3. The columbia had a different leading edge substructure than	100.00	0.00	11
4. Multiple debris shedding events are observed as Columbia pas	100.00	0.00	11
5. Columbia broke up over Texas about Mach 18 at 200,000 feet.	100.00	0.00	11
6. The Columbia broke up in a flight regime in which, given the	90.91	9.09	11
7. The Columbia sat on the launch pad for 28 days prior to laun	90.91	9.09	11
8. At the final LOS all hydraulic fluid telemetered pressure an	90.91	9.09	11
9. Two cameras film ET separation from the orbiter umbilical we	81.82	18.18	11
10. There was no possibility of reaching the ISS after Columbia	81.82	18.18	11
11. The orbiter was damaged prior to EI.	45.45	54.55	11
12. The flight crew was properly trained.	45.45	54.55	11
13. Pre LOS, 14 debris shedding events had been observed	45.45	54.55	11
14. There was no possibility of on-orbit repair to the TPS	27.27	72.73	11
15. Request for on-orbit imagery was turned off	18.18	81.82	11
16. The same teams of two persons for a total of three teams wor	9.09	90.91	11
17. Columbia experienced an off nominal absolute angle at 62 sec	9.09	90.91	11
18. Cryopumping was the reason the bipod foam flew off	0.00	100.00	11
19. The FRR was conducted IAW NASA guidelines	0.00	100.00	11
20. Columbia was the first to fly with Block II engines	0.00	100.00	11
21. The Pre Launch Certification process was followed properly i	0.00	100.00	11

Ballot Items in Original Order

1. Cryopumping was the reason the bipod foam flew off

2. Two cameras film ET separation from the orbiter umbilical well, but these are all film cameras which require return of the film to earth; there is no telemetry of this information.

3. The columbia's first flight was April 12 1981

4. Something separated from Columbia on orbit on the second day after launch

The space debris following Columbia came from Columbia.

5. The orbiter was damaged prior to EI.

6. There was no possibility of on-orbit repair to the TPS

7. There was no possibility of reaching the ISS after Columbia launched.

8. The Columbia broke up in a flight regime in which, given the design of the orbiter, there was no possibility of crew survival.

9. Request for on-orbit imagery was turned off

10. The columbia had a different leading edge substructure than the other orbiters.

11. The same teams of two persons for a total of three teams worked on the bipod foam area for the last 12 years

12. The Columbia sat on the launch pad for 28 days prior to launch.

13. Multiple debris shedding events are observed as Columbia passed from California thru structural breakup over Texas.

14. Columbia experienced an off nominal absolute angle at 62 seconds on ascent.

15. The FRR was conducted IAW NASA guidelines

16. Columbia broke up over Texas about Mach 18 at 200,000 feet.

17. Columbia was the first to fly with Block II engines

18. The flight crew was properly trained.

19. At the final LOS all hydraulic fluid telemetered pressure and quantity indicated zero

20. The Pre Launch Certification process was followed properly iaw NASA regs.

21. Pre LOS, 14 debris shedding events had been observed

Vote 3 (Vote)

Ballot Items in Original Order

1. Available on-orbit imaging capabilities were not utilized.
2. The contract for Columbia was awarded in 1972.
3. No debris was found west of Texas.
4. The OEX recorder was recovered. Useable data is on the tape.
5. External tank foam debris hit the Columbia leading edge at 82 seconds into the ascent
6. E-mail traffic expressing concern about the orbiter's condition did not reach the proper decision-levels.
7. ET foam has separated from the ET on every shuttle launch.
8. The 1979 piggyback flight of Columbia was stopped before takeoff due to tile loss.
9. the orbiter experienced off nominal aerodynamic forces before crossing the California coast.
10. RCC non-destructive testing was visual inspection only.
11. Foam from the bipod area on the ET separated from the ET on 3 previous flights
12. superheated air in the left wing created structural damage
13. Two workers died in 1981 due to nitrogen in the engine compartment.
14. Search parties covered over 1.5 million acres.
15. NASA and DCMA Quality Assurance manning levels have shrunk to unacceptable levels to provide adequate oversight of contractor performance.
16. An adequate fix to prevent bipod foam from separating from the ET was never implemented
17. temperature sensors in the left wing show anomalous increases and then drop off scale
18. RCC can deteriorate from interior oxidation attack
19. The OEX recorder yielded usable temperature, pressure, and strain data.
20. The left wing came off the orbiter before the right wing
21. OV-102 lost 16 tiles and had damage to 148 others on its first flight.

22. External Tank foam NDE is insufficient to detect manufacturing process defects.

23. The Kirtland photo indicated that most of the orbiter was still intact.

24. An adequate fix to prevent bipod foam from departing the ET was not perceived as a safety of flight requirement

25. The orbiter experienced an intense heating environment upon reentry

26. The bi-pod foam shedding event on STS 112 was not classified as an in-flight anomaly, nor was the resolution of the issue a constraint to subsequent flights.

27. The fleetwide average number of debris strikes which cause TPS tile damage > 1 inch is X (about 40)

28. NASA accepted bipod ramp foam loss as an acceptable risk following STS-112, and did not pursue a fix before the subsequent two STS missions.

29. On OV-102's 4th flight it had SRB and parachute problems.

30. Columbia flew STS 107 because it was Columbia's turn to fly vs. a critical mission that had to be accomplished

31. Changes to reentry criteria would not have helped Columbia on this flight.

32. The temperatures experienced during the accident scenario melted the aluminum structure of the orbiter.

33. In a 1983 flight a spacewalk was cancelled due to bad gear.

34. On orbit inspections of TPS is possible.

35. The true condition of the RCC on Columbia was unknown at the time of the mishap

36. Five MMT meetings were held during the STS 107 mission.

37. High resolution imagery of the debris strike at 82 seconds shows several debris objects, but only one can be confirmed as hitting the orbiter

38. On orbit repair of TPS is possible.

39. The initial event causing this accident may never be determined absolutely.

40. Combustion of aluminum occurred as hot gases impacted internal structure of the left wing.

41. NASA building infrastructure repairs have received insufficient funding to address the extent of the aging facilities.

42. The January 1986 launch was delayed 6 times due to hardware problems.

43. Columbia was completed in 1979.

44. RCC degradation caused by pinholes was identified in 1995 but was not perceived to be a safety of flight issue.

45. NDE evaluation of the RCC is not conducted by NASA before each flight

46. The Crater analysis was not briefed to the MMT directly, but was verbally briefed by the MER manager.

47. There was no viable EVA capability on STS-107.

48. Aging materials may be an important issue for the safety of orbiter reentry.

49. NASA has not provided examples of instances where recommendations of independent mission assurance or NASA's safety board impacts mission or program.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 05, 2003
These Minutes Contain No Sensitive Data

Purpose: Space Shuttle Main Engine Working Group Fault Tree Closeout Presentation

Date: 05 April 2003 **Time:** 0900 –1235

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

Admiral Gehman convened the meeting at 0900 hours. Admiral Gehman turned over the floor to Mr. Randy Stone in order to introduce the speaker for this session.

Mr. Stone introduced Mr. Richard Schmidgall from Marshall Space Flight Center(MSFC), who covered the Space Shuttle Main Engine (SSME) Multi-element Fault Overview. Mr. Schmidgall discussed the three levels of the fault tree covered in their analysis and that the personnel from MSFC would be covering the 22 bottom level events during the presentation. Mr. Schmidgall then introduced Dr. Helen McConnaughey, Chairperson of the SSME Working Group, would provide the more detailed presentation.

Dr. McConnaughey then proceeded to walk through the approach taken, composition of the MSFC team, the data systems used for the analysis, the fault tree analysis results, and the conclusions drawn from the analysis.

Dr. McConnaughey described the sources of data used for the analysis, which consisted of three types of data:

Engine performance data
High frequency data
Photographic data

There were additional data collected from NASA/JSC, NASA/KSC, Boeing, and USA which included investigation sub-system team reports, flight assessments, photography, film and video review.

Dr. McConnaughey then described the fault tree development process. This process was generated considering the SSME as the primary contributor to the STS-107 accident. She then went through the fault tree pedigree verification process.

Dr. McConnaughey then entered into the fault tree analysis which went through two primary branches:

E1.0 SSME causes structural failure of Orbiter
E2.0 SSME causes failure of Orbiter system

Dr. McConnaughey then drilled down a representative branch of the tree:
E1.0 > E1.1 > E1.1.1 SSME hydraulic leak provides fuel for explosion/combustion
E.1.0 > E1.3 > E1.3.3 Off-nominal thermal loads

Dr. McConnaughey demonstrated the data types, sources, scenarios, and analysis that was used to determine whether defined scenarios were contributing factors.

Dr. McConnaughey then presented the conclusion that no credible evidence pointed to the SSME as a contributor to the STS-107 accident.

Mr. Schmidgall stated that each fault event covered in this presentation would map into the Orbiter Integration and Columbia Accident Investigation (CAI) fault trees. He also stated that five of the 22 events did not require Orbiter Vehicle Engineering Working Group(OVEWG) and the NASA Accident Investigation Team(NAIT) review.

The Admiral noted that in the solid rocket booster area there had been unusual nozzle deflections on ascent and wanted to know if those were measured on the SSME deflections as well. Mr. Schmidgall said yes.

Mr. Steve Wallace asked if the approach taken by the MSFC Team was the normal way to initiate development of a fault tree. Dr. McConnaughey answered that their approach was one way of generating a fault tree.

Dr. Hallock asked if the analysis looked at the SSME as a secondary contributor. Dr. McConnaughey stated that they had not used that approach, they had only used the perspective of the SSME as the primary contributor to the accident.

MGen Barry asked if STS-107 was the first time that OV-102 had used the Block II engines in conjunction with the lightweight tank. Dr. McConnaughey responded in the affirmative.

MGen Barry asked why STS-109 data were used in comparison with STS-107, and also wondered if there should be greater differences between data sets due to use of Block II. Dr. McConnaughey stated that STS-109 happened to be the previous flight of Columbia, but that the SSME Team looked at all flight data and selected those data sets that were most relevant to the particular point being covered.

Admiral Gehman asked if the CAIB would be able to go bore down into the data relative to specific questions (rough ascent, all data was nominal, perhaps at the margin) without affecting the closure of the SSME fault tree. This boring down into the data may provide arrows to other areas of interest. Dr. McConnaughey stated that all the data used was available. At this point Mr. Lambert Austin pointed out that an integrated fault analysis that would address some of these types of issues was coming soon. Mr. Austin said the integrated analysis was waiting for completion of the rigid and flex body work.

MGen Barry then asked about out-of-experience items that were within the margins. Dr. McConnaughey stated that there were several but were not considered as impacts external to the SSME.

MGen Barry asked about debris hits within the aft compartment area and whether they were reflected in this fault tree. Dr. McConnaughey stated that there had been some ablative material that had landed on the body flap and that the data was included in the tree.

Admiral Gehman asked if the E1.2 branch addressed Mr. H. McDonald's concerns (e.g. pins coming through the engine). The Admiral had seen post flight reports and pictures showing lots of debris hitting the aft compartment at launch and was concerned that this might be dismissed. Dr. McConnaughey responded by saying that there was not any evidence showing anything like that happening, but also conceded that there was not any evidence showing that it did not.

Admiral Gehman and LtCol Bloomfield posed the question about the Orbiter running through it's own plume on ascent and de-orbit burn. Mr. Austin replied that that question would best be deferred to the integration analysis. Mr. Austin also pointed out that questions relative to gimballing since those questions also dealt with the Flight Control System (FCS) and all indications show that the SSME responded nominally to the FCS.

MGen Barry raised a question about the safety factor on the G6 shim. It was his understanding that it should be 1.4. The MSFC Team researched the question in real time and responded that the margin was in fact 1.2.

LtCol Bloomfield questioned Dr. McConnaughey about the gap between what could be measured by SSME instrumentation and what had to be determined by analysis. Dr. McConnaughey responded by describing the encapsulation leak test and the affects of leaks that fell below the instrumentation threshold.

Admiral Gehman expressed concern that the analysis of E1.3.3 started off with a compelling argument, then in essence argued the leak away. The Admiral asked what would the leak do to the aft compartment. None of the data is compelling relative to answering the question "what if I had a leak?". The Admiral was concerned that the analysis did not address an event that could cause damage. Dr. McConnaughey responded by saying that the analysis shows that if a leak did happen during launch, it would not damage that aft compartment. Dr. McConnaughey stated that they had not looked at post launch possibilities. The Admiral said that he would find the argument more compelling if the fault tree addressed the one in a million event as if it happened. Then the analysis could show what happened after the leak, would it have been detected, what would the impact have been.

MGen Barry asked if there had been any recommendations generated out of the analysis done on E1.3.3. Dr. McConnaughey stated that there three findings but no recommendations so far. The finding relative to E1.3.3 was that there is insufficient instrumentation to fully capture compartment data.

Admiral Gehman asked if the MSFC team was content that there was sufficient acoustic instrumentation to answer the keys questions relative to E1.3.4. Mr. Buzzard answered that the instrumentation at the launch pad covered all the known drivers and all were within parameters.

Admiral Gehman asked if the data found on the OEX would be fed back into the SSME fault tree analysis. Mr. Mike Kynard answered that the OEX data would be fed into the data analysis sections of the fault and then into the final report.

Dr. Hallock asked if the additional weight of the Block II engines impact the structural integrity of the Orbiter. Mr. Kynard stated that the engines fell well within the margins specified by the Interface Control Document (ICD).

Admiral Gehman expressed concern that the analysis looked like two different processes. The Admiral felt that the analysis should be looking at "what could happen", then answer "did it happen?"

Admiral Gehman asked about the body flap, specifically, if the body flap were moving as directed, but required excessive hydraulic pressure to move it, would it be detected. Mr. Austin responded in the affirmative

Admiral Gehman expressed some concern about the statement on E2.4.2 indicating the FCS performed nominally. The admiral then asked two questions. First, if the main engine nozzle were not in position and violated the outer mold line, would it cause loss of the Orbiter? Second, if a nozzle broke off, would the change in the center of gravity cause the loss of the Orbiter? Mr. Kynard said yes. Mr. Greene added that all the historical information on the Block II engine thrust load indicators and Columbia were provided in the analysis.

MGen Barry asked if, based on the critical items list for Challenger and Columbia, any recommendation were being made. Mr. Kynard answered that there were projects underway that would address some of the observations made; The Automated Health Monitoring System (Phase II), the development of the linear engine model, and the development of a new nozzle. MGen Barry then observed that it may be a good idea to ask all teams presenting analyses to identify the benefits that will come from the reports.

Mr. Buzzard asked if the CAIB wanted the final report. Admiral Gehman responded by saying yes, the CAIB wanted the final report but would not be a signatory on it. The Board would concur, concur with comment, or recommend further study.

Dr. McConnaughey concluded the presentation.

Admiral Gehman made some closing comments. Until the integration report is complete, all items remain open. Also, the Board will have to think about whether they want to direct more work or analysis to address any additional questions relative to the leaking flange event. Until those questions are answered and fed into the integrated analysis it can not be closed out. Lastly, it is important that the fault tree be updated as new material, new data , and new analyses becomes available (e.g. OEX data).

Dr. McConnaughey stated that would not be a problem and could easily be done.

Admiral Gehman stated that once the questions had been answered or updated the Board would concur with close out. The Admiral stated the SSME Fault Tree Analysis was a great product. The Board will write a document that states the Board concurs with comment with the comments being of an editorial nature.

This meeting adjourned 1235.

Identified Actions

- The CAIB "concurred with comments" on the NAIT recommendation to closeout the SSME fault tree. The following comments were submitted:

- Comment 1: The rationale for closing out the line on hot gas leaks from main engine impinging on aluminum structure was not convincing. Determine the impact of a hot gas leak in the flange area as part of the integrated fault tree analysis.
- Comment 2: Amend SSME fault tree charts and report to take into account new material, new analysis, and new data (e.g. OEX recorder data). In particular, several supporting documents reference "preliminary reports".
- Comment 3: Items indicated as being carried over to the integrated fault tree are considered open until the integration fault tree is closed.

Identified Requests For Information (RFIs)

- Provide out of experience data. (MGen Barry)
- Look at SSME pressure field that might arise that moves toward the Orbiter before MECO. (LtCol Bloomfield)
- Did nominal specifications change over time due to an aging spacecraft? (MGen Barry)

These minutes are hereby submitted for the record.

Approved

FOR

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7527
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Wallace	CAIB	281-283-7508
Mr. Buzzard	CTF	281-483-8412
LtCol Bloomfield	CAIB Staff	281-283-7809
Mr. Choban	Audio	281-483-4890
Mr. Huslage	Recorder	281-280-8033
Mike Kynard	NASA/MSFC	256-544-8314
William D. Greene	NASA/MSFC	256-544-1038
Sandy Coleman	NASA/MSFC	256-544-6201
R.H. Coates	NASA/MSFC	256-544-0549
Chris Kirchhoff	CAIB	281-283-7821
Rob Ellison	NASA/KSC	321-867-3135
Ruth Harrison	CTF	281-483-8550
Elizabeth Fountain	CTF	281-483-5257
Bob Vallaster	CAIB GP I	281-283-7578
John Primbs	CAIB GP III	281-283-7438
Lambert D. Austin	NASA/JSC/MS	281-483-0969
Ron Tepool	NASA/MSFC	256-544-1224
Phin Jones	Rocketdyne	818-346-3438
Doug Bradley	Rocketdyne	818-586-4686
Martin Carson	NASA/MSFC	256-544-0106
Lewis Maddux	NASA/MSFC	256-544-4057
Dan Thompson	MSFC/HEI	256-544-7444
Steve Poulos	NASA/JSC/EC	281-483-9108
Katherine VanHooser	NASA/MSFC	256-544-3326
Randy Stone	NASA/JSC	281-483-2465
Frank Benz	NASA/JSC	281-483-3199
Dr. Helen V. McConnaughey	NASA/MSFC	256-544-1165
David Lengyel	CAIB Staff	281-283-7581

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
7 April, 2003
These Minutes Contain No Sensitive Data

Purpose: NASA/Navy Benchmarking Exchange Report Outbriefing

Date: 07 April 2003 **Time:** 0845 to 1015

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the CAIB PBMA web site.

There were no action items or requests for information generated from this meeting.

RAdm. Walt Cantrell presented a briefing and participated in a discussion of the recently completed NASA/Navy Benchmarking Exchange in which NASA studied the Navy Submarine Safety Assurance Program (SUBSAFE). A second phase of the study will be conducted whereby NASA hosts events so the Navy can study NASAs human spaceflight safety policies and procedures.

1. The Naval organizational structure, just like NASAs, is very complicated but responsibilities are well defined. Basically a submarine has 3 organizations responsible for its development and sustainment: the vessel builder, the reactor organization (Department of Energy), any the weapons organization. Mr. Hallock asked if the DoE participation was limited to regulatory only. ANS: No, they also have a funding responsibility.
2. Paragraphs 4 and 5 of the executive summary of the Navy report on this effort contain the essence of the report.
3. The Navy established a separate SUBSAFE office just before the Challenger and Chernobyl incidents. They spent the next 2 years validating safety requirements and used reports from the Challenger and Chernobyl mishaps to completely revamp SUBSAFE.
4. In a resource limited environment only needed assets can be procured. Added value assets and features have to be bypassed as must mission assurance. Safety requirements are met first and then as much of the mission assurance requirements as can be accommodated within available resources are then procured.
5. The Navy process is to always achieve a technical answer before allowing other pressures of budget and schedule to influence a program.
6. Safety is achieved through the systems engineering process and preserved in subsequent recertifications of a ship's safety.
7. Dr. Hallock asked about the separation of the safety and mission assurance functions. ANS: The program manager is responsible for resolving conflicts however, safety always comes first and mission needs are accommodated to the extent of available resources after safety needs are met. A big difference between NASA and the Navy is that the Navy maintains a separate organization that sets requirements and the program manager cannot override safety requirements because this separate organization monitors program results to insure safety requirements are met. Again, safety is part of systems engineering, not a stand-alone organization.
    a. MGen Barry asked how such an organizational structure as the Navy used would apply to NASA. ANS: A number of divisions within the program office would

have to report periodically to NASA Headquarters. MGen Barry then wondered how often the NASA Safety "Stop Card" had been used.

8. Mr. Bradley then observed that when a Navy LDO stops a reactor that person has full confidence the whole institution is behind him/her. Mr. Bradley does not have the same feeling if someone were to play the NASA Stop Card.
9. MGen Hess then observed that Code Q at NASA Headquarters was not independent enough to have its own sources of technical data to play a stop card. Essentially they are forced to just put a different logo on someone else's slides.
10. MGen Barry observed that NASA engineering works for the program manager who pays them, writes their performance reports, etc. The Center is responsible for training and equipping the engineers and finding them jobs.
11. Mr. Tetrault cautioned the CAIB not to get hung up on organization. He believes we are dealing more with cultural issues. If the NASA culture were the same as that of the Navy the Columbia E-mails would have been sent to safety and to management.
12. Navy safety related designs must be approved through an independent review by HQ Sea Systems Command and then continually certified.
13. RAdm. Cantrell related he had visited the OMM facility at KSC and observed safety related work being performed without current drawings.
14. Navy submarines are not normally allowed to operate with a waiver to requirements. Mr. Buzzard asked if the definition of a waiver is different between NASA and the Navy. ANS: There are differences between internal NASA definitions while the Navy has one definition. Mr. Buzzard then observed that NASA waivers single point failures that can not be fixed while the Navy designs in margins.
15. RAdm. Cantrell said he had attended the FRR for STS-111 and heard things which were troubling such as escapes, flying with out of specification conditions. He noted that out of spec conditions cause a stop in the Navy.
16. Mr. Bradley indicated SUBSAFE has been developed from scratch starting 40 years ago and is not the result of statistical analyses of a relatively small number of flights. He thinks the Shuttle Program by and large has adequate processes but that there are deviations in the diligence in which these processes are applied.
17. Admiral Gehman observed that a robust and independent safety technical requirements group is necessary to bound the program risks and understand them. This group cannot be subordinate to the program manager trying to meet a flight manifest. On the other hand, NASA cannot be like the Naval Reactors organization or it would never fly, but things can get better. A question was asked about applying the SUBSAFE requirements to R&D submarines the same way they are applied to operational boats. ANS: Yes, SUBSAFE requirements are applied to all submarines. Admiral Gehman then observed that SUBSAFE applies to old submarines as well as new construction.
18. RAdm. Cantrell indicated he had just come from the Shuttle Life Extension Program (SLEP) summit with some degree of unease. He related that in the 1980s the Navy had to determine whether submarines could be operated longer than their 20 year design life. The Navy spent 6 years independently examining whether design life could be extended and found that if safety certifications could be maintained, boat lifetimes could be extended for up to 30 years. He cautioned not to dare to take comfort with a system or subsystem just because no bad things have happened yet. He believes the Shuttle Program needs to have a Shuttle Life Assessment Program (SLAP) prior to embarking on a Shuttle Life Extension Program (SLEP). Mr. Wallace wondered if the Shuttle life

extension was being done with the same safety standards or are we raising the bar. There are lots of requirements in "guidance documents" that the Shuttle doesn't meet. It is unclear who makes the decision on such requirements as crew escape. Many other requirements which are not met have been waived along the way. Mr. Buzzard observes that he believes NASA incorrectly perceived the risk.

19. There was then a discussion on whether the Shuttle is R&D or operational. Operational vehicles have the characteristics of operating with significant margins, are driven by schedules, etc. Admiral Gehman indicated the CAIB should outline a path forward for NASA. Proper characterization of the risk is useful and the risk has to be measured against some technical standard. Dr. Hallock observed that he contends considering the Shuttle as an operational vehicle has colored many decisions. Admiral Gehman indicated that the issue is not how obviously fatal flaws are handled but how annoying little in-flight anomalies (IFA) get administratively taken care of. He is not sure if corporate NASA may have lost track of the real risk number.

These minutes are hereby submitted for the record.

Approved

FOR

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

SIGN HERE

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
7 April, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Logsdon	CAIB	281-283-7594
Dr. Osheroff	CAIB	281-283-7511
Dr. Ride	CAIB	281-283-7503
Mr. Tetrault	CAIB	281-283-7509
Mr. Wallace	CAIB	281-283-7508
Mr. Lengyel	CAIB Ex. Secretary	281-283-7581
Mr. Hartman	Recorder	281-283-7591
Mr. Buzzard	CTF	281-483-8412
LtCol. Bloomfield	CAIB Staff	281-283-7809
Steve Schmidt	CAIB Staff	281-283-7577
Dave Lengyel	CAIB Staff	281-283-7581
Jim Mosquera	CAIB Staff	281-283-7546
Bill Sikora	CAIB Staff	281-283-7564
Chris Kirchoff	CAIB Staff	281-283-7821
Tyrone Woodyard	CAIB Staff	281-283-7520
Dwayne Day	CAIB Staff	
Les Reingold	CAIB Staff	281-283-7539
Terry Williams	CAIB Staff	
Patricia Brach	CAIB Staff	

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 09, 2003
These Minutes Contain No Sensitive Data

Purpose: Reusable Solid Rocket Motor (RSRM) Working Group Fault Tree Closeout Briefing to the CAIB

Date: 09 April 2003 **Time:** 0900 - 1130

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

There was one action item generated from this meeting and listed at the end of this report.

Executive Summary

The charter of the RSRM Working Group was to assess whether the RSRM was either the root cause or contributed to the loss of Columbia on reentry. This was accomplished independent from the RSRM Project thru a bottoms-up review of RSRM-88 pedigree and performance and a top-down system-based fault-tree analysis of all potential physical mechanisms. The results of their investigation led them to conclude that the RSRM was neither a root cause of nor a direct contributor to the loss of Columbia on reentry.

Bottoms-Up Approach

Assessment of flight data indicates motor performance was well within Contract End Item (CEI) specification limits. All analyses have shown that internal ballistics performance of the two motors was nominal and well matched. All hardware and process changes (except Class IIA & Type III editorial changes) associated with STS-107 were reviewed against available postflight evidence and mechanistic links to the Columbia Accident.

There were two post flight reportable observations that drew considerable discussion from the Board: (1) Gas paths/penetrations through 88A/88B nozzle joint 2 RTV; and (2) Long, 57-inch tear in flex boot internal diameter adjacent to the inner boot ring.

Gas Penetrations -The gas penetrations apparently are a common occurrence. While no heat effects to the primary O-ring or metal surfaces have been observed, the Board is nonetheless concerned that these occurrences have been normalized in light of the fact that the RTV seal is not behaving as designed. The RSRM Project noted that they are redesigning the joint so the RTV can be replaced by carbon fiber rope, which is now common in the design of many rocket motors. It may be a couple of years before the new design is in place, as they have to go through a full-scale static testing effort. First flight with the redesigned joint will depend on a Shuttle Program decision to first use the RSRM sets that remain from the current inventory of fifteen sets.

Flex Boot Tear - The flex boot is constructed of seven rubber plies with carbon cloth sandwiched between the plies. The boot provides a thermal protection barrier for the flex bearing and bearing protector. The tear was in the first of seven rubber plies, which the RSRM Project believes can be attributed to the ply having only 3 layers as opposed to the typical 5 layers. Since there was no evidence of gas penetration or

thermal effects on the flex bearing or the protector, the Project speculates that the tear occurred post burn. Nevertheless, the tear in the flex boot is a reportable in-flight anomaly that the RSRM Project has to close out.

These two issues did not pose credible challenges to fault tree closure rationale. The RSRM Working Group concluded that RSRM-88 motor set performance was nominal, and there is no credible correlation to the STS-107 Accident

Top-Down (Fault Tree) Approach

The fault tree that the RSRM WG developed had three main branches—one addressing each of the following scenarios: (1) RSRM generates debris/FOD that impacts other elements during ascent; (2) RSRM transfers anomalous loads through attach points; and (3) RSRM generates anomalous induced environments. Fault tree details are included in the attachment.

Debris
The debris branch considered two sources: debris that falls off of the RSRM on ascent, and debris thrown or rebounding at ignition/liftoff.

For ascent they postulated that debris could result from the following failure modes:

- Structural failure of systems tunnel floor plate assembly, the RSRM stiffener rings, or systems tunnel splice plates
- Failed factory weather seal or field joint TPS
- Anomalous loss of paint from the case surface
- Loss of insulation from Ground Environment Instrumentation (GEI) or stiffener rings
- Ice debris originating from the RSRM
- Failure to contain motor combustion gases generates debris during ascent

For debris thrown or rebounding during liftoff/ascent they considered:

- Nozzle plug debris rebounds from the Mobile Launch Pad (MLP) at ignition
- Debris from non-RSRM components, either from the pad or other vehicle elements, rebounds from the MLP at ignition
- Internal components such as propellant, inhibitor, nozzle phenolics, and igniter assembly are expelled from the motor during the boost phase and impact other elements
- RSRM external components, including nozzle TPS, depart the motor, rebound from the MLP and impact other elements

Loads
For the anomalous loads branch they considered:

- Anomalous thermal loads caused by excessive convective/conducted heat transferred through hard attach points into other affected elements
- Unsteady (>1Hz) and transient loads caused by anomalous initial impulse, thrust oscillations, nozzle deflections, or SRB separations
- Steady loads caused by anomalous balanced/unbalanced thrust, pressure perturbations, or nozzle deflections

Induced Environments

For the anomalous induced environments branch they considered:

- Excessive acoustic loads caused by motor ignition overpressure, motor exhaust noise in the vicinity of the pad, and noise generated by the relative motion of the motor through the atmosphere
- Thermal anomalies caused by motor plume rebound off the MLP at liftoff, excessive plume convective recirculation during ascent, or inadvertent leakage of motor combustion gases during the boost phase

Summary

Since the RSRM Working Group presented multiple pieces of evidence to close all fault tree blocks, the Board concurred with the fault tree closure rationale and agreed that the RSRM was not a root cause and did not directly contribute to the loss of Columbia on reentry. The Board will concur on the final report after it is amended to reflect the fact that the OEX recorder was indeed found.

The RSRM WG noted that during their investigation they came up with approximately 25 observations or areas of improvement that will be included in the final report. For example:

- The RSRM project needs more bandwidth for telemetry during ascent, such as high sample rate thrust chamber pressures
- Thiokol uses three totally different systems to process paper
- Finite element models need to be refined

Identified Actions

The Columbia Accident Investigation Board (CAIB) "concurred with comments" on the NAIT's recommendation to close out the RSRM fault tree. The following comments were submitted for action:

> Comment 1: Amend the RSRM fault tree charts and report to take into account new material, new analysis, and new data (e.g., OEX recorder data). In particular, several supporting documents reference "preliminary reports."
>
> Comment 2: Items indicated as being carried over to the integrated fault tree are considered open until the integration fault tree is closed.

This meeting was adjourned at 1130.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 09, 2003
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NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
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Mr. Hubbard	CAIB	281-283-7517
Dr. Logston	CAIB	281-283-7594
Dr. Ride	CAIB	281-283-7503
Mr. Buzzard	CTF	281-483-8412
Dr. Widnall	CAIB	281-283-7579
Rear Admiral Turcotte	CAIB	281-283-7557
Colonel Bloomfield	CAIB	281-283-9809
Pete Choban	Audio	281-283-7591
Mike Boulavsky	Recorder	281-280-8062
Tom Nesman	TD63/MSFC	256-544-1546
Louise Semmel	ED34/MSFC	256-544-3650
Jennifer Stevens	TD51/MSFC	256-544-5004
Andrew Schorr	MP51/MSFC	256-544-5837
Scott Tillery	ED34/MSFC	256-544-8651
Jim Hawkins	ED22/MSFC	256-544-2780
Pat Lampton	TD51/MSFC	256-544-6171
Dave Ladrach	JSC/MS3	281-483-0987
Steve Poulos	JSC/EC	281-483-9108
Pat Pilola	JSC/OL	281-244-7071
Rob Ellison	KSC/AA-A	321-867-3135
Ruth Harrison	NASA/CTF	281-483-8550
Kelly Beck	NASA/CTF	281-483-8440
Wade Thompson	CAIB	281-283-7573
Lambert Austin	JSC/MS	281-483-0969
Rodney Wallace	JSC/MS2	281-483-3904
Don Noah	JSC/MS	281-483-2166
Cary Ralston	Thiokol	435-863-2258
Jody Singer	MSFC/RSRM	256-544-0612
Chris Cianciole	MSFC	256-544-7744
Louie Clayton	MSFC	256-244-2322
Rick Burt	MSFC/RSRM	256-544-9129
David Lengyel	CAIB Staff	281-283-7581

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 09, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 09 April 2003 **Time:** 1230 - 1430

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

Debris Update

Mr. Tetrault stated that the current hypothesis is that the failure occurred at the T-seal interface between RCC panels 8 & 9. They are attempting to prove the hypothesis by analyzing the oxygen content of the slag on the RCC debris. In theory, at low altitudes the slag would have high oxygen content and a uniform distribution across the front. The slag on the right wing debris is uniform across the front side, suggesting that it was oxidized at a relatively low altitude. At high altitudes the slag would have lower oxygen content due to the rarefied atmosphere. Further, the slag on the backside of the left wing RCC panels where the breach is thought to occur should be scattered, with more scatter close to the breach. They still have some work to do—samples analyzed by two different people are coming up with two different results.

The hypothesis was based on analysis of T-seal failure modes and examination of RCC debris. T-seals tend to fracture in three ways: (1) at the apex (like RCC); (2) along an edge; and (3) at the attach points. Each failure could result in a breach, allowing entry of the hot gases. Examination of the debris from RCC panels 8 & 9 shows that the edges on both panels were severely eroded, with the faces completely missing from panel 9. There was heavy slag behind panel 8, suggesting that there was indeed a gap between 8 & 9 (a missing T-seal would leave a 1.15" space between RCC panels).

At KSC they are building Plexiglas jigs to hold the RCC pieces in their proper orientations for examination. They are also building tile tables so they can look at flows across tile sections. For example, there is evidence of flow from aft forward and also port to starboard.

Impact Testing

Mr. Hubbard reported that NASA senior management has put their attention to resolving the issues with the testing to be performed at Southwest Research. They have agreed to give highest priority to testing required for fault tree closeout—such as RCC testing. Testing for other purposes, such as for CRATER validation, is secondary and will be performed later.

Panel 6 will be tested first, since this was already in work. The panel will have T-seals on both ends, but the impact will be directed at the panel itself. Next they will test panel 9 and the 8-9 T-seal, with focus on the T-seal.

Group 2

Major General Hess and Mr. Wallace provided status on their work to identify root and contributing causes. While their work is not complete, the team concluded that Payloads, Training, and the Life Sciences (crew health) were not contributing factors. Mr. Wallace did note that 7 of 77 STS-107 flight controllers did not have current certification paper. This was not a safety issue, as there was no evidence that the controllers were not qualified, but it may be a reflection on how rules are being followed. He further noted that this was not addressed at the MOD CoFR.

MGen. Hess reported that in the Mission Management area they are examining decision processes and committees that certify that a flight is ready to go and manage it once it is on orbit. They are still in a fact finding mode – currently looking at meeting minutes. The next step will be to ask the "so what" questions to determine the relationship to STS-107 and develop an understanding of how decisions were made.

Admiral Gehman asked if the scope of investigation would examine the PRCB process. From an investigative perspective the Board needs to understand how things were filtered on the way up to the PRCB. (Affirmative response)

Dr. Osheroff asked how NASA decided that foam wass or was not a problem. Admiral Gehman noted that they are going thru audio and written records of PRCBs that addressed foam issues.

Dr. Ride stated that one question she would ask is how quantitative is this decision making process? If they don't like the implications do they change the process? MGen. Hess added that when you take the corporate decision to use CRATER and combine it with email on the validity of the model, and combine it with how they handle foam issues over time, you get a broad look at an informal decision making process that turns formal really fast. The answer will be intriguing for this mishap.

Crew Escape & Survivability

In the discussion of the Aerospace Safety Advisory Panel (ASAP) recommendation that NASA add crew escape capability; Dr. Osheroff noted that adding this capability would significantly reduce payload capability, and that they should consider looking at beefing up the structure for survivability instead. Admiral Gehman responded that per some safety theories, adding safety features to complex systems with complex, tightly coupled failure modes simply makes a complex system more complex. They need to somehow decouple crew survivability from the complexity of the system.

NASA Return to Flight (RTF) Effort

Mr. Wallace noted that the NASA's preliminary RTF planning schedule shows the final CAIB report out in August and NASA implementation of fixes within 4 months (December). Admiral Gehman speculated that preliminary findings should be out by June; and that all findings should be out by July even if the final report is not signed. He also expressed some reservation about NASA's intent to be ready to fly in December.

Dr. Ride responded that she understands why NASA says that—but the message to the designers is that they have to come up with a design that can be implemented within four months. This really constrains thinking and steers the focus away from "real fixes". Management can stand up to this kind of stuff—but for the engineers down in the trenches trying to think up fixes, having a chart with a launch date of December hanging over their heads can have a real effect on what they think about.

Foam Events

MGen. Hess reported that his team is developing a matrix to track foam events and the management decisions that were made in response (as opposed to technical implementation). They will use the exact words that were used in the minutes to get a sense of what was really being said.

This meeting was adjourned at 1430.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman 4/29/03

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 09, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Logsdon	CAIB	202-994-7292
Dr. Osheroff via telecon	CAIB	281-283-7511
Dr. Ride	CAIB	281-283-7503
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Buzzard	CTF	281-483-8412
Mr. Cooke	CAIB	202-329-8844
Steve Schmidt	CAIB	281-283-7577
Mike Boulavsky	Recorder	281-280-8062
Pete Choban	Audio	281-483-4890
Pat Goodman	CAIB Sprt.	281-283-7569
Matt Granger	CAIB Grp 2	281-283-7567
Tracy Dillinger	CAIB Grp 2	281-283-7845
Lisa Reed	CAIB Grp 2	281-283-7815
David Kral	CAIB Grp 2	281-283-7571
Greg Phillips	CAIB Grp 2	281-283-7816
Dan Diggins	CAIB Grp 2	281-283-7814
Robert "Moose" Cobb	NASA IG	202-358-1220
Dwayne Day	CAIB Grp 4	281-283-8353
Patricia Brach	CAIB PAO	281-283-7849
Paul Wilde	CAIB	281-283-7560
Tyrone Woodyard	CAIB	281-283-7565
Jim Fraser	CAIB	281-283-7818
Bob Vallaster	CAIB Grp 1	281-283-7578
Lisa Sayegh	CAIB Grp 1	281-283-7519
Les Reingold	CAIB	281-283-7539
Chris Kirchoff	CAIB	281-283-7821
D. Pye	CAIB	281-283-7549
Doug Griffen	CAIB Sprt.	281-283-7593

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 10, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting on Protecting the Space Shuttle from Meteoroids and Orbital Debris

Date: 10 April 2003 **Time:** 1630 - 1730

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

There were no action items generated from this meeting.

Admiral Gehman convened the meeting at 1630 and introduced Mr. Rick Hauck of AXA Space. Mr. Hauck made a presentation on "Protecting the Space Shuttle from Meteoroids and Orbital Debris".

Mr. Hauck opened the presentation by saying that the presentation had last been given in 1997 to the NASA Advisory Council and that he would indicate when the data had been updated. He also stated that he would provide specific details from the National Research Council (NRC) report written on this topic.

Mr. Hauck opened the presentation by discussing some of the history driving the original NRC study. One key point was that when the Shuttle was designed, orbital debris was not recognized as a hazard. Mr. Hubbard asked why that perspective was taken. Mr. Nicholas Johnson responded that the design effort took place prior to the meteoroid and orbital debris program.

Mr. Hauck stated his interest in orbital debris began in 1983 on his first shuttle flight when he noticed a small pit in one of the orbiter windows. Later analysis show titanium and aluminum residue indicative of a paint chip. This was one of the first indications that orbital debris could pose a hazard to the shuttle.

Mr. Hauck continued with historical information about the initiation of the NASA study of the problem, establishment of guidelines to reduce risk, modifications to the orbiter, and requirements issued to the Department of Defense (DoD) to improve collision avoidance.

Mr. Hauck then went on to discuss the following:

- Orbiter Vulnerability
- Impact Predictions
- Damage Thresholds

Mr. Hauck stated that over 95% of the objects that could cause critical damage to the orbiter are not catalogued because they are too small to be reliably detected by the Space Surveillance Network (SSN).

Mr. Hauck indicated that once a threat had been identified by the SSN, the decision to maneuver the shuttle for collision avoidance must be made. Two flights rules (A4.1.3-6 and C4.3.2-1) that have a direct influence on this decision appear to put mission success ahead of flight safety.

Mr. Hauck stated that debris in orbit typically moves at 10 kilometers/second (km/s) and that even millimeter (mm) sized objects can cause considerable damage. Meteoroids are believed to have impact velocities around 19 km/s with a mass density around 0.5 grams per cubic centimeter (g/cm3). Aluminum, which is the most common material used in spacecraft has a density around 2.7 g/cm3.

Mr. Hauck pointed out that the only entry in the orbiter specifications that referred to impact damage was intended to minimize low energy, around 0.008 joules, dings and dents in the thermal tiles. By comparison, a 1mm aluminum sphere impacting at 9 km/s has a kinetic energy of 57 joules.

Mr. Hauck stated that shuttle's subsystems redundancies were designed to minimize the impact of fire, short circuits, and explosions. NASA did not take into account the threat from penetrating meteoroids and orbital debris.

Mr. Hauck characterized the risk of a non-critical penetration of the soft material of the astronauts suits during a six hour extra-vehicular activity (EVA) to be 1/4800. A critical penetration, a hole larger than 4 mm, was characterized as 1/31000.

Mr. Hauck indicated that he was concerned with probabilistic risk assessments (PRA) in that uncertainty was not adequately indicated. He was also concerned that the last shuttle PRA in 1995 did not take into account the effects of meteoroids and orbital debris. After the PRA, NASA established interim guidance that the risk of being struck by a meteoroid or orbital debris should not exceed 1 in 200 (1/200) for a particular mission. In addition, the maximum acceptable predicted risk for damage that would cause termination of a mission was set at 1/60.

Mr. Hauck then provided some guidelines on penetration and detection timelines for the crew cabin. He said that once the crew detects that there is a penetration, the interior of the pressure vessel would be accessible for leak detection and damage control as follows:

60% in 30 minutes to two hours
The next 20% in two to three hours
The last 20% in three or more hours.

Mr. Hauck stated that based on these timelines, NASA decided to expedite reentry. In the event of a one half inch diameter hole, the nitrogen supply was designed to last 165 minutes. In this case, emergency reentry could be initiated in 20 minutes if the Shuttle is not docked, and five hours if docked to the International Space Station. Once reentry is initiated, it takes 60 minutes to land.

Mr. Hauck then presented the findings of the study:

NASA needs to improve its understanding of the hazard
Models must be enhanced to include error bars and confidence models
NASA needs to improve understanding of effects of penetration
Need to update the Shuttle probabilistic risk assessment (PRA)
NASA should rethink the risk guidelines

NASA and DoD need to work together to improve the Space Surveillance Network
NASA should re-examine the flight rules dealing with collision avoidance
NASA should continue to assess need for hardware modifications
NASA needs to continually assess operational risk mitigation

Mr. Hauck then summarized the presentation by saying that NASA has made great strides in addressing the risk of debris and meteoroid damage. Mr. Hauck emphasized that the risk is real and dealing with it must be a priority and that and end-to-end survivability assessment must be done. Mr. Hauck mentioned that a new shuttle PRA was due to be concluded in March 2003 but he could not state whether it had been completed yet.

Admiral Gehman asked if the risk to pressurized tanks had been evaluated. Mr. Hauck answered that the various risk assessments did include the risk to the various pressurized tanks but these assessments typically rolled the data up into structural risk data.

Admiral Gehman then asked if the instrumentation or alarms would provide an indication of an insidious leak due to a small penetration. Mr. Hauck answered that he did not believe so.

Admiral Gehman then asked if there would be an indication if the atmospheric systems had to work harder to maintain environment or pressure. Mr. Frank Buzzard stated that the system would annunciate any change in condition. Mr. Hauck then added his belief that a shock monitor should be added to Shuttle instrumentation.

Admiral Gehman asked if the risk was the same on every flight. Mr. Hauck stated that the risk is based on the attitude of the orbiter. Mr. Johnson added that the duration of the mission was also a factor in the risk calculations.

Admiral Gehman asked if a similar study had been done for the International Space Station (ISS). Mr. Hauck responded that a study had been done and that had led former NASA Administrator Dan Goldin to request a PRA be done for the Shuttle program.

Admiral Gehman asked if the debris environment was growing worse. Mr. Johnson stated that the environment is getting both better and worse. He elaborated by saying that centimeter size debris is decreasing but millimeter size debris is increasing. Mr. Johnson also stated that this data is being incorporated into the various models being used to predict debris impacts. Mr. Johnson then mentioned that the typical life time of a millimeter particle is weeks to months, however, the supply of particles is being constantly renewed.

MGen Barry then asked if there were only one recorded penetration of the reinforced carbon-carbon (RCC) panels. Dr. Eric Christiansen stated that he had no data on any penetration of a panel.

Admiral Gehman stated that accusing people of bad analysis based on hindsight was unfair, e.g. O-ring burn through and foam. The Admiral believes that people should be looking for repeating risks that are not being addressed especially when there is an opportunity for serious or catastrophic events. The Admiral stated that he was confused by the statistics of only one or two RCC panels being replaced as opposed to 55 shuttle windows. Admiral Gehman then asked if the program is ignoring this risk.

Mr. Hauck answered by saying that the windows have different characteristics that the thermal protection system. Penetrations of windows may leave residual hazards that are manifested on later re-entries.

Admiral Gehman suggested that the windows provide a good sample and may be used to identify the magnitude of the danger. The Admiral stated that he can not characterize the size of the risk and that he is looking for foresight. The Admiral stated that the windows are being hit at a rate that can be calculated. Mr. Hauck suggested that the CAIB look at the latest PRA done on the Shuttle.

Dr. Christiansen mentioned that the number of windows replaced to date was now 130. He also stated that the risk for STS-107 was 1/359. For the left wing the risk of impact was 1/2500, and 1/7700 for the area of particular interest for STS-107

Mr. Buzzard asked if actual experience was being folded into the models. Mr. Johnson explained that the models are based on experience. Mr. Buzzard then made the comment that uncertainty comes into the prediction. Dr. Wendell Mendell then said that actual data collected during each flight is compared to the predicted baseline and the models are then updated as required.

The Admiral then suggested some form of damage control process for the Shuttle should be looked at as he felt something could be done about a breach within the crew compartment.

Dr. Sally Ride then asked what were the risk probabilities of a mission to the ISS. Dr. Christiansen responded that they were the same as a non-ISS mission.

This was the last question from the Board.

The Admiral thanked Mr. Hauck and the meeting was adjourned at 1730.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Ride	CAIB	281-283-7503
RADM Turcotte	CAIB	281-283-7557
Mr. Buzzard	CTF	281-483-8412
Mr. Choban	Audio	281-283-7591
Mr. Huslage	Recorder	281-280-8033
Mr. Rick Hauck	AXA Space	202-314-6300
Dave Lengyel	CAIB	202-283-7581
Mr. Kirchhoff	CAIB	281-283-7821
Mr. Pye	CAIB	281-283-7549
Kenneth Brown	MV6	281-483-3891
Dr. Eric Chrstiansen	JSC/SX	281-283-5311
Bill Sikora	CAIB	281-283-7564
Dr. Wendell Mendell	JSC/SX	281-483-5064
Steve Schmidt	CAIB	202-283-7577
Les Reingold	CAIB	281-283-7539
Nicholas Johnson	JSC/SX	281-483-5313
Jim Wetherbee	JSC/SR&QA	281-244-8918
Steve Hawley	JSC/SA	281-244-2989
Dwayne Day	CAIB	281-283-7588
Kelly Beck	CTF	281-483-8440
Chuck Babish	CAIB	281-283-7840
Steve Paulos	JSC/EC	281-483-9108
Clare Paul	CAIB	281-283-7461
Frank Benz	NAIT	281-483-3319
Jim Bagian	CAIB	202-285-0241
Jim Mosquera	CAIB	202-281-7546
Jim Smiley	CAIB	281-283-7545

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 11, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 11 April 2003 **Time:** 1230 - 1400

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

VIRTUAL RECONSTRUCTION OF SHUTTLE DEBRIS

Mr. Larry Schmidt provided a briefing describing the Scan Team's efforts to develop a virtual reconstruction of Shuttle debris using 3D scanning and modeling techniques. The current 2-D layout on the floor of the Shuttle Landing Facility (SLF) does not lend itself to engineering analysis and 3-D reassembly is impractical. The solution is to create computer models of the debris and virtually place the parts on a 3-D orbiter model.

The team is currently using two different scanning systems—the MENSI 3-D laser scanner and the Advanced Topometric Sensor (ATOS) 3-D white light scanner. With resolution down to 1/1000", the ATOS is used when high accuracy is required. The processed data is stored in a database and shared via a secure FTP server. Unfortunately, JSC does not yet have the software updates necessary to do the 3-D manipulation that they can do at KSC. There are also problems with dealing with firewalls. The database contains pertinent information associated with the parts that they have scanned. For example, one can find out where and when the item was found, descriptions of slag or scorches that are on it, and so forth.

One of the problems they are having is that they do not have good models to work with. In some cases they do not have any models at all to work with. For example, they do not have a model of the RCC panels, which are extremely hard to identify. So the team created a model by scanning the left wing of OV-103, which has the same mold line as Columbia (although the bracketry and spars are quite different). Texture mapping technology is used on items that merit detailed imaging. However, texture mapping is an extremely time-consuming process, because every angle that you see on the debris has to be photographed at right angles.

Major General Barry noted that the engineers at KSC do not always know exactly where a particular debris item belongs, so having a visual qualifier goes a long way to give them some semblance of confidence that they have correctly identified the item/location. Mr. Schmidt noted that on one occasion they had an item that was thought to be from the left wing, but after it was scanned, it was determined to be from the right wing. He also speculated that there might be some tiles that they think came from the right hand side that actually came from the left.

Admiral Gehman asked what the prognosis is for putting any kind of slag patterns, scorch marks or burn marks on top of the scanned in debris, because things like that show directionality which helps in placing the tile. Mr. Schmidt responded that they did texture mapping of the RCC piece that had all the slag on it and he understands that it turned out quite well.

Mr. Hubbard asked if the OV-103 based model has the right T-seal positions for Columbia, because one of the big problems that the industry and construction people have is that they do not have any good CAD model of Columbia. Mr. Schmidt replied that the T-seals are the same, they are just attached differently within the wing.

Admiral Gehman closed the discussion on the 3D scanning and modeling by observing that they now a have good tool for visualizing how the parts fit on the orbiter but the Board's perspective is that they need to go to the next step, which is using the tool to assess damage, and for that reason they would much rather have burn patterns and slag patterns.

TEAM TWO

Mr. Hubbard reported the original analysis determining that the foam hit the wing in the panels 5, 6, & 7 region was based solely on the high-resolution film. When the analysts factored in the lower resolution video, which added extra frames to the end of the trajectory, the predicted impact of the foam "blob" shifted from the panels 5, 6 area to panels 7, 8. If the video analysts and debris analysts agree that panels 7 & 8 is the correct location, that may create a problem for the Board in the end. It normally takes approximately five weeks to build up a test article. However, the contour transition from panels 7 to 8 is much more drastic. The substructure behind this transition is much more complex. As a result, test article build time goes from five weeks to as many as fifteen weeks. In an effort to save fabrication time, the team is trying to determine if the results of panel 7-8 testing can be derived analytically by combining the results of the currently planned testing of panels 5, 6, & 7 with the testing of panels 8, 9, & 10.

Delivery of the first test article to Southwest Research has slipped to May 15 due to a delay in building up the sub-structure. The RCC itself (panel 6) is available (it takes eighteen months to actually build up a new RCC). Another important point—Southwest Research can only take three shots every two weeks. It takes approximately one week around-the-clock to CT scan a complete panel. It takes another week to get the inspection data. So it will be the end of May before we get anything useful.

TEAM THREE

Major General Barry reported that his team is continuing to look at the Space Flight Operations Contract (SFOC). One of the first observations is that NASA did not do a baseline for cost/benefit analysis before implementing SFOC. Admiral Gehman stated that he wanted the contract examined in detail to determine if it rewards negative behavior.

Examination of the Orbiter drawing system revealed that 1,763 Orbiter drawings have 10 or more unincorporated Engineering Orders (EOs). And it is getting worse.

The qualification testing that was done on the SRB bolt catcher did not have the real test hardware and flight configuration. They did not have the correct TPS, and they had a different bolt attachment style and a different honeycomb catcher. There is no apparent connection with this and the STS 107 mishap, but this is something we need to follow.

Dr. Osheroff expressed his concern that NASA has a mindset that they understand things that they really do not. After reading in the Feynman book about the way they treated O-rings—if it burns through one third of the radius then they have a factor of three safety margin. It reminds him of what they are faced with here. The processes that happen over and over again, they think they understand them so they think they have them under control. But, if it does not do exactly the same thing every time then they are really in trouble. Admiral Gehman said that an example of that was the gas penetration of the RTV sealant on the RSRM. While the seal is not behaving as designed, since it is not causing any harm NASA concluded that it does not pose any problems. There is a tendency to attribute facts where there is precious little knowledge.

This meeting was adjourned at 1400.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 11, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff via telecon	CAIB	281-283-7511
Pete Choban	Audio	281-283-7591
Mike Boulavsky	Recorder	281-280-8062
Rick Burgess	CAIB	281-283-7566
Dave Lengyel	CAIB	281-283-7581
Lisa Chu-Thielbar	CAIB staff	281-283-7568
Mike Francis	CAIB staff	281-283-7574
Ron Gress	CAIB staff	281-283-7532
Jack Lehman	CAIB staff	281-283-7842
Bill Sikora	CAIB	281-283-7564
Colonel Tim Bair	CAIB staff	281-283-7521
Steve Schmidt	CAIB	281-283-7577
Bob Vallaster	CAIB Grp 1	281-283-7578
Colonel Dave Nakayama	CAIB Grp 2	281-283-7835
Lt. Colonel Woody Woodyard	CAIB PAO	281-283-7565

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 14, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 14 April 2003 **Time:** 1230 - 1500

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

There were three action items generated from this meeting and listed at the end of this report.

Admiral Gehman convened the meeting at 1230 hours. Admiral Gehman then turned over the floor to Mr. Tetrault via telecon from KSC for him to status his activities.

Mr. Tetrault's Activities

- One of the things that we have been doing is to start the process of centroids of debris. This gets very interesting when we are doing it, rather than just plotting all of the debris, pick a center of it. So, we plotted the left wing, the right wing, the tail, the fuselage (on the ground), and if you assumed that you had about the same amount and type of stuff, big stuff and small stuff coming off. A centroid actually acts pretty well on the ground in terms of when the events happened in space. What we are seeing is the left wing, then the tail, then the right wing, then and the fuselage. I believe the left wing, the tail, and the right wing are events A, B, and C. The events are very close together; there is 60 miles difference on the ground between the left wing and the right wing.

Adm. Gehman stated that Dave Whittle had provided some interesting e-mails, which have three files/charts. Mr. Whittle has drawn a colored line from each of the RCC panels. Starting with 5, 6, 7 are one color then a yellow line for 8, a green line for 9, and a blue line for 10. Then a line references a map location where the pieces were found. Obviously there is a pattern here. It appears like the wing unzipped from the outside end toward the fuselage. The panels number 12, 11, and 10 were found around Corsicana, 9 was found in between Palestine and Corsicana, 8 was found further east, 7 was found further east than 8, and 6 was found further east than 7. This is backwards from the Admiral's original understanding.

- When you are looking at the RCC panels there are uppers and a lot of lowers that are missing. The way that we are seeing this is that the wing probably parted between 7 and 8, or 8 and 9, and then the wing structure broke in half again. The other panels 5, 6, and 7 go down with the fuselage and go further downstream. The second half of the wing flies fairly far downstream but it is all top half of the RCC not the bottom half.

- We had asked NASA to pull the Orbital Maneuvering System (OMS) pod out, and they have done that and it looks riddled just like the tail. So what you're seeing is a huge amount of debris going backwards and hitting the OMS pod.

Adm. Gehman stated that later in this meeting Mr. Dave Whittle would be calling in to provide a status of the search

The Admiral believes that Mr. Whittle will argue that he wants to close the search out at the end of this month. Mr. Whittle is now searching west of interstate 45 aggressively. Every day the search teams are picking up 4-8 RCCs or left wing tile. The Admiral believes that Mr. Whittle will argue that this pattern has been established and you are not going to find the initiating point by walking the ground west of Corsicana. What is being found west of Corsicana are tiles and RCC 10, 11, 12, 13, and 14. Adm. Gehman stated that he believed Mr. Whittle would argue there is no point in searching (not contributing to what we are looking for), although he will continue to search until the 30th of April.

Mr. Tetrault observed that by the time you get into Texas all of the lower panels, certainly 8 and 9 are gone.

Adm. Gehman stated that Mr. Whittle has a couple hundred people searching west of interstate of 45. They are now 20 miles west of I-45 and expect to get almost to I-35 by the end of the month. Mr. Whittle's problem is that he needs to give the Forest Service a couple of weeks advanced notice as to what the board wants them to do. The current understanding is that on the 30th the Forest Service starts going home. If we, the board, want to give them any other signal we have to do it this week. Adm. Gehman proposed that an additional two weeks past the April 30th timeframe should be sufficient.

Mr. Tetrault agreed and offered that by the end of two weeks with Spring coming it will be difficult to find stuff on the ground. If we can get two weeks out of him I would be certainly content.

Adm. Gehman stated that he was particularly pleased that Mr. Whittle acted on the board's requests and immediately put a couple of hundred people searching to the west of Corsicana. Corsicana is one of the Forest Service bases and they can search east or west of there. Adm. Gehman believes that Mr. Whittle has done what the board asked.

- The location of the tiles found west of I-45 can be instructive. We have not tried to put those together. I think when we start looking at the tiles west of I-45 and their locations; it will be instructive in terms of how the burn occurred – in what direction it was heading in.

Dr. Osheroff suggested that the board should consider rather than going continuously, that we should possibly jump a piece. He observed that what is really wanted is early stuff and we are not getting that yet.

Adm. Gehman stated that even going west of Corsicana is not early enough. We need to go to Arizona and New Mexico. We do not have any tracking data for New Mexico.

Dr. Hallock questioned if Palestine is one of the areas that they did a very dense search. Admiral Gehman stated that they had covered that area thoroughly.

Mr. Hubbard stated that if you give the benefit of the doubt to all of the data lines that we got, we are not looking at anything earlier than RCC-5 nor later than RCC-10 panels.

Dr. Osheroff questioned if we understand why all of the bottoms seem to be falling off before the tops?

- Mr. Tetrault responded to Dr. Osheroff's question stating it appears that the mechanism is the unzipping which goes down the wing but it goes down from the edge of the wing which is up into the stream and as a result, you melt the structure holding the bottom end of the RCC first. It appears that the bottom half of the RCC is lost and you keep the top half. So, we have a whole series of bottom halves that are missing where we have the top halves.

Dr. Osheroff does not understand the validity of this scenario unless the wing was somehow collapsing.

BGen Deal's Activities

- I have been conducting interviews at Michoud. Still have morale issues, house keeping problems, and the amount of oversight. I will be preparing a recommendation for you.
- As opposed to the Cape, here I have found about three areas where one person alone can perform a closeout where no one else takes a look. I am not sure we should be doing that especially if we take RAdm. Cantrell's approach. Good news, some of the initial disgruntled employees talked about inequity, bonuses, and experience levels proved to be at a noise level versus anything that is a major problem.
- Before I leave tomorrow to go to Kennedy to perform more interviews (for 2 1/2 days), I will be doing some more security looks around here as well. I will be able to closeout the security issues once we get the FBI results back in.

Adm. Gehman had two questions for Mr. Tetrault at KSC.

- Find out if FBI has been there and taken samples for explosive work or foul play.
  - Mr.Tetrault stated that it was his understanding that they have about a week or week and a half ago. He has not heard anything since, but has not asked. He will ask for an update.
- When Mr. Tetrault returns, the board would like your views on how we can energize or empower the Debris Analysis Working Group (DAWG). Adm. Gehman feels that they are waiting for some sort of stimulus from some place.
  - Mr. Tetrault responded that they had a meeting with Julie Kramer last Friday relating to this subject.

- They agreed on an arc jet test that we think will be helpful in proving that the breach occurred at the T-seal between 8 and 9. We want to run an arc jet to see if it gives you the same kind of edges. Scott Hubbard- Before coming to this meeting I read a note from Cal Schaumburg who said that the arc jet testing was not a good idea and did not want to do it. Jim Arnold was spearheading this for us. I will ask Jim Arnold.
- The other thing we agreed on was not to come up with a tile-testing plan, because at this particular point everything is pointing toward the RCC and I am not sure what we would test on the tiles to give us any better information than we have. For the moment, we are deferring a tile-testing plan.
- We agreed to disagree on the issue of slag testing. The main issue with slag testing is that by looking at the oxygen you can get a scatter gram that will help point you where you are. We are having problems with the tests done outside of KSC at a variety of labs that have come back with a high variability in the testing results both in the trace elements and for oxygen. At the moment we cannot count on anyone's data. The first thing we have to do is to get these labs squared away so that they can test the same sample and come up with the same results. Not sure who is in error, which makes solving the problem difficult.
- We are also looking at eddy current testing of the slag as a particular test also but we do not have agreement on that test at this time. This test is to determine what altitude that events took place.

Dr. Widnall had two questions for Mr. Tetrault.

- Is there anything systemic or systematic that we can learn from the right wing? Mr. Tetrault responded that there are two issues in terms of separating out what is the event versus what is heating from aerodynamic entry and also what is flow when the shuttle broke up and actually turned. We have flow from port to starboard, but we also have flow from aft forward. The right wing can be used to discern what was reentry damage and what were flow patterns without having broken up.
- The right wing RCC panels are as old as the left wing panels and might be a source of data that we might be more willing to examine carefully without damaging the sacred left wing. Mr. Tetrault responded that we have already started doing that. We are doing destructive evaluation of pieces on the right wing. We are trying to use the right wing where we can before touching the left wing and making errors.

At this time in the meeting Adm. Gehman requested the Activation of Groupware

Dr. Osheroff questioned what has happened with the OEX data, particularly on ascent?

- Dr. Hallock responded that last Wednesday they had a briefing where NASA was looking at data in clumps. He understood that the week after next NASA was heading toward actually having a formal presentation at the public hearing.

- Selective analysis is being performed. There is clustering of data, there are times when things are happening and they die off. Then there is another group of data where everything dies at the very end when the shuttle is breaking up completely.

Adm. Gehman pondered the best methodology for the board to get once a week updates or something like that. Adm. Gehman stated that he would like Mr. Buzzard and company to provide this function. The board should get the OEX data periodically as they know something about it. Mr. Buzzard was tasked to have an interim report on Wednesday at the 12:30 meeting. This should be done periodically, like once a week or every 10 days.

Dr. Hallock noted that last week; NASA has been able to come up with certain conclusions. For example, to try and explain the event that is being seen, NASA is agreeing that you really need to be further than RCC panels 5 and 6, more like the 7, 8, 9 area to start to explain a lot of what they are seeing. They are trying to understand first a decrease and then an increase in the OMS pod area. They think that a shock front has been created in that particular area.

RAdm Turcotte Activities

RAdm Turcotte is heading off to Dallas with our RCC group on Monday to look at status of where the manufacturer is in their investigation. We are looking for results of the engineering investigation that has been on going on the number of flight RCC panels that were pulled off (16R, 10R, and 12R) from previous shuttles involving carbon substrate oxidation. All panels are undergoing lab analysis at manufacturer's facility.

Dr. Hallock Activities

- Dr. Hallock stated that the SRB Working Group would like to come to the board to close out the fault tree except for the bolt catcher issue, which is requiring further analysis. Dr. Hallock and Adm. Gehman agreed with this concept.

- I have been doing a lot of background reading on orbital debris and micrometeorites prior to discussing this with NASA.

- IMU data (accelerometers) have been analyzed for the flight. Currently, there are up to 13 events that they cannot correlate with anything else. Dr. Hallock stated that he had not looked at data as of yet.

Adm. Gehman stated he would like to task someone from Dr. Hallock's group to send e-mail with URL of OEX timeline located on the PBMA to save the board time.

Mr. Hubbard's Activities

- My charts and graphics are ready for the press conference. My theme-representing group 3 is a snapshot in time and flexibility in this test.

- On April 11, there was an impact analysis workshop that Dr. Paul Wilde went to. They are trying to pull together all of the experts that might help us come up with better analytical models. One interesting point, they have done some small size foam impact tests at Glen Research Center that shows that the force applied is insensitive to foam temperature and pressure differences.

- I sent you the Group 3 summary on CRATER.

Adm. Gehman- If we know that we are not happy with CRATER as an analytical model, can we write an interim recommendation? However, this is not the highest priority. An argument against an interim recommendation on CRATER is that it does not rise to the level of significance to be a "real" finding.

- A couple of problems with CRATER. One is that CRATER is semi-empirical. It is not based on the physics of either the impacting material or what is being hit, and the database that supports the spreadsheet is very limited. The assessment is that it is not what you really want.

Adm. Gehman– And besides that it predicts more damage than what you see, and so they ignore it from their experience. It is not just the model; there are other things that are wrong with it.

- Impact Testing update. A review this morning came up with reasonably firm dates for the Test Readiness Reviews (TRRs). One, since the main landing gear door was already in work, that TRR will be April 24th. The RCC TRR is somewhere around the middle of May (possibly May 12th). The trajectory work continues to have a big issue of what is the right size. This may be handed to the CAIB.
- Memo to File documenting the agreement that we worked out over the weekend between the CAIB and NASA about what we are going to do, and how we are going to do it, and why (See attached).

Adm. Gehman – Did you want to go back and talk about test article and which RCC panels we are going to shoot at?

- It was panels 5, 6, 7 – the center panel 6, new visual evidence suggest 7, 8, but they are still refining their error budgets. The debris evidence suggests maybe 8, 9. Taking this information together, it says that the breach seems to be moving toward the 7, 8, 9 area, but it will be the end of the month before the analytic guys have a good error budget. It takes 5 weeks to build an RCC test article, so we agreed to a flexible test setup where we will have 5, 6, 7 and 8, 9, 10. The 6, 7, 8 interface is where the big transition in the wing angle takes place. This will not be reproduced exactly because it is very complicated structure, but structurally strong enough.

Dr. Widnall's Activities

- The aero-thermal group pulled together a three-day aero-thermal summit bringing in people from Ames and Langley. We are hoping that they provide some substance in the next briefing.
- We have also gotten the JASONS involved.
- I spent a day at Lincoln Labs and they are reexamining the radar data for second day piece.
- I am spending time examining original analysis of shuttle thermal system.
- I did task NASA to do calculations on a scenario provided and requested rolling moments.

MGen Barry's Activities

- MGen. Barry – The Air Force Research Lab (Dr. Brian Vent) will be briefing the Day 2 piece data to KSC on April 22nd and will then come and brief the board on April 23rd. This piece was estimated to have reentered somewhere in the south Pacific.
- SRB ETA ring – The issue where the decision was made less than 24 hours prior to launch in the tanking meeting to waive the 1.4 safety factor for the connecting part of the SRB to the ET. We are following this because this was a management decision and is not the normal procedure. The reason they were doing this was that they thought this thing was better than it was. In the course of performing a linear analysis they found that it had less than 1.4. They have performed non-linear analysis also. They have not reviewed the STS-107 SRBs as of yet. Trying to determine if this is a problem for future flights. I think a recommendation will be to buy new ETA rings. ETA rings were supposed to be spec'd to 40 flights.

Adm. Gehman – A component has always been out of spec. Why did this surface so late? Is this another instance of a near miss or diving catch that we need to investigate? This gets into the culture's approach to margin.

- MGen Barry asked that the analysis be performed on the left SRB ETA ring prior to the right one on STS-107 SRBs.
- The Group I matrix will be available.
- Ralph Roe will come to the board on Wednesday and has looked or will look at every RCC panel. The plan is to use ultrasonic wet and dry, and use radiology (x-ray). They will also do thermography (heat flash). The only databases that they have are on ultrasonic wet/dry and radiology. That is why they want to rely on that primarily. Tomagraphy (CAT scan) takes 100 hours per panel. If they find something wrong with the ultrasound, radiology, or the thermography, then they will do a tomography effort. They are trying to get enough equipment to have capabilities at KSC, Dallas, JSC, and at MSFC.

Dr. Osheroff asked if anyone doing destructive test analysis of the RCC panels that have been replaced. These things are very complex. They are repeatedly heated up to high temperatures. If they recrystalize do they have the same strength that is measured when they are new? RAdm. Turcotte- No they have not. They have some test data from twenty-year-old technology.

Dr. Osheroff- concerning the tiles, has anyone looked at the thermal conductivity of these things? If they keep injecting stuff in them, then I would think that they would have to re-certify the part.

- MGen Barry did affirm that NASA did start cutting in Michoud on ET 94. They have found 3 flaws on the right and none on the left to date. They are continuing this effort.

- The reason there is going to be a delay on closing out the SRB bolt catcher on the fault tree is that the original qualification testing was performed with no TPS, a different bolt attachment style, and a different type of honeycomb catcher plug. So obviously this was not very useful.

A general discussion ensued about the on-orbit repair of RCC panels without reaching any conclusions.

MGen. Hess's Activities

- After we had our session with the group last week we have been working with the suggestions of other filters on our infamous cloud chart. We believe that if we look at foam and whether or not we have a picture and use the CRATER analysis we can come up with a fairly indicting opinion of NASA decision making at large. We think we need to investigate additional cases where NASA ran the traps correctly. So that the issue does not twist on decision-making but why this decision was unique. So we are currently searching for those cases. An example could be something like the STS-109 cold plate failure on the freon loop, which threatened to result in a minimum duration mission.
- While we are talking about the recommendations that need to be addressed by the board, the issue of how many cameras need to be working during launch. We are looking into this situation.

Discussion ensued on the concept of changing the shuttle program from "operational" to a rating of some version of flight test. This change would dictate the use of additional instrumentation for the fleet of Orbiters.

Dr. Osheroff's Activities

- Concluded foam tests yesterday. These were the tests, which were performed to determine the capability of the foam to absorb water. There is no evidence for the foam to absorb substantial amounts of water at low temperatures.

Group discussion ensued on the foam shedding phenomenon. The emphasis was on the amount of previous events, which had occurred, and the lack of concern that these events seemed to have generated in the NASA community.

Mr. Dave Whittle of the Mishap Investigation Team joins investigation meeting via telecon.

Adm. Gehman states that they have three files from Mr. Whittle to support the meeting.

Mr. Whittle requested the telecon because some decisions need to be made in the near future as far as search resources. The forest service has made it clear that their commitment will end on the 30th of April. If we are going to perform significant ground searching in the future then there are things that need to be activated right now. Mr. Whittle wanted to explain to the board the current ground search situation and provide a recommendation.

The files provided contain charts concerning the left wing and the HSRI. It shows location of debris and is mapped to the wing. We have a pretty good sampling of the tile across the left wing. Another chart shows the left wing RCC, and the last chart shows the structure and where they were found.

We currently have the Corsicana team heading to the west and due to limitations that the forest service has, they are going to get to block 120 which is just before the Texas Johnson county line, reasonably close, approximately 6 miles, to I-35 East. We are finding primarily tile and pieces of RCC, but it is tapering off.

Our helicopter resources have been tasked to search blocks from east of Granbury westward along the projected debris path. The trend that we are seeing is that the helicopters are not as efficient as the ground search in these areas.

Mr. Whittle believes that keeping the Forest Service engaged beyond April 30th which equates to block 120, may not be the right thing to do. Adm. Gehman agrees with this decision and asked what resources Mr. Whittle will have when the forest service departs. Mr. Whittle stated that this is dependent on the location of additional searches. FEMA will be the primary agency for enabling the resources with the Emergency Operations Center (EOC) at JSC coordinating as point of contact for the board for searches. Additional search blocks are TBD awaiting ballistics, radar, and video analysis.

The western boxes still have activity taking place.

- The Albuquerque box will reactivate again if it has not already.
- The Utah box 9 is being searched by volunteers on weekends. This is being reevaluated and will try and get a more complete effort.
- The Nevada boxes are being searched by prisoners. They are covering about 6 acres per day per person, which is consistent with what is being performed in Texas.
- The Utah box 6 has peaks, valleys, and mountains and they are trying not to search this particular area.

Comment from the board was that the helicopter search might be able to be terminated earlier. The board agreed to accept Mr. Whittle's termination plan for the debris search.

Identified Actions

- Action to Mr. Tetrault to find out if the FBI has been at KSC and taken samples for explosive work or foul play.

- Action to Mr. Buzzard to establish a process to status the OEX recorder data periodically to the Board as information of interest becomes available.

- The CAIB agreed with Mr. Whittle of the MIT on the following action to terminate the debris search:
    - Conclude the ground search on April 30th while getting "as far west as you can", which is estimated to be the Johnson County line (grid #120)

- Ground search the Granbury NTSB box #1, the Nevada search box #7, the Utah box #9, and the New Mexico box #5
- Conclude the western helo searches at MIT discretion, since they are not recovering much debris

This meeting was adjourned at 1500.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal via telecon	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
MGen Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff	CAIB	281-283-7511
Mr. Tetrault via telecon	CAIB	281-283-7509
Mr. Wallace	CAIB	281-283-7508
Mr. Buzzard	CTF	281-483-8412
Dr. Widnall	CAIB	281-283-7579
Rear Admiral Turcotte	CAIB	281-283-7557
LtC Bloomfield	CAIB	281-283-9809
Mr. Choban	Recorder	281-283-7591
Mike Boulavsky	CTF	281-280-8062
Dave Lengyel	CAIB	281-283-7581
Mr. Kirchhoff	CAIB	281-283-7821
Mr. D Pye	CAIB	281-283-7549
Doug Cooke	CAIB	202-329-8844
Paul Wilde	CAIB	301-775-6797
Bill Sikora	CAIB	281-283-7564
John Primbs	CAIB	281-283-3837
Steve Schmidt	CAIB	202-283-7577
Les Reingold	CAIB	281-283-7539
Dave Whittle	MIT	281-483-4282
Jim Mosquera	CAIB	281-286-7546
LCDR Johnny Wolfe	CAIB	281-283-7543
LtC Tyrone Woodyard	CAIB PAO	281-283-7565
Patricia Brach	CAIB PAO	281-283-7520
Dwayne Day	CAIB	281-283-7588
Guy Bluford	CAIB	281-283-7563

Memo To File

4/12/2003

Subject: RCC Impact Test, Test Assembly

- Based on early photo analysis of the STS 107 foam impact the projected point of contact was estimated to be at RCC panel 6L. This led to the development of a three-panel impact test assembly that encompassed panels 5, 6, and 7.

- Subsequently forensic assessments of recovered RCC parts indicated that significant damage occurred at the front of portion of panel 9, possibly as a result of an impact on the T-seal between panel 8 and 9.

- Given the uncertainty in the photo analysis impact location, the trending of this analysis to impact locations aft of panel 6, and the forensic evidence at panel 9, a decision was made to make a second test assembly. This decision was made in an April 9, 2003, meeting between NASA (Benz, Miller), CAIB (Hubbard, Babish, and Pye). The second three-panel assembly would encompass panels 8, 9, and 10 and would tentatively be planned for a test of foam impact on the T-seal between panel 8 and 9.

- Continued photo analysis has led to the estimated foam contact point moving further aft and outboard on the left wing to approximately panel 7 and 8. The details behind the changes in photo analysis predictions were reviewed in an April 10, discussion between NASA (Byne) to CAIB (Hubbard, Arnold, and Pye).

  This was an interim report, as photo analysis work was continuing. NASA estimated that analysis should be sufficient by the end of April to establish an error budget for the various pieces of the analysis.

- Based on the April 10 discussion, CAIB (Babish and Pye) reviewed the design of the second test assembly to ensure that it provided the necessary coverage and flexibility given the potential for further input from forensic evidence and photo analysis. This was the subject of a discussion among Glenn Miller, John Mulholland, Wayne Jermstad, and CAIB (Babish and Pye). The key points from this discussion were:

  > Testing of panel 6 (one of the weaker panels) in the first impact test assembly, and the testing of panel 9 (a stronger panel containing doublers) would provide sufficient data for analysts to assess the potential loads imparted to Panel 7 if the T-seal between panel 7 and 8 were to become the point of impact.
  >
  > A shift of the foam impact point from the panel 8-9 intersection to the middle of panel 8 could be accommodated with the planned 8-9-10 test assembly.

A test rig to include the T-seal between panel 7 and 8 would require the inclusion of a significant amount of back up structure to simulate the significant changes in wing spar support in this region. This more complex support structure would extend the current fabrication span time for a three-panel test assembly from 5 weeks to something between 5 and 15 weeks.

- CAIB (Babish and Pye) recommended that the second impact test assembly proceed on the basis of the current concept and encompass panels 8, 9, and 10.

- The recommended course of action was reviewed with and agreed to by Admiral Gehman, General Barry, and S. Hubbard on April 11, 2003.

- On April 11, 2003, subsequent to the above agreement, NASA (Benz, Jermstad) presented a modified test assembly concept to the CAIB (Babish and Pye).

The proposed concept employs a common backup structure that encompasses both of the three-panel test assemblies. The simplified backup structure will provide the necessary structural support as determined by analysis. While structurally equivalent, the proposed structure is less prototypic than the concept discussed above for a test assembly that includes the junction of panel 7 and 8. This reduces fabrication span time.

The proposed concept provides significant flexibility to the impact test program. Specifically,

Either or both of the test assemblies can be mounted to the backup structure when they are available.

Both test assemblies, and the backup structure can be built in parallel. With adequate resources both should be delivered to the test site about May 15, 2003. (NASA is working to identify and arrange for the necessary resources)

With both test assemblies mounted on the backup structure the capability exists to test the T-seal between panel 7 and 8 if that becomes necessary based on future forensic evidence or photo analysis.

Babish and Pye agreed that NASA should proceed with this concept on April 11, 2003 (PM). This action was discussed with and agreed to by S. Hubbard on April 12, 2003.

D. B. Pye

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 16, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 16 April 2003 **Time:** 1230 - 1400

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

Admiral Gehman led a discussion on the format and content of the final report and the process he envisions for developing the final product. Once the Board agrees on the rough outline of the chapters the writers can go ahead and develop a rough draft of the report. The Admiral stated that he would like to have this completed before they leave Houston. The second draft will focus on refining the narratives in the individual chapters. The objective for the third draft will be to identify and link references and supporting data across chapters so that the content will be better integrated and readable.

By the time the Board moves the base of operations to Washington, D.C., the report should be in the editing phase. The ultimate decision over content of the report will be subject to majority vote of the Board. Minority opinions are encouraged and will be included in the report.

The rest of the meeting was devoted to finalizing the preliminary recommendations for: (1) improved inspection and testing of RCC components; and (2) imaging the Shuttle while on orbit. Emphasis was on making sure the facts were accurate and verifiable, and the message was clear and unambiguous (see attachments).

This meeting was adjourned at 1400.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 16, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal via telecon	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff via telecon	CAIB	281-283-7511
Dr. Logsdon via telecon	CAIB	281-283-7594
Mr. Wallace	CAIB	281-283-7508
Mr. Buzzard	CTF	281-483-8412
Dr. Widnall	CAIB	281-283-7579
Dr. Bluford via telecon	CAIB	281-283-7563
Lt. Colonel Bloomfield	CAIB	281-283-9809
Mike Boulavsky	Recorder	281-280-8062
Dave Lengyel	CAIB	281-283-7581
Mr. Kirchhoff	CAIB	281-283-7821
Mr. D Pye	CAIB	281-283-7549
Lt Col. Woody Woodyard	CAIB PAO	281-283-7565
Paul Wilde	CAIB	301-775-6797
Bill Sikora	CAIB	281-283-7564
Jim Mosquera	CAIB	281-283-7546
LCDR Johnny Wolfe	CAIB	281-283-7543
Patricia Brach	CAIB PAO	281-283-7520
Jim Smiley	CAIB	281-283-7545
Dwayne Day	CAIB	281-283-7588
Ron Gress	CAIB	281-283-7532
Pat Garrett	CAIB	281-283-7593
1st Lt. Steve Clark	CAIB	281-283-7525
Terry Williams	CAIB	281-283-7520

:

PRELIMINARY DECISIONAL MATERIAL - NOT FOR RELEASE

April XX, 2003

From: Chairman, Columbia Accident Investigation Board

To: Administrator, National Aeronautics and Space Administration

Subject: Columbia Accident Investigation Board Preliminary Recommendation No. 1: Improved Inspection and Testing of RCC Components

The CAIB issues this finding and recommendation in advance of its appearance in the final report.

Facts:

- The Reinforced Carbon-Carbon (RCC) system (including all RCC, supporting structure and attaching hardware) is an essential component of the Space Shuttle Orbiter Thermal Protection System (TPS) and has a Criticality Rating of 1 (loss of crew - loss of vehicle).

- The RCC composite consists of a reinforced carbon-carbon substrate that carries the structural loads, a tetraethyl orthosilicate impregnation that reduces inherent substrate porosity, a silicon carbide treatment that protects the substrate from oxidation, and a sealant coating that provides additional oxidation protection. These composite structures are attached to the shuttle by a metal support system.

- During initial manufacturing acceptance, the integrity of production composites used in the RCC system is checked at various points in production by physical tap, ultrasonic, radiographic, eddy current, weight gain, and visual tests. In addition, a flat plate control panel made in parallel with the production piece is destructively tested at various points in the production process.

- A projected design mission life has been established for each RCC component. These projections are based on analysis correlated to simulated flight load testing, and assume the presence of sound composite material and metal support structure.

DRAFT

- Visual external inspections and tactile checks are the only specified post flight inspections of RCC composite components. The planned interval for removing RCC composite components for more thorough inspection is typically many flights, unless their removal is dictated by an observed visual surface condition or necessitated by the requirement to provide access for other operations.

- Non-destructive testing of some post-flight RCC components has shown indications of RCC material defects not previously identified by visual inspection methods currently employed.

PRELIMINARY DECISIONAL MATERIAL – NOT FOR RELEASE

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DRAFT

Discussion:

Indications of subsurface flaws in RCC components have been found using advanced inspection methods. Despite the incomplete state of qualification for some of these methods, these results strongly suggest that current inspection methods are not adequate.

Satisfactory performance of the RCC composite material and the associated metal support system is essential to the overall performance of the Thermal Protective System and shuttle safety. As shuttle systems age, both in years and flight cycles, measurement of aging effects is critical.

Finding:

Current inspection techniques are not adequate to assess structural integrity of RCC, supporting structure, and attaching hardware.

Recommendation:

Prior to return to flight, develop and implement a comprehensive inspection plan
to determine the structural integrity of all RCC system components. This inspection plan should take advantage of advanced non-destructive inspection technology.

H. W. Gehman
Admiral, U.S. Navy (Retired)

Copy to:
Chairman, Columbia Task Force
Chairman, NASA Accident Investigation Team
Chairman and Ranking Minority Member, Senate Committee on Commerce,
Science and Transportation
Chairman and Ranking Minority Member, House Science Committee
Chairman and Ranking Member, Senate Appropriations Committee,
Subcommittee on HUD/VA and Independent Agencies
Chairman and Ranking Member, House Appropriations Committee,
Subcommittee on HUD/VA and Independent Agencies
Director, Office of Science and Technology Policy

DRAFT

PRELIMINARY DECISIONAL MATERIAL - NOT FOR RELEASE

PRELIMINARY DECISIONAL MATERIAL – NOT FOR RELEASE

April XX, 2003

From: Chairman, Columbia Accident Investigation Board

To: Administrator, National Aeronautics and Space Administration

Subject: Columbia Accident Investigation Board Preliminary Recommendation No. 2: Shuttle Imaging on Orbit

The CAIB issues this finding and recommendation in advance of its appearance in the final report.

Facts:

- The U.S. Government has the capability to image the Shuttle on orbit.
- A Memorandum of Agreement exists between NASA and National Imagery and Mapping Agency (NIMA) regarding on-orbit imaging of the Shuttle.
- During the flight of STS-107, there were no on-orbit images taken of sufficient resolution to assess the Orbiter's condition.

DRAFT

Discussion:

Except forthe first few shuttle missions, the only routine surveillance of the Orbiter has been by ground-based assets to deconflict the orbiter's projected flight path from known objects. When such a conflict arises - called a conjunction - this data is provided to NASA by the Air Force Space Command's Space Control Center, prompting NASA to consider altering the orbit.

With prior planning, a variety of resources exist to make orbiter condition assessments. Additionally, such requests are not unduly difficult or expensive to execute, and the results can be provided in near real-time for assessment and baselining orbiter condition. Over the years U.S. imaging capability has improved to the point where it can significantly add to the body of knowledge regarding the condition of an orbiter.

PRELIMINARY DECISIONAL MATERIAL – NOT FOR RELEASE

It is the perspective of the Board that, given the developmental nature of human space flight, the Shuttle is a test vehicle being used in an operational application. When test vehicles fly in other arenas, they will generally have chase planes/photo ships to record their activity. The imaging capabilities of the United States are the on-orbit "chase planes/photo ships" for the Shuttle. The routine use of on-orbit imaging for baselining, if for no other reason, is advisable.

Finding:

The full capabilities of the United States to image the Columbia during STS-107 were not utilized.

Recommendation:

DRAFT

Prior to return to flight, NASA should modify its Memorandum of Agreement with NIMA, to make on-orbit imaging for each Shuttle flight a standard requirement.

H. W. Gehman
Admiral, U.S. Navy (Retired)

Copy to:
Chairman, Columbia Task Force
Chairman, NASA Accident Investigation Team
Chairman and Ranking Minority Member, Senate Committee on Commerce,
Science and Transportation
Chairman and Ranking Minority Member, House Science Committee
Chairman and Ranking Member, Senate Appropriations Committee,
Subcommittee on HUD/VA and Independent Agencies
Chairman and Ranking Member, House Appropriations Committee,
Subcommittee on HUD/VA and Independent Agencies

Director, Office of Science and Technology Policy

PRELIMINARY DECISIONAL MATERIAL – NOT FOR RELEASE

DRAFT

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 22, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting
Date: 22 April 2003 **Time:** 0900 - 1150

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

Admiral Gehman convened the meeting at 0900 and began with discussing Roger Tetrault's and Group 3's upcoming presentation to the NASA Accident Investigation Team on Thursday. Roger and his group have developed a working hypothesis describing the sequence of events in Columbia's breakup; this was the subject of a front page article in today's Houston Chronicle and may well come up in this afternoon's press conference.

The next order of business was voting on the potential facts list of 16 April with the Group Systems Software. After voting was complete, Admiral Gehman led a discussion of potential facts that had failed to achieve more than 80% yes votes. The Potential Facts Vote is attached; salient points or actions from the discussion are given below and follow the numbering given by the voting software:

25 – the fleet wide average number of debris strikes causing Thermal Protection System (TPS) tile damage should be determined and captured for this potential fact

#26 – there is no External Tank foam non-destructive evaluation (NDE)

#27 – the External Tank foam debris hit the leading edge (mid 6) at 81.7 seconds into the ascent; there was a 2nd hit at 8 as well as hits to the underside "acreage"

Admiral Gehman paused in his review to question how best to level Board expertise given that some members have had more exposure to technical briefings and other materials; he also stated that potential facts need to be restated with correct data, as was indicated for #25 above.

#28 -- the numbers of lost and damaged tiles in OV-102's 1st flight should be determined and captured for this potential fact

#29 – the number of acres covered by search parties should be determined and captured for this potential fact

#30 – the order in which the wings came off is probably not as relevant as saying that the left wing was the malfunctioning element

#31 – the combustion of aluminum should be verified through further analysis of soot and search for evidence of an exothermic reaction; Dr. Widnall noted that the aero tests cannot reproduce roll and thus an energy source such as aluminum combustion may be needed to resolve the roll rate anomaly

#32 – there were several debris objects detected, but imagery analysis can only confirm that one debris object struck the orbiter

#33 – this potential fact is poorly worded ("most of the orbiter was intact"); photo is basically a silhouette of the orbiter, too fuzzy to contribute much; seemingly shows a difference between the left and right sides

#34 – an "absolute" statement, not particularly relevant

#35 – the case of the 1979 piggyback flight should be restated

#36 – Steve Wallace noted that the group doing e-mail should present their findings; Scott Hubbard noted that there were also office visits and other communications besides e-mail; Admiral Gehman pointed out that e-mail was not a "smoking gun" but rather a symptom of an overall problem

#37 – on-orbit repair of TPS is planned; Admiral Gehman: if the repair capability is developed, will NASA be obliged to repair everything? RAdm Turcotte noted the 25-year old presentation made by Langley (LaRC) on tile repair; Dr. Ride recalled there was also a parallel 25-year old ops effort; Steve Wallace recalled Paul Hill's presentation that TPS repair would be available in October 2003 and RCC repair in December 2003; MGen Hess asked if foam were viewed as a threat, would that threat have been addressed? Admiral Gehman challenged the Board on whether 25-year old assumptions and conclusions have to be maintained; Dr. Ride recalled the tremendous effort between STS-1 and STS-4 that focused on the two issues of Main Engines and tiles – there was discussion whether to launch STS-1 without tile repair capability – but the conclusion of the astronauts and engineering was repairs were not feasible – the experience of STS returning with missing tiles led to "expectation of deviation" [Vaughn, also Charles Perrow's "tightly vs. loosely coupled"]; Admiral Gehman noted the sequence -- 1st make sure nothing hits the tiles then 2nd fix the tiles when something hits them...

#38 – foam from the bipod area on the External Tank separated from the External Tank on four previous flights [vice three times]

#39 – the January 1986 launch delays do not seem relevant

#40 – OV-102's 4th flight problems do not seem relevant

#41 – action or inaction on the recommendations of independent mission assurance or safety boards is a matter for analysis; Dr. Logsdon and Group 4 will log previous recommendations and NASA responses; Admiral Gehman noted that Board members have questioned the effectiveness of Safety & Mission Assurance (S&MA); MGen Hess noted that when S&MA and Engineering work on jointly defined hazards, S&MA is quite effective – but not when Engineering does not recognize an S&MA hazard

#42 – the death of two workers in 1981 does not seem relevant

#43 – External Tank foam separation cannot be observed in night launches; Scott Hubbard said the community nonetheless believes that separation occurs on every flight

#44 – RCC non-destructive testing includes both visual inspection and tactile (tap) testing; RAdm Turcotte stated that ultrasound testing is used in manufacturing; this potential fact should refer to in-service testing

#45 – Dr. Hallock said that only cutting Columbia's mass by half would have helped; Scott Hubbard noted that reentry angle change would have only produced 5 to 10 % improvement in heat load; in response to Dr. Ride's comment about not having seen all reentry change proposals, Dr. Hallock cited a previous briefing to the Board; Dr. Widnall expressed her dismay that NASA didn't try to change from nominal reentry; Steve Wallace added that the biggest issue is not trying; Dr. Logsdon pointed to problems in decision making; Admiral Gehman raised landing at Edwards AFB.

#46 – there were two EVA suits onboard STS-107

#47 – 1983 space walk does not seem relevant

#48 – it just was Columbia's turn to fly, but there was pressure for a science mission; Columbia was 10K pounds heavier than other orbiters, lacked an external airlock (more mass) and the delta V for a plane change to that of ISS; Dave Lengyel offered an RFI to have Michelle Brekke and John Coggeshall provide the Board with the manifest rationale for this flight

#49 – while NASA and DCMA QA manning levels have shrunk, it is a matter of analysis to determine the adequacy of contractor oversight.

Admiral Gehman returned to Roger Tetrault's working hypothesis on how heat entered Columbia's left wing and the path it took from there. As mentioned, Roger and Doug Cook are to make their presentation Thursday. Scott Hubbard had just received a draft of the briefing and reported that the briefing looks at the failure of T-seal #9 as the first step, although the failure of RCC 8 or 9 cannot be ruled out. New in this is the level of detail on how the T-seal would fail and the coupling of a timeline from OEX data to what piece fell off when. A list of failure points and modes is given, some of which is speculative or intuitive. Scott characterized the briefing as expressing Group 3's opinion. Dr. Widnall mentioned that she has seen an equally speculative briefing by NASA on off-nominal wing flex, taking the wing flexure from strain gauges and matching to the aero forces. Dr. Hallock said he does not totally agree with NASA's view, as for examples, the lower temperature on the OMS pod could be explained by the heat flow into the wing and there could have been other events at 1 and 2; however, he expects that Mr. Tetrault's and NASA's views will be basically in agreement. Admiral Gehman noted that 11 weeks into the investigation it is OK for a member to make a working hypothesis, which will certainly be helpful in organizing the debris data. It was decided to have Mr. Tetrault provide his presentation via teleconference to the Board on Wednesday, tentatively at 1700. Mr. Lengyel will organize the briefing.

Admiral Gehman then turned to Dr. Logsdon for discussion of the report content from Group 4; the Admiral also noted that all members should review and comment on the current report outline, Rev. 1. The report outline features "Direct Cause" (heat), "Contributing Causes" (management), and "Root Causes" (culture, budget) – the latter being Group 4's area. These outline headers may change. Dr. Logsdon opened with general concerns on the level of detail in providing evidence and the use of interviews as data points. [Admiral Gehman returned to these concerns later, noting that Group 4 should provide about 1/4 of the Board's report and that the history of previous boards and commissions would make Group 4's contributions key to all other groups. Interviews can be cited but not for attribution; collaboration from multiple interviews is expected to provide evidentiary support.] Dr. Logsdon noted he had provided a Shuttle storyboard as a draft for policy, budget and management history as well as a sense of the direction being taken. He has just returned from Washington with selected papers from Dan Goldin's tenure; the papers principally focus on issues of workforce, safety and SFOC. While Group 4 focuses on Washington, Group 1 has its focus on the NASA centers and SFOC; the interface boundary between the groups is HQ NASA.

Dr. Logsdon continued by stating that Howard McCurdy would contribute to the Group 4 report from the literature of high performance organizations as it applies to NASA's performance in recent years particularly for NASA management of risk and use of the image of STS as an operational system that was put forth to gain Congressional support. Mr. Goldin's actions from 1999 that demonstrated extreme concern with STS safety will be included as well his visit to the White House that got the NASA budget decline reversed. Particularly interesting is the first meeting of Sean O'Keefe and Mr. Goldin in September 2001 that dealt with privatization of the STS operations and crew. The residence of program management will be discussed, noting the shift of program management responsibilities in 1996. Interviews planned for next week will be held with former NASA managers Joe Rothenberg, Wil Trafton, and Wayne Littles as well as Steve Isokowitz (OMB), and Skip Johns (OSTP). Mr. Buzzard asked about changes in the STS

privatization approach since September 2001. Dr. Logsdon noted that the approach had been coordinated by NASA both through OMB and the Strategic Resources Review. Dr. Ride asked whether pressures induced by ISS budget problems would be highlighted; Dr. Logsdon replied that schedule pressures would be noted. Dr. Ride requested that Group 4 trace the STS program's efforts to gain schedule relief. Dr. Logsdon mentioned an RFI for Ron Dittemore's up-channel memos or briefings. MGen Hess added that there seemed to be a buffer at mid-management levels that worked against the up flow of information. Admiral Gehman asked whether schedule pressures in the mid-1990s had been to launch quicker than ready; Dr. Logsdon said that the pressure was also for processing more quickly; Scott Hubbard added that dispositions also had to be faster. Dr. Logsdon said his group would focus on the pressures that were perceived at HQ NASA. Admiral Gehman noted that the effects of SFOC, privatization and schedule or budget pressures from ISS had been recognized at JSC. Dr. Logsdon pointed out that OMB had directed that ISS budget shortfalls be recouped from within the HEDS element; however, the only other human spaceflight activity was STS. One of the charts from Mr. Goldin's push for increased funding showed that the STS budget had declined by 67%. Dr. Ride noted the Goldin-Rothenberg memo on reducing in-flight anomalies (IFA) could have been interpreted as either fixing IFAs or just not declaring them. Dr. Logsdon said that program commitment agreements (NPG 7120 series) would be studied.

Dr. Widnall asked how the report would deal with previous boards and commissions. Admiral Gehman said they would be included in the "Root Causes" section of the report; he further noted that despite STS being classified as an "experimental system", NASA had pushed for privatization. Col. Mike Bloomfield said the Board's report should provide definitions of experimental, developmental and operational systems. Dr. Logsdon noted that in 1993 the STS was considered "done" and direction was given not to change the system; however, safety concerns arose that changed this direction. The first safety change was the Electric Auxiliary Power Unit (EAPU), which unfortunately did not work and thus "blackened" the whole safety upgrades effort.

Dr. Logsdon mentioned that he intends for a relatively limited effort from The Aerospace Corporation on presenting its risk approach for launch vehicles, primarily the checks implemented for Titan IV. Admiral Gehman said that the Board should review the proposed statement of work for Aerospace. Dennis Jenkins added that Aerospace in the past had established process checks for the Air Force Shuttle that was to have been launched from Vandenberg AFB, CA.

Admiral Gehman brought up the SFOC review to be conducted by Lehman, Foster and Olsen – all of whom have experience as Contracting Officer Technical Representatives (COTR). Their review will determine whether Government oversight of SFOC has been at the appropriate place and level. Award fee structure and other contract incentives will be reviewed for understanding contractor perceived financial and schedule pressures and whether contractor motivation is aligned with NASA's intent. The Admiral noted that COTRs are familiar with Government-Owned, Contractor-Operated (GOCO) efforts, which typically have small profit margins on the order of 1.5 %; this contrasts sharply with the large profit margin for SFOC. The review will attempt to determine the rationale for the SFOC profit margin under the current contract. Dr. Logsdon mentioned last fall's high-level review of SFOC to determine whether to recompete the contract, which is consistent with Mr. O'Keefe's emphasis on competition.

The RFI for Bill Readdy and the RAND study on this topic were also cited. Dr. Logsdon then asked whether to include information on how the United Space Alliance came into existence; Admiral Gehman said the subject was certainly worth a paragraph in the report.

Scott Hubbard returned to the STS program management history of shifts from center to HQ NASA and back; he asked whether the Board felt these shifts contributed to the accident. Admiral Gehman referenced the RAdm Walt Cantrell presentation and said it was useful in pointing out that shifts in program management and safety responsibilities should not have affected the discharge of those responsibilities although it had in this case. Mike Bloomfield asked whether the shifts were that important. Dr. Logsdon replied that the pendulum-like nature of the shifts is an indication that something is out of balance and that HQ and JSC have strikingly different cultures. Dr. Ride noted that in addition to center vs. HQ differences there are also those between program and line. Steve Wallace asked how to use these cultural differences in writing the report; Dr. Logsdon suggested that the other groups could illustrate Group 4 descriptions of cultures via examples found in their work.

The Admiral reminded the Board of the 1300 press conference and adjourned the meeting at 1150.

Identified Actions

- Set up teleconference briefing of Board by Roger Tetrault, Doug Cook for 1700 23 April – Dave Lengyel.

Identified Requests for Information (RFI)

- Set up briefing on STS-107 manifest rationale by Michelle Brekke and John Coggeshall – Dave Lengyel

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Logsdon	CAIB	281-283-7594
Dr. Ride	CAIB	281-283-7503
RADM Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mike Boulavsky	Audio	281-281-8062
Patricia Brach	PAO	281-283-7849
Mr. Buzzard	CTF	281-483-8412
Spencer Campbell	Recorder	281-280-8033
Mike Francis	Group 1	281-283-7574
Rudy Gazarek	Group Systems Support	281-283-7593
Dennis Jenkins	Group 4 Support	281-283-7589
Dave Lengyel	CAIB	281-283-7581
Steve Schmidt	CAIB	281-283-7577
Bill Sikora	CAIB Counsel	281-283-7564

Attachment: Potential Facts Vote, April 22, 2003

Potential Facts Vote

Tuesday, April 22, 2003

Potential Facts Vote - - 22 April 2003 (Vote) 3

Potential Facts Vote - - 22 April 2003 (Vote)

Number of Votes in Each Rating

	Yes %	No %	n
1. RCC can deteriorate from interior oxidation attack	100.00	0.00	9
2. The true condition of the RCC on Columbia was unknown at the	100.00	0.00	9
3. The temperatures experienced during the accident scenario me	100.00	0.00	10
4. NDE evaluation of the RCC is not conducted by NASA before ea	100.00	0.00	10
5. An adequate fix to prevent bipod foam from separating from t	100.00	0.00	10
6. NASA accepted bipod ramp foam loss as an acceptable risk fol	100.00	0.00	10
7. Available on-orbit imaging capabilities were not utilized	100.00	0.00	10
8. The orbiter experienced an intense heating environment upon	100.00	0.00	10
9. Temperature sensors in the left wing show anomalous increase	100.00	0.00	10
10. The OEX recorder was recovered. Useable data is on the tape	100.00	0.00	10
11. The OEX recorder yielded usable temperature, pressure, and s	100.00	0.00	10
12. The Crater analysis was not briefed to the MMT directly, but	90.00	10.00	10
13. Aging materials may be an important issue for the safety of	90.00	10.00	10
14. Superheated air in the left wing created structural damage	90.00	10.00	10
15. Five MMT meetings were held during the STS 107 mission	90.00	10.00	10
16. On-orbit inspections of TPS is possible	90.00	10.00	10
17. The bi-pod foam shedding event on STS 112 was not classified	90.00	10.00	10
18. An adequate fix to prevent bipod foam from departing the ET	90.00	10.00	10
19. No debris was found west of Texas	90.00	10.00	10
20. The orbiter experienced off nominal aerodynamic forces befor	88.89	11.11	9
21. The contract for Columbia was awarded in 1972	88.89	11.11	9
22. RCC degradation caused by pinholes was identified in 1995 bu	88.89	11.11	9
23. Columbia was completed in 1979	88.89	11.11	9
24. NASA building infrastructure repairs have received insuffici	88.89	11.11	9
25. The fleetwide average number of debris strikes which cause T	80.00	20.00	10
26. External Tank foam NDE is insufficient to detect manufacturi	80.00	20.00	10
27. External tank foam debris hit the Columbia leading edge at 8	80.00	20.00	10
28. OV-102 lost 16 tiles and had damage to 148 others on its fir	77.78	22.22	9
29. Search parties covered over 1.5 million acres	77.78	22.22	9
30. The left wing came off the orbiter before the right wing	77.78	22.22	9
31. Combustion of aluminum occurred as hot gases impacted intern	77.78	22.22	9

	Yes %	No %	n
32. High resolution imagery of the debris strike at 82 seconds s	70.00	30.00	10
33. The Kirtland photo indicated that most of the orbiter was st	70.00	30.00	10
34. The initial event causing this accident may never be determi	70.00	30.00	10
35. The 1979 piggyback flight of Columbia was stopped before tak	66.67	33.33	9
36. E-mail traffic expressing concern about the orbiter's condit	60.00	40.00	10
37. On-orbit repair of TPS is possible	60.00	40.00	10
38. Foam from the bipod area on the ET separated from the ET on	60.00	40.00	10
39. The January 1986 launch was delayed 6 times due to hardware	55.56	44.44	9
40. On OV-102's 4th flight it had SRB and parachute problems.	55.56	44.44	9
41. NASA has not provided examples of instances where recommenda	55.56	44.44	9
42. Two workers died in 1981 due to nitrogen in the engine compa	55.56	44.44	9
43. ET foam has separated from the ET on every shuttle launch.	50.00	50.00	10
44. RCC non-destructive testing was visual inspection only	44.44	55.56	9
45. Changes to reentry criteria would not have helped Columbia o	40.00	60.00	10
46. There was no viable EVA capability on STS-107.	40.00	60.00	10
47. In a 1983 flight a space walk was cancelled due to bad gear	33.33	66.67	9
48. Columbia flew STS 107 because it was Columbia's turn to fly	20.00	80.00	10
49. NASA and DCMA Quality Assurance manning levels have shrunk t	20.00	80.00	10

Ballot Items in Original Order

1. **The initial event causing this accident may never be determined absolutely.**
2. **External tank foam debris hit the Columbia leading edge at 82 seconds into the ascent**
3. **ET foam has separated from the ET on every shuttle launch.**
4. **Foam from the bipod area on the ET separated from the ET on 3 previous flights**
5. **An adequate fix to prevent bipod foam from separating from the ET was never implemented**
6. **External Tank foam NDE is insufficient to detect manufacturing process defects.**
7. **An adequate fix to prevent bipod foam from departing the ET was not perceived as a safety of flight requirement**
8. **NASA accepted bipod ramp foam loss as an acceptable risk following STS-112, and did not pursue a fix before the subsequent two STS missions**
9. **The Kirtland photo indicated that most of the orbiter was still intact.**
10. **The orbiter experienced an intense heating environment upon reentry**
11. **The bi-pod foam shedding event on STS 112 was not classified as an in-flight anomaly, nor was the resolution of the issue a constraint to subsequent flights.**
12. **The fleetwide average number of debris strikes which cause TPS tile damage > 1 inch is X (about 40)**
13. **High resolution imagery of the debris strike at 82 seconds shows several debris objects, but only one can be confirmed as hitting the orbiter**
14. **On OV-102's 4th flight it had SRB and parachute problems.**
15. **The January 1986 launch was delayed 6 times due to hardware problems**
16. **There was no viable EVA capability on STS-107.**
17. **Available on-orbit imaging capabilities were not utilized**
18. **The OEX recorder was recovered. Useable data is on the tape**
19. **The OEX recorder yielded usable temperature, pressure, and strain data**
20. **E-mail traffic expressing concern about the orbiter's condition did not reach the proper decision-levels**
21. **Temperature sensors in the left wing show anomalous increases and then drop off scale**
22. **On-orbit inspections of TPS is possible**
23. **On-orbit repair of TPS is possible**
24. **Five MMT meetings were held during the STS 107 mission**

25. The Crater analysis was not briefed to the MMT directly, but was verbally briefed by the MER manager

26. NASA has not provided examples of instances where recommendations of independent mission assurance or NASA's safety board impacts mission or program.

27. The contract for Columbia was awarded in 1972

28. The 1979 piggyback flight of Columbia was stopped before takeoff due to tile loss

29. Two workers died in 1981 due to nitrogen in the engine compartment

30. NASA and DCMA Quality Assurance manning levels have shrunk to unacceptable levels to provide adequate oversight of contractor performance

31. OV-102 lost 16 tiles and had damage to 148 others on its first flight

32. Columbia flew STS 107 because it was Columbia's turn to fly vs. a critical mission that had to be accomplished

33. In a 1983 flight a space walk was cancelled due to bad gear

34. NASA building infrastructure repairs have received insufficient funding to address the extent of the aging facilities

35. Columbia was completed in 1979

36. No debris was found west of Texas

37. The orbiter experienced off nominal aerodynamic forces before crossing the California coast

38. Superheated air in the left wing created structural damage

39. Search parties covered over 1.5 million acres

40. The left wing came off the orbiter before the right wing

41. Changes to reentry criteria would not have helped Columbia on this flight.

42. The temperatures experienced during the accident scenario melted the aluminum structure of the orbiter

43. Combustion of aluminum occurred as hot gases impacted internal structure of the left wing

44. RCC non-destructive testing was visual inspection only

45. RCC can deteriorate from interior oxidation attack

46. RCC degradation caused by pinholes was identified in 1995 but was not perceived to be a safety of flight issue

47. The true condition of the RCC on Columbia was unknown at the time of the mishap

48. NDE evaluation of the RCC is not conducted by NASA before each flight

49. Aging materials may be an important issue for the safety of orbiter reentry.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 28, 2003
These Minutes Contain No Sensitive Data

Purpose: Safety Symposium

Date: 28 April 2003 **Time:** 0830- 1500

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the DOJ CDS Database.

Background - The CAIB hosted this symposium to raise their awareness of industry and organizational safety standards and practices. Discussion topics included safety management and programs, decision-making processes, and culture. They also reviewed accident investigation models, metrics and leading indicators.

Safety Leadership and Culture - Presented by Alan McMillan, Executive Vice President and Chief Operating Officer of the National Safety Council (NSC)

The NSC was formed at the turn of the century as a not-for-profit organization that focused on worker occupational safety in the rust belt around Chicago. Chartered in 1953 by Congress to "arouse the nation to the issue of accident prevention", the Council currently focuses their efforts on the three following areas: (1) safety and health in the workplace, (2) safety and health on the highways, and (3) safety and health in the home and community. This is significant because experience has shown that corporations sometimes get into trouble because they only focused on certain aspects of safety, but did not create a culture of safety that transcended across all activities of the organization.

Mr. McMillan then presented the seven key elements and indicators of safety leadership (see attached) that were based on what the NSC learned from the "best in class" of major corporations and how the leadership created the culture of safety.

Vision and Values - Simply setting a goal of reducing trips and falls is not adequate. When safety becomes a core value, the only appropriate goal is zero. And, per the NSC code of ethics, the CEO personally leads all aspects in building a climate of safety.

Participation – Safety and health will never be at the pinnacle if it belongs to the safety and health office. It has to be driven outside where all people can be engaged—where all employees consider safety and health to be not only a part of their jobs but when they are off work too. This also applies to vendors and subcontractors.

Vendors and subcontractors - For example, all subs and contractors at Intel are integrated into their safety culture. Their award fee is tied to safety metrics. On the other hand, Phillips Petroleum had a good safety program that they were proud of, but for perceived liability reasons they maintained a hands-off relationship with their subcontractors. This led to unsafe conditions where ultimately the subcontractors blew up the plant.

Leadership - Some CEOs treat safety and mission assurance at the same level as the balance sheet, reporting what, why, and how. They focus on accountability, not blame.

Operations Leadership –Presented by Ms. Deborah Grubbe, Corporate Director - Safety and Health, DuPont

DuPont believes that incidents are not accidents--accidents suggest something that was not foreseen or controllable. The corporate belief is that all injuries and incidents are preventable.

Ethics is the foundation, because you cannot have a good safety program without having ethics first. It is easy for individuals to ignore or cover things up. If you do not create a culture that encourages people to bring forward the near misses, abnormal events or concerns, you will miss a lot of opportunities for improvement.

There must be a unified set of beliefs around safety; a passion around safety at all levels, from top management down to the suppliers. For example, anyone in DuPont can stop a job at anytime if they believe that it is unsafe.

You must have clear roles at the corporate level. You need people at an oversight level to provide encouragement, guidance, and audit processes; and who are accountable to the top. You also need to have accountability and metrics, with rewards for good and repercussions for bad. Safety is a balance between the carrot and the stick, and there is a direct relationship between safety and production,

TIPS – Thinking Individuals Promote Safety (see attached)

DuPont policy is that if anybody is hurt on the job or killed off the job there is a report on the CEOs desk within 24 hours. The DuPont medical team is reporting globally every two days on Severe Acute Respiratory Syndrome (SARS) (Intel is giving a SARS update every day). There is a constant educational process--employees have mandatory monthly safety meetings to reinforce belief that safety is important.

Safety leadership must be measured through audits, and the audits in turn are measured—how often do they occur? Who is doing them? What are the results? Are the results followed up? There must be education—what is it? Is it happening all the time? Does it reflect current issues? Finally, there must be continuous improvement processes. The minute you think you are good around safety—that is when you are not.

Dr. M. Sam Mannan, Director of the Mary Kay O'Connor Process Safety Center at Texas A&M University, followed by noting that, while many organizations claim that safety is their first priority, it is rarely given the same attention as financial or operating concerns. He then provided an example where there was lack of commitment at the top--safety was delegated downward and made a line responsibility. The primary measure of safety performance was on OSHA reportable lost time. Process safety was ignored. In the mid 1980's this company [Note: Dr. Mannan requested that the company not be named] faced several hostile takeover attempts. To make the company less attractive they took on a massive debt load. The increased debt resulted in reductions in qualified personnel, reductions in maintenance, and increased reliance on contract

labor.

Risk analysis performed as part of the site survey before the plant was built showed strong potential for failure. This information was not passed downward. The maintenance task was not easy, there was a lack of experience and there was lack of training.

Dr. Mannan believes NASA's decision-making processes are similar. In complex bureaucracies, those who are knowledgeable and concerned about problems are not the decision makers. There are inadequate systems to ensure communications amongst the parties. NASA's organizational structure is particularly complex, with decision makers, who are sometimes contractors, spread out over various locations.

Mr. McMillan stated that OSHA data might be misleading. In the 1970's the practice of contracting out high hazard work began to take place. But some companies don't fold in all the data from their subcontractors or data from manufacturing plants overseas.

Mr. Wallace believes that at NASA there is a lack of imagination versus a lack of processes. NASA has processes on top of processes. This is not about workplace injuries or any thing like that—this about disasters caused by something you didn't see coming. Mr. McMillan replied that you could over rely on procedures, which become the end instead of a means to the end.

Mr. Hubbard followed up by asking, "how do you find a blind spot which is by definition—a blind spot. Where do you find the people who find the little "blivets" that get you down the road?" Mr. Wick of Intel replied that lots of leaders can check off blocks--great companies really believe all injuries can be prevented, believe that this effort is worthy, and are always looking for the blind spots.

Cognitive Engineering and the Benefits of Hindsight -. Presented by Dr. David Woods, professor at Ohio State University and co-director, Cognitive Systems Engineering Laboratory

The fundamental question that his research addresses is "How do we escape from hindsight and other biases that block the learning processes?" To answer that question his research specializes in looking in detail how teams of people solve problems, considering both individual factors and organizational factors

Doing things safely is ongoing. All effective operational organizations have some sensitivity to possible failure paths, and they develop strategies to try and short-circuit those paths so they don't happen. These are not groups that are unaware of or trying to hide from the risks, rather that they think they understand the risks and that they have effective strategies for managing those risks. So when we look at how failure can happen we see that there is only a partial awareness of potential paths that lead to failure. Since the world is changing the potential paths change, and the coping strategies for managing these risks may not be as strong as we think. There is pervasive overconfidence that we have thought through all the risks and that we can deal with them effectively.

One of the most common patterns leading up to failure is missing the side effects of change. People do not make mistakes out of the blue. They use current or old data while world changes.

Eventually there is a surprising event that everyone notices. When we go look after an incident, we are in a different position than people before the incident. Outcome bias is a well-replicated phenomenon

The hindsight puzzle -- it is simple to assemble all the data after the fact, we know clearly what was signal and what was noise. So in hindsight we ignore all the interesting cognitive work that is necessary before the fact to actually make distinctions between signal and noise, degrees of hazard or effectiveness of our strategy. Before the event the participants have to navigate a complex landscape—trading off between different risks. In hindsight bias we end up looking backward—seeing only the forks in the road that were actually taken. And reviewers are governed by a set of oversimplification biases. To overcome this, rather than stand outside with hindsight, we need get in and see what the situation actually looked like.

Practitioners who actually touch and deal with hazards—to understand what they are doing we need to understand the organizational context which creates resources and, in many cases, builds additional constraints which plague them. Instead of giving them tools to help them cope with the difficulties inherent in their particular field, the organization can get in the way and exacerbate "double binds".

The process of tracing out mindset—follow the knowledge. See how this knowledge develops into mindset. See how they activate and bring to bear the knowledge and integrate it to paint a big picture of what is really going on.

Critical events are always marked by some unanticipated effects or surprise when you have multiple goals or conflicts between the goals. Progress on safety depends on understanding how practitioners cope with complexities of technical work. The corollary is you look for sources of success. To understand failure you need to understand success. Another corollary is that to understand what makes a problem difficult you need to look for difficult problems.

Adaptations are directed at coping with complexity. Critical incidents are often marked by unanticipated variability. This led him to research why the Mission Control Center works so well. They found that what often prevailed when they (MCC) were handling an anomaly -- the involved groups not only address their own group's stance but the stances of the other groups. That led to new expectations of what might happen and anticipation of requests for analysis or data. The process worked because the operations and engineering communities recognized the differences between them.

Hindsight does not equal foresight. Knowledge about the outcome biases judgment about the processes that led up to that outcome. Creating foresight is not a simple process—it involves leadership involvement, it also requires the technical analysis and assessments to look in detail at how cognitive work is actually accomplished. The objective is to create foresight to anticipate the changing shape of risk, vulnerability, and paths to disaster before anyone is injured.

During the ensuing roundtable discussion, MGen Barry asked how to prioritize critical items (CILs) when you have so many. Dr. Leveson argued that relying on a Critical Items List is not going to be an effective approach for dealing with a complex system. These kinds of FMEAs (failure modes and affects analysis) are designed for simple mechanical systems that fail because of individual component failures, because the design was simple enough and the interactions were

simple enough that potential failures could be eliminated during the design phase. This is now being applied in a situation where there are millions of interactions between the components. The problem is oversimplified by only looking at the individual failure modes. The shuttle is too complex to prioritize. This should instead be handled with systems safety analysis– NASA used to be good at this technique, but their capability has degenerated over time.

Dr. Leveson further stated that she does not believe most of the risk assessment numbers. Dr. Osheroff added that he is convinced that for both Columbia and Challenger the risk was not understood.

Dr. Woods – There are two cognitive things that are very specific—one is assumption testing. What things are challenging your assumptions about the families of vulnerabilities that you have designed your system to handle? Is there evidence that something is changing? These things have precursors. Once you know what to look for you see the warning signs, but they were not recognized as significant—they were discounted.

MGen Barry – The challenge is going to be to provide a recommendation that can help NASA improve.

Dr. Leveson – There are classical engineering techniques for doing this. It is not that difficult, they (NASA) simply got away from the "what-if" analysis.

Mr. Hubbard – How do you get the right people in leadership? The very best space flight development managers are supremely confident and extremely skeptical.

Dr. Woods – In the end I do not believe it is a personality issue—it is more a function of how well you coordinate with the different subgroups.

Mr. Cobb – How do you self-assess your safety organization to make sure it is working?

Dr. Woods – The absolute key thing is that the effective organization is constantly looking at the difference between their perception and the reality of what is happening. An effective organization is trying to close that gap—not because the workers are wrong or doing something crazy and they need to be disciplined, but rather they are updating their models, standards, and policies. The gap is impossible to close because the world is always changing.

A New Approach to Accident Analysis – presented by Professor Nancy Leveson, professor of Aeronautics and Astronautics at MIT

The underlying analysis models were based on older, simpler times and technologies. Accidents were always a chain of events. Instead of thinking of accidents as chains of events, think of them as a control problem—as inadequate enforcement of safety constraints on development, manufacturing, and operations. Where were/are the inadequate controls that allowed the accident to occur?

There is asynchronous organizational and engineering evolution -- some things in the system advance faster than others -- leading to incompatibilities. Accidents often result from

inconsistencies between models and actual process state.

In systems safety engineering the measure of success is that nothing happens—there are no accidents. As a result, the need for continued emphasis on systems safety is often questioned. The more successful you are in this area, the more likely those efforts in this area will be decreased.

Dr. Osheroff – It has been my impression that NASA has an extremely complex safety system that is very expensive and very laborious. And obviously it did not work very well. It is not just a question of cost but also a question of quality. Dr. Leveson disagreed, stating that the systems safety studies performed in early shuttle development were very good. However, NASA decided that systems safety is only needed during development, and subsequently downsized the safety staff and assigned their functions to the engineers.

MGen Barry -- Given the limited dollars, how do you allocate resources in a systematic way?

Dr. Leveson –Models describe the various things you can do, but they cannot make the tradeoff decisions for you. There is no simple solution. You try to ensure that you have sufficient controls in place for the safety areas—otherwise you have to accept the risk. You have to provide management the data needed to make those resource decisions. There may be a point where you cut resources so low that you say you cannot do it.

Mr. Hubbard—At the public hearing we had with Roy Bridges he dared Goldin to fire him and put his job on the line by saying that the privatization and the cuts and the introduction of the SFOC contract have reduced support to the point that he could not guarantee a safe shuttle launch.

Dr. Osheroff mentioned that he thought having 8500 mandatory inspection points prior to launch appears to be an impressive program compared to the studies that should have been but never were done. Dr. Leveson asked how NASA knows that all 8500 things lead to a hazard? There are a lot of things that are done in the name of safety that are not necessarily the things that need to be done

Dr. Woods – the point is that we are missing coordinated mechanisms. We have a brute force old solution that is not viable under the economic pressures that are not going to go away. Things can be relaxed temporarily but you are still swimming upstream. Coordination becomes the real issue because short-term fixes are not sustainable in the long run.

Dr. Osheroff asked if the shuttle is too complex to do a quantitative probabilistic risk assessment (PRA). Dr. Leveson responded that it is indeed too complex, and that experience has shown that with most complex systems they oversimplify the models. They include the things they can measure and leave out the things they cannot—or they make the numbers up. Further, they ignore software and human error because they cannot be quantified.

An informal poll conducted by MGen Barry indicated that there were no fans of PRA in the room

Leading and Trailing Indicators and Lessons Learned - presented by Dr. M. Sam Mannan, professor at Texas A&M University and Director of the Mary Kay O'Connor Process Safety Center

Dr. Mannan began his presentation by stating that his organization is named in honor of an employee who died in a Phillips Petroleum plant explosion. Dr. Mannan then propose a method to determine whether safety performance is getting better or worse without an incident or extreme event occurring. He brought up the importance of using indicators, and used the example of health screening indicators used in medicine to prevent extreme events such as heart attacks. Dr. Mannan identified two types of indicators: leading and trailing. Trailing indicators measure failures, such as counting heart attacks.

A roundtable discussion ensued regarding the widespread use of trailing indicators, and the difficulty of implementing a safety reporting system without suppressing incidents, especially when group awards are based on safety thresholds. The concern was raised that peer pressure can encourage underreporting if it affects group goals.

Dr. Mannan continued by stating that an effective audit system is vital for capturing all incidents and introduced the incident definition for the chemical industry (see charts). He then presented a pyramid diagram of trailing indicators with four separate tiers of increasing severity: incidents (IV), injuries (III), serious injuries (II), and fatalities (I). In all four categories of these trailing indicators, the underlying causes are the same. Dr. Mannan used the example of the variable consequences of a flammable gas, and stated that lessons learned from Tier IV incidents can and should be used to prevent Tier I incidents. He also stressed the need to keep process and personnel safety separate.

Dr. Mannan then began his discussion of leading indicators, which vary according to the activity and mission of the organization. He presented a list of typical leading indicators (see charts). Ms. Grubbe submitted her perspective of some leading indicators used at DuPont, and remarked on the use of colored lights at the entrance of DuPont plants to convey caution levels to employees. The intent is to raise awareness of possible hazards and thereby reduce incidents. Group discussion ensued regarding the importance of using leading indicators in the Space Shuttle Program well before launch. Dr. Osheroff commented on using repetitive maintenance and foam shedding for trend analysis, and how foam shedding had not been treated as a departure. The panel briefly discussed the difficulty of identifying meaningful trends prior to an incident.

Dr. Mannan continued his presentation by advocating a hierarchical approach with safety culture on top, management systems in the middle, and procedures, technology, etc. on the bottom. He stated that leadership must establish ownership of the process to determine leading indicators and trends.

At this point Admiral Gehman encouraged more group discussion, and stated that NASA needs more outside help in safety. Admiral Gehman also addressed leading indicators in light of budgetary constraints. Ms. Grubbe commented that safety has priority over profitability at DuPont – if it cannot be done safely, DuPont will not do it. Admiral Gehman stated that one business model tradeoff would be the option of grounding the Space Shuttle for a period of time; however, egos and national pride are involved to a greater extent than other industries. Dr. Ride

commented that the Space Shuttle fleet was grounded for three years after the Challenger incident. More group discussion ensued on safety, the return to flight, and ISS survivability.

Dr. Mannan continued with a further discussion of safety culture. He stated that the Bhopal incident was the beginning of the downfall for Union Carbide, and that extreme incidents had the same effect on the nuclear industry. The panel then briefly discussed the perception of risk and the importance of moving forward from this point. There was general agreement that the person is charge of an organization is the chief safety person and is ultimately responsible for safety. Dr. Mannan concluded his presentation by stressing three points:

- Properly identifying leading indicators
- Take a hierarchical approach
- Establishing a safety culture

After the presentation, the panel had a general discussion on the unique situation of simulating and designing for spaceflight launch/reentry environments versus the problems encountered in ground-based endeavors such as the chemical industry. Dr. Osheroff made the point that the behavior of shuttle systems on launch and reentry are difficult to characterize and very difficult to study, and that creates unique problems that do not tend to exist in the chemical industry. He concluded that one has to try harder to understand the limits of the behavior that is likely with the shuttle—and that NASA has tended to not do that.

Dr. Woods noted that all of these systems have fundamental dilemmas and tradeoffs for which there are no optimal solutions—but have optimal ways to make the tradeoff. For example, the technical dilemma that arises with every bi-pass surgery--it is simply there. What makes a skilled cardiologist or anesthesiologist is how they manage that tradeoff in real-time. The tradeoff does not define every action. There needs to be sensitivity to when that tradeoff gets more intense--whether to go this way or that. There is no one way to define a solution to that tradeoff, yet that tradeoff is inherent and fundamental. In the cognitive world one of the problems is that people do what is tractable—they just look at half the tradeoff. As a result they define an optimum way to make decisions for half of the tradeoff function.

MGen Hess asked if these situations create an issue of accountability. Are individuals held accountable or is it always the organization's fault?

Dr. Woods responded that in health care they are moving away from a team environment where a single team under a single physician is responsible for an individual's health care to the industrial model with many groups and many people interacting to produce a successful outcome for a patient. This has created a problem in that now there is distributed responsibility. As pressure is increased the incentives to coordinate and cooperate are reduced. Therefore, the wrong systems of accountability reduce the incentives for cooperation and undermine the organization's ability to be successful.

The distributed model also creates double binds that are very debilitating to effective performance. People either feel helpless and give up, and follow the rules without doing anything extra to make up for gaps in the system, or you have people who are determined to make the system work. They covertly fill in the gaps, violating rules or policies in the process. They are so committed to getting the job done right, but with a covert work system it is hard for people to

learn what works and what does not work, so you can get burned, which leads to more pressure and regimentation to garner ourselves against these people who burned us, creating a vicious cycle.

Environmental Health and Safety (EHS) – presented by Mr. James Wick, Corporate Safety and Health Manager, Intel Corporation

Mr. Wick opened his presentation by stating that safety is the right thing to do and it is cost efficient. He stressed that indicators must be measured and changed as needed. He continued by showing the evolution of the safety program at Intel (see charts). Mr. Wick commented that he has found Voluntary Protection Programs (VPPs) are not very effective for safety at Intel and can be cost prohibitive, given Intel's already excellent safety performance .He then illustrated the relationship between proactive measurements (leading indicators) and lagging measurements (trailing indicators). Mr. Wick presented a pyramid graphic with an extended base for proactive measurements, similar to the pyramid presented by Dr. Mannan.

Mr. Wick then listed the key ingredients for EHS success and presented the Intel safety model (see charts). A general group discussion ensued whether NASA has a safety model, and questions were raised regarding the differences between R&D safety and production safety. Mr. Wick stressed that key to any safety program is to get employees to include safety in their thinking process. It is Intel's philosophy that every injury is preventable and that safety pays for itself several times over. Mr. Wick concluded his presentation by stating that leadership is essential for establishing an effective safety program.

A brief group discussion ensued regarding environmental safety, particularly the ability to measure stress in an organization.

MGen Hess closed the meeting with remarks of appreciation to the speakers.

The meeting was adjourned at 1500

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Dr. Osheroff	CAIB	281-283-7511
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Mr. Bloomfield	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Ride	CAIB	281-283-7503
Dr. Bluford	CAIB	281-283-7813
Mike Boulavsky	Recorder	281-280-8062
Mr. Buzzard	CTF	281-283-8412
Lt. Col Tyrone Woodyard	CAIB Staff	281-283-7565
Lester Reingold	CAIB Staff	281-283-7539
Dave Lengyel	CAIB Staff	281-283-7581
Lt. Col Don White	Support	281-283-7570
1st Lt. Matt Granger	Group 2	281-283-7567
D.R. Pye	CAIB IAST	281-283-7549
Major Tracy Dillinger	Group 2	281-283-7845
Dennis R. Jenkins	Group 4	281-283-7589
Bill Sikora	CAIB Counsel	281-283-7564
Dwayne Day	Group 4	281-283-7588
John Shannon	CTF	281-483-0716
Robert Cobb	NASA IG	202-358-1770
Dan Diggins	CAIB Staff	281-283-7814
Major Dave Kral	CAIB Staff	281-283-7500
Capt. Jim Wetherbee	NASA	281-244-8918
Gary W. Johnson	NASA SRQA	281-483-4136

Elements of Strong Leadership

1. Vision and Values
2. Employee Participation
3. Focus On and Off The Job
4. Vendors & Subcontractors
5. Public Transparency
6. Recognize Excellence
7. Operational Leadership

1. Vision & Values

- Position Safety & Health as part of the organization's vision
- Establish Safety and health as a core value
- Adopt Code of Ethics
- Set Goal at Zero Injuries
- Create culture for sharing of values
- Build climate of commitment and trust

2. Engage Employee Participation

- Share leadership with employees and, where organized, their unions
- Provide ongoing job safety training and education
- Engage employees in physical hazard inspections and job safety analyses
- Encourage innovation and creativity
- Offer off-the-job education and activities

3. Focus On and Off the Job

8x More Fatalities Occur To Workers

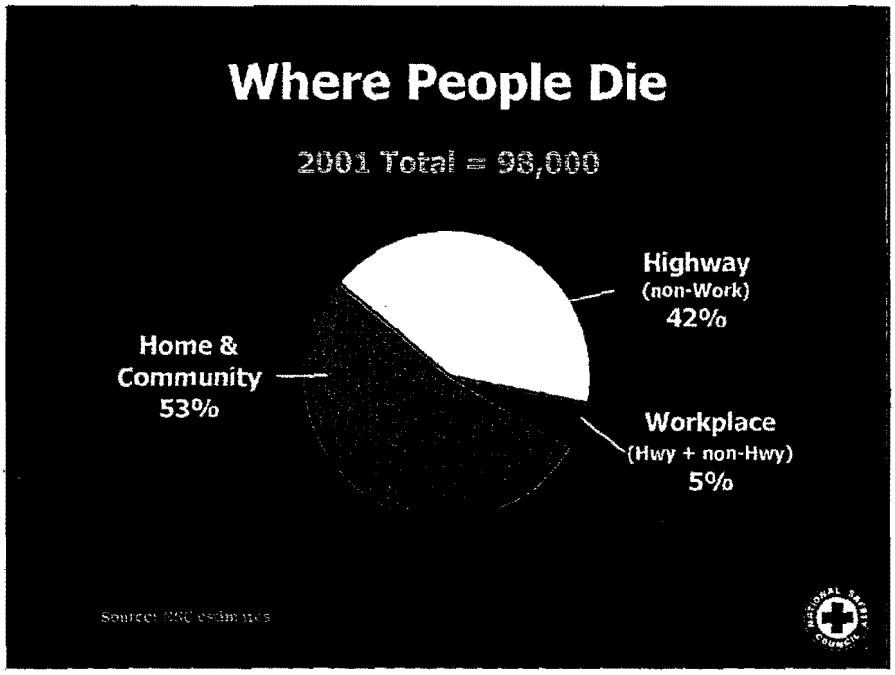
than

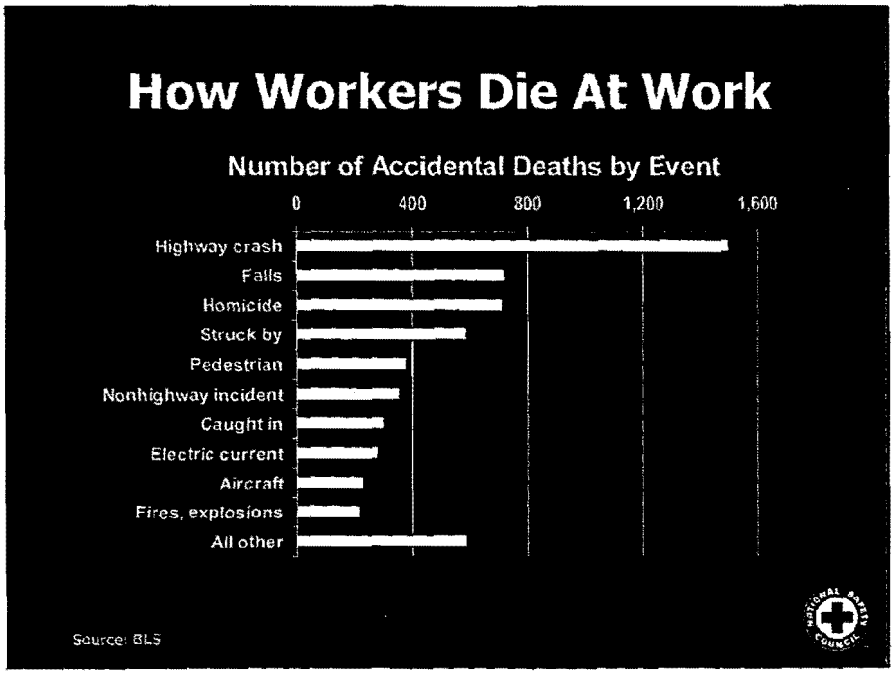
On-the-Job

The Challenge Of Unintentional Injuries

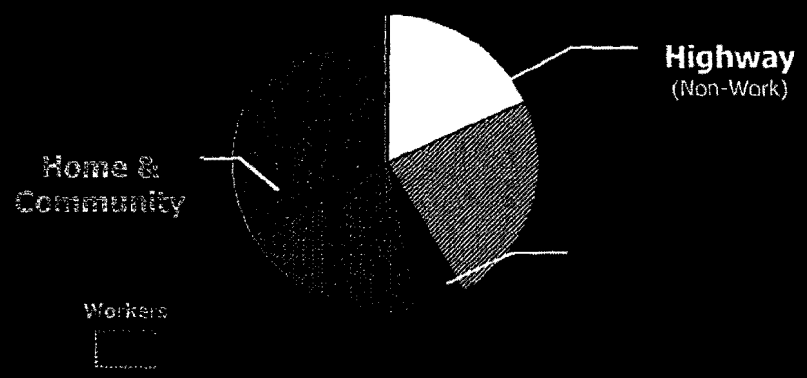
- 98,000 deaths in 2001 -- #1 cause of death for people 1 to 38 years old
- 5th leading cause of death overall
- 20.4 million disabling injuries
- 34.4 million (1 in 8) Americans annually suffer one or more injuries requiring medical attention
  - 40.4 million emergency dept. visits
  - 9.5 million outpatient visits
  - 2.5 million hospitalizations
- $516.9 billion in costs to society

Source: NCHS


Where People Die
2001 Total = 98,000
Highway
(non-Work)
42%
Home &
Community
53%
Workplace
(Hwy + non-Hwy)
5%


How Workers Die At Work
Number of Accidental Deaths by Event
0
400
800
1,200
1,600
Highway crash
Falls
Homicide
Struck by
Pedestrian
Nonhighway incident
Caught in
Electric current
Aircraft
Fires, explosions
All other
Source: BLS

All Accidental Deaths: 48% are Workers



Source: NSC estimates

4. Vendors & Subcontractors

- Establish Criteria and Standards for Project and Product Design and Performance
- Require organizational work rules are adopted by others working on-site

CMM006-0070

5. Balance Public Transparency with Liability Issues

Communicate Openly About Safety and Health with all constituents

- Employees
- Unions
- Elected Officials
- Regulatory Agencies (OSHA, MSHA, EPA)
- Local community leaders
- News Media
- Financial Community

6. Never Stop Recognizing Excellence

- Recognize leaders and employees at all levels for significant improvement
- Provide special recognition for demonstrated excellence

CMM006-0071

7. Operational Leadership

- State safety and health policy
- Define safety goals and objectives
- Organize structure, systems and processes
- Establish authority and accountability
- Commit Resources
- Review programs, projects, and results
- Oversee incident investigations and analyses
- Share learning rapidly through the organization

NATIONAL SAFETY COUNCIL™

www.nsc.org

TALKING POINTS -- OPERATIONAL LEADERSHIP

LINE MANAGEMENT PROCESSES, SYSTEMS AND STRUCTURE

Key elements:

1. Strong ethics value and policy to support needed behaviors (getting people to report the near misses – do you terminate people who cover up a safety incident?)
2. Safety is an organizational value, and is acted upon by all
3. Unified around safety beliefs - e.g. all injuries and incidents can be prevented
4. Passion for safety held by all - pervasive
5. Understand that safety excellence is a journey, not "instant pudding" - Reactive >> Dependent >> Independent >> Interdependent (See charts in separate file included in this email.)
6. Sufficient resources with clear roles e.g. corporate oversight, line execution, new idea generation and continuous improvement
7. People who feel clearly responsible to act – TIPS "Thinking Individuals Promote Safety." E.g. How to give TIPS and how to receive TIPS. TIPS pledge below:

THE TIPS PLEDGE

I am a thinking individual. Thinking Individuals Promote Safety (TIPS).

I WILL PROMOTE SAFETY IN THREE WAYS:

- I will not perform an unsafe act
- If I observe an unsafe act, I will correct it in a helpful and courteous manner.
- If I unknowingly perform an unsafe act, I will accept correction in the proper spirit.

THE TIPS WAY:

HOW TO GIVE TIPS:

- Be Alert For Unsafe Acts
- Know The Safe Way
- Be Friendly, Not Critical
- Offer Advice That Is Helpful
- If Disagreement Occurs, Don't Argue--You've Made Your Point

HOW TO TAKE TIPS:

- Keep An Open Mind
- The Suggestion May Save You From Injury
- Be Friendly
- Accept Advice In The Proper Spirit
- Remember That Someone Is Trying To Help You

THINKING INDIVIDUALS PROMOTE SAFETY

8. Entire line is accountable for results, includes a place to go to lodge concerns e.g. even a chemical plant operator can contact corporate around a safety concern
9. Recognition of excellent execution is integral, done by top management and line management (totems, rituals)
10. Accountability around poor results also felt (salary, removing people from the job)
11. Communications are quick and widespread for successes and problems, e.g. Lost time injuries are reported to the CEO within 24 hours, contractor injuries within 24 hours, off the job fatalities
12. Constant education in methods and in new subject areas – e.g. required monthly safety meetings; new subjects for DuPont: ergonomics, security, operational discipline
13. Active in management of all aspects: audit, education, planning, communications, procedures, policy development, continuous improvement

If you are not getting better in safety, you are getting worse. There is no staying the same.

LEADING INDICATORS

Deborah L. Grubbe
April, 2003

DuPont sites and businesses use four key areas of leading indicators. Also, every plant has a visual color indicator at its main entrance that indicates the current state of safety at that site or at that unit - a snapshot in time.

Every plant does not use every leading indicator. Also, there is no standard process for determining the measure. At this point in the development, we leave it up to individual sites to choose what works for them. I believe, that, as we get better at it, and as we continue to improve our understanding of the opportunity, we will become more prescriptive.

SAFETY TASK PERFORMANCE

Relief valve/Vessel inspections
Audit Schedule Adherence
Housekeeping
Incident followup
Training tasks completed
Safety meetings held and attendance

INDEX TRENDS

Open violations of procedures
No knowledge of rules
Level of organization aptitude

ATTITUDE

Spirit of the work force - labor strife, security
% of employees involved in safety activities
# of repeat violations
Employee use of systems (reporting, avenue of appeal, measurement)

DISTRACTION

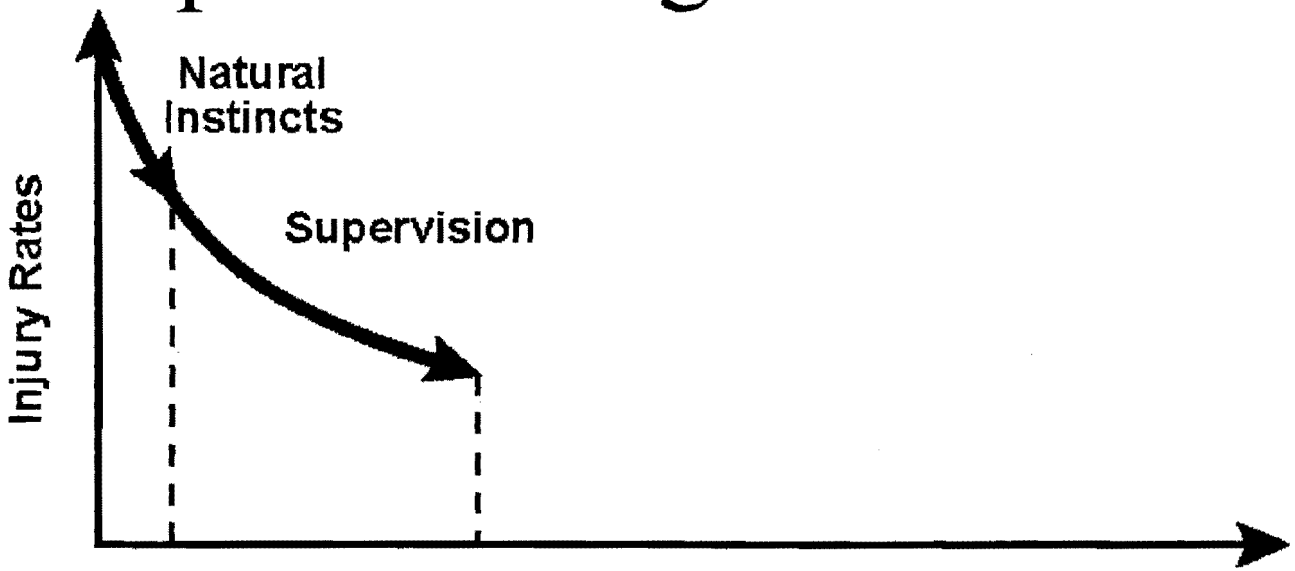
High job turnover; % of people in new assignments
Employment security or lack thereof
Level of overtime
# of Employee Assistance Program visits
Labor union issues
Trust between exempt professionals and management
% of time that management spends "walking around"
State of the business - Making money? Losing Money?
# of external community issues

Evolution of Safety Culture

Where are you on your safety journey?

Derived from Bradley Curve - DL Grubbe
April, 2003

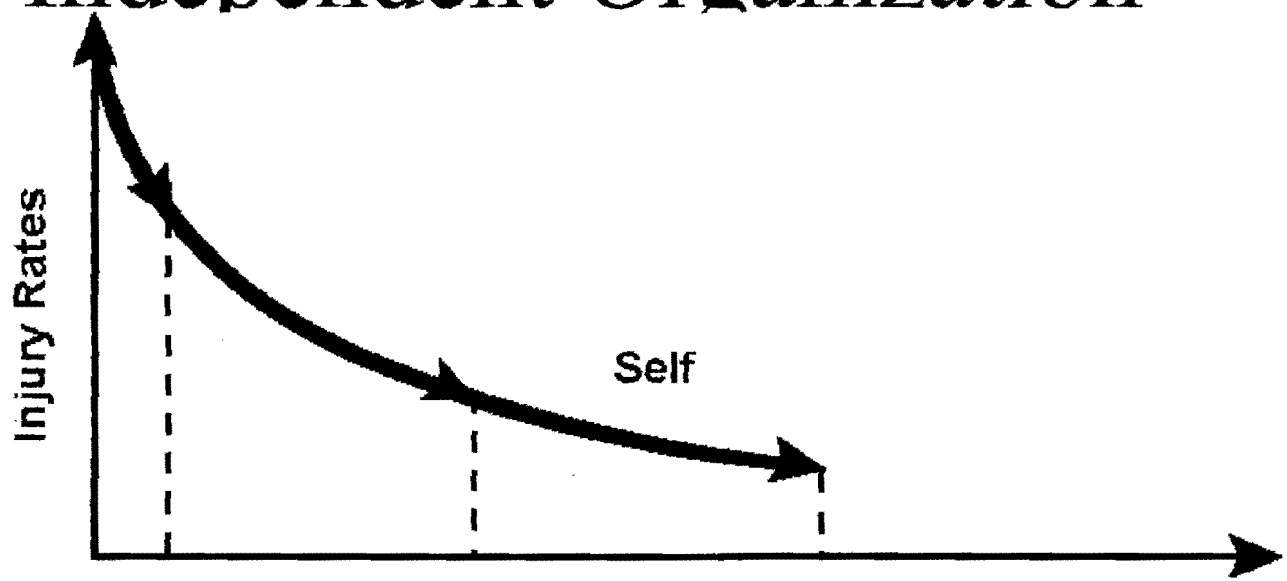
Elements of the Dependent Organization



Dependent

- Management commitment
- Safety as a condition of employment
- Use of fear/discipline
- Enforcement of rules/procedures
- Supervisory control, emphasis, and goals
- Training

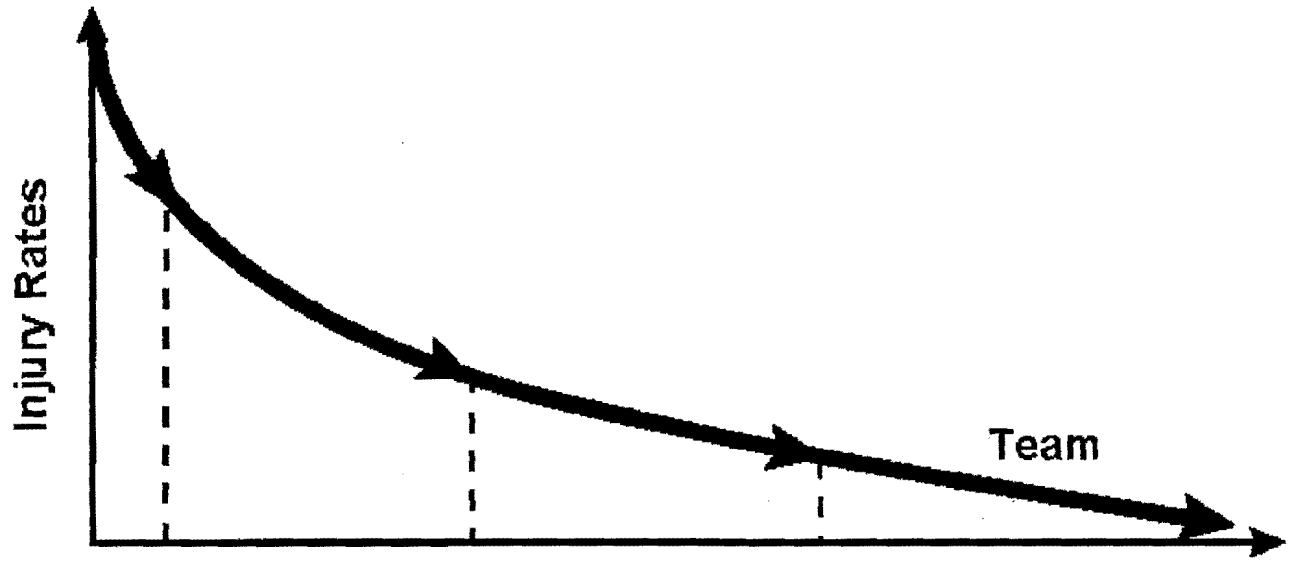
Elements of the Independent Organization



Independent

- **Personal knowledge, commitment, and standards**
- **Internalized, personal value for safety**
- **Care for self**
- ***Practice, habits***
- **Individual recognition**

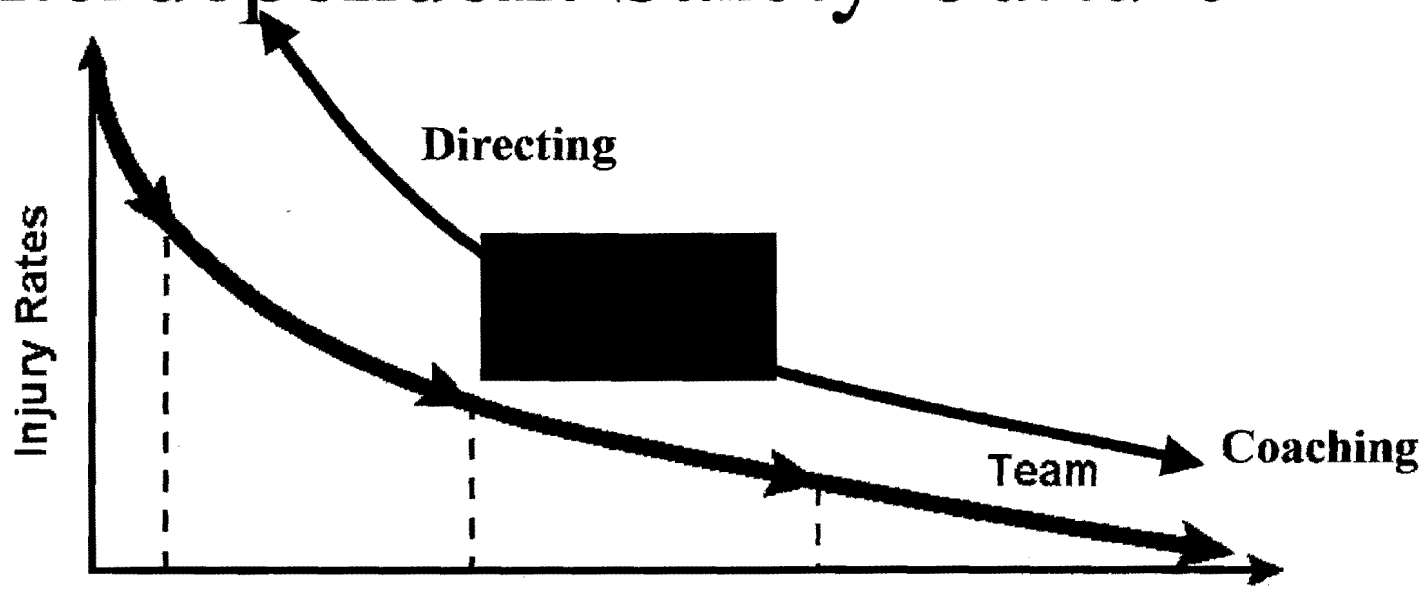
Elements of the Interdependent Safety Culture



Interdependent

- Helping others conform
- Others' keeper
- Networking contributor
- Care for others
- Organizational pride

Elements of the Interdependent Safety Culture



CMM006-0080

Leadership

- Line organization leads
- Leadership needs to be involved and engaged at all levels
- Safety organization is the consultant, not the leader

Behind Human Error

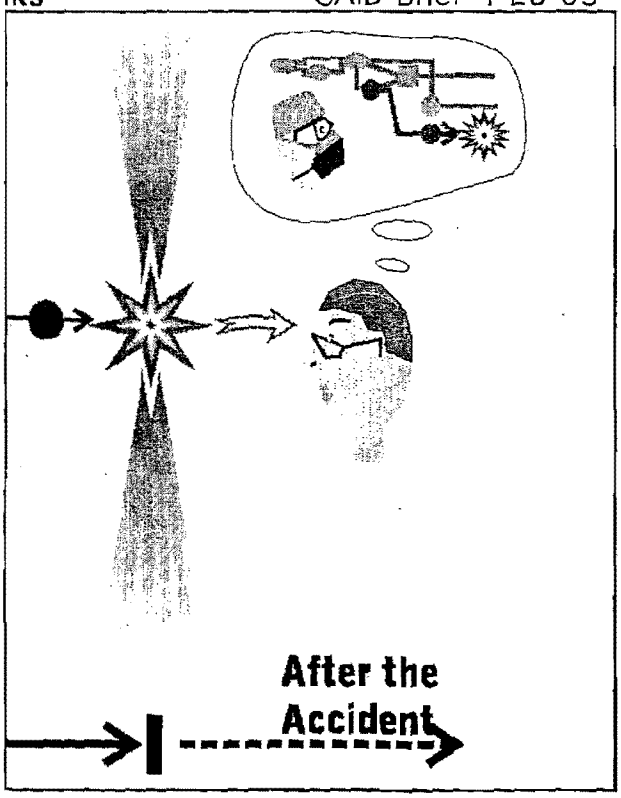
Escaping Hindsight and other biases

David Woods
Cognitive Engineering
Ohhio State University

Briefing to CAIB

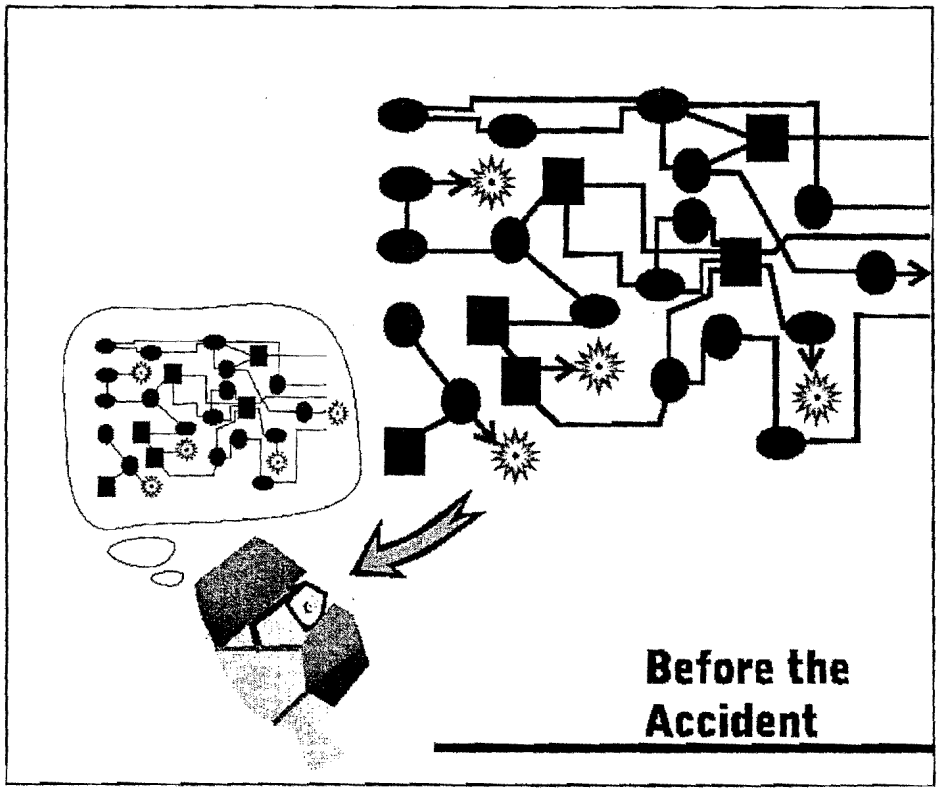
Script

File: patient safety talks CAIB Brief 4-28-03



"...although all of the necessary data was physically available, it was not operationally effective. No one could assemble the separate bits of data to see what was going on."

One report after Three Mile Island



Hindsight bias:
we look backwards, seeing only those forks in the road that they decided to take.

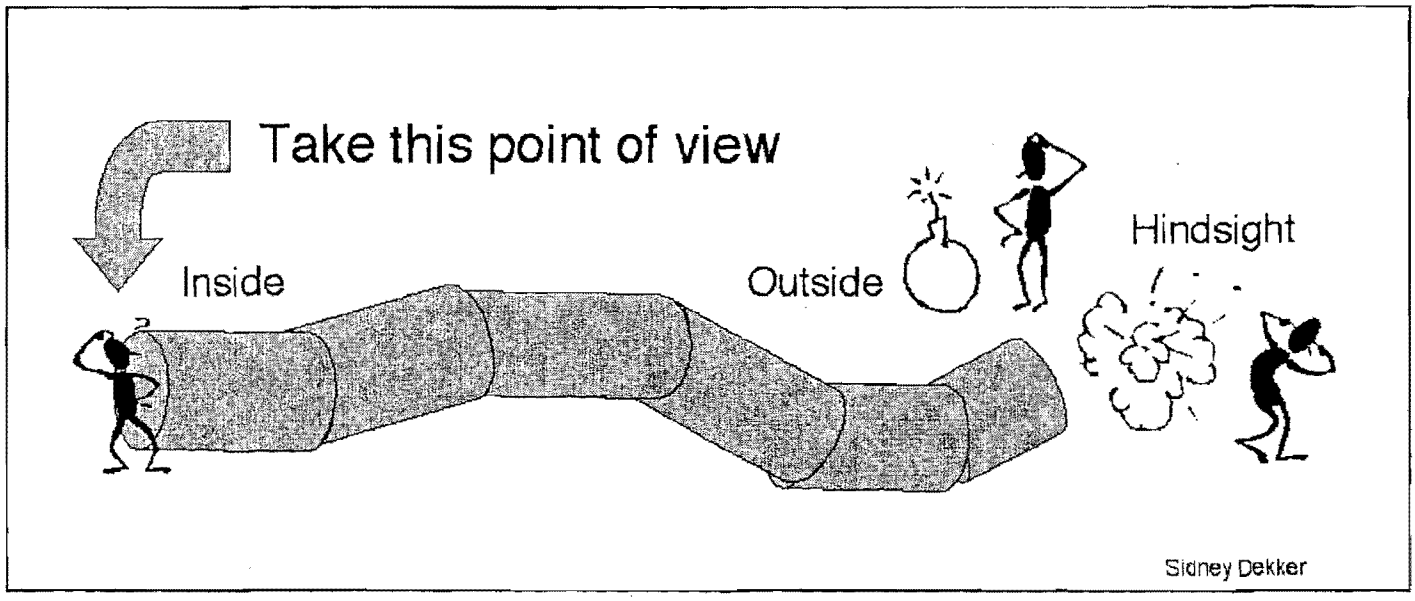
reviewers simplify situation actually faced by practitioners, missing or underemphasizing
- ~ uncertainties and possibilities,
- ~ attentional demands of multiple tasks,
- ~ double binds and tradeoffs

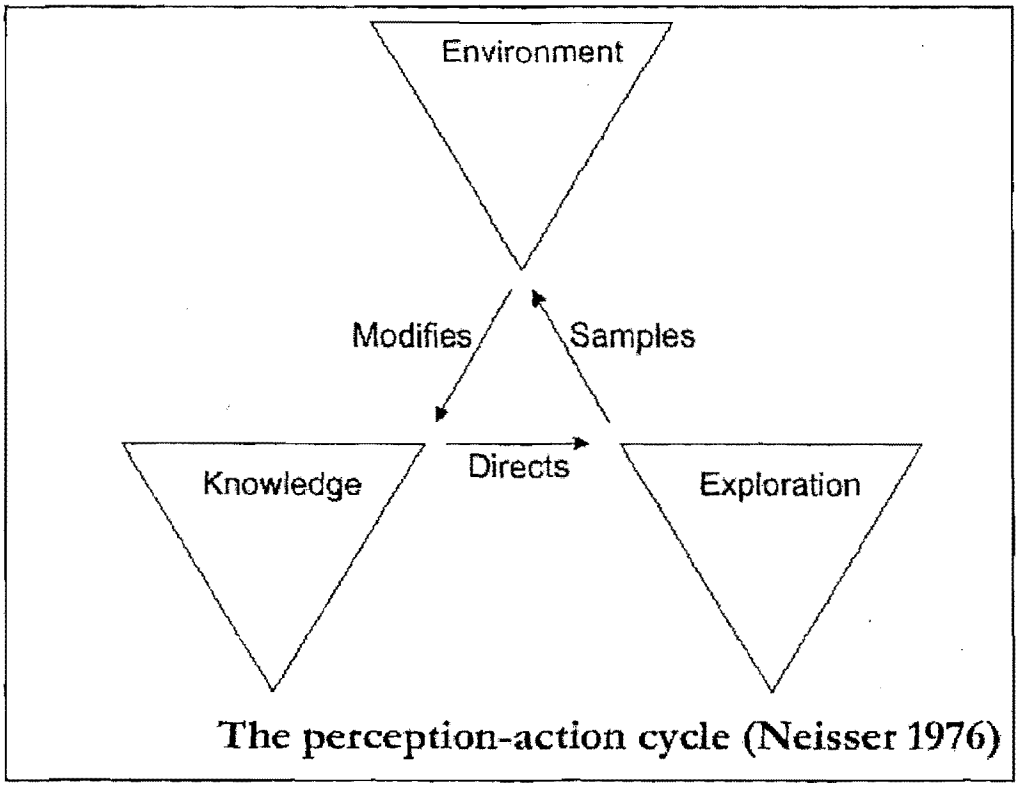
Error analysis
reconstructing what the view was like or would have been like had we stood on the road

Some oversimplification fallacies

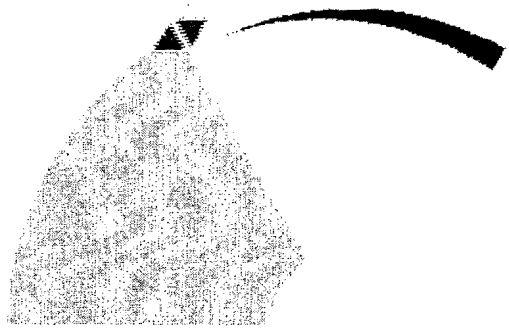
- Treat dynamic processes statically
- Mistake surface similarities for deeper relationships
- Treat multi-dimensional phenomenon as uni-dimensional
- Treat a complex whole as merely the sum of its parts

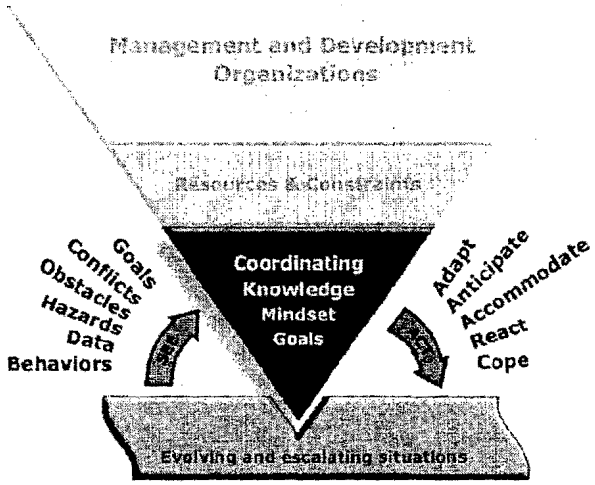
Useful heuristic? or over-simplification?

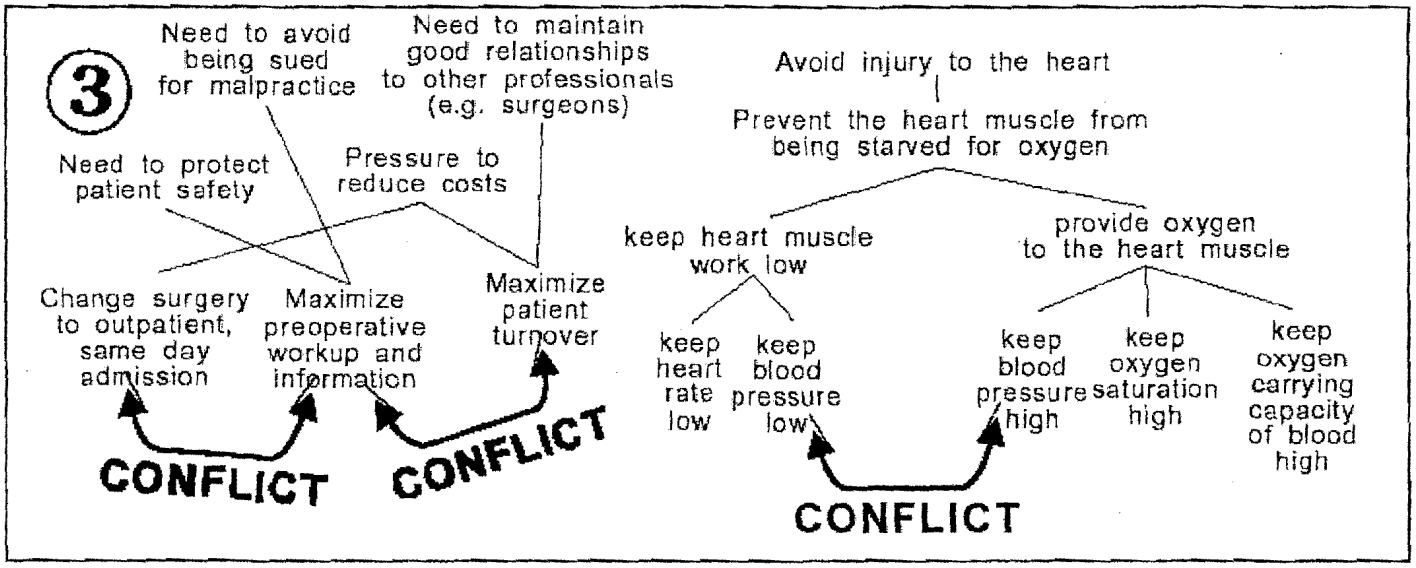


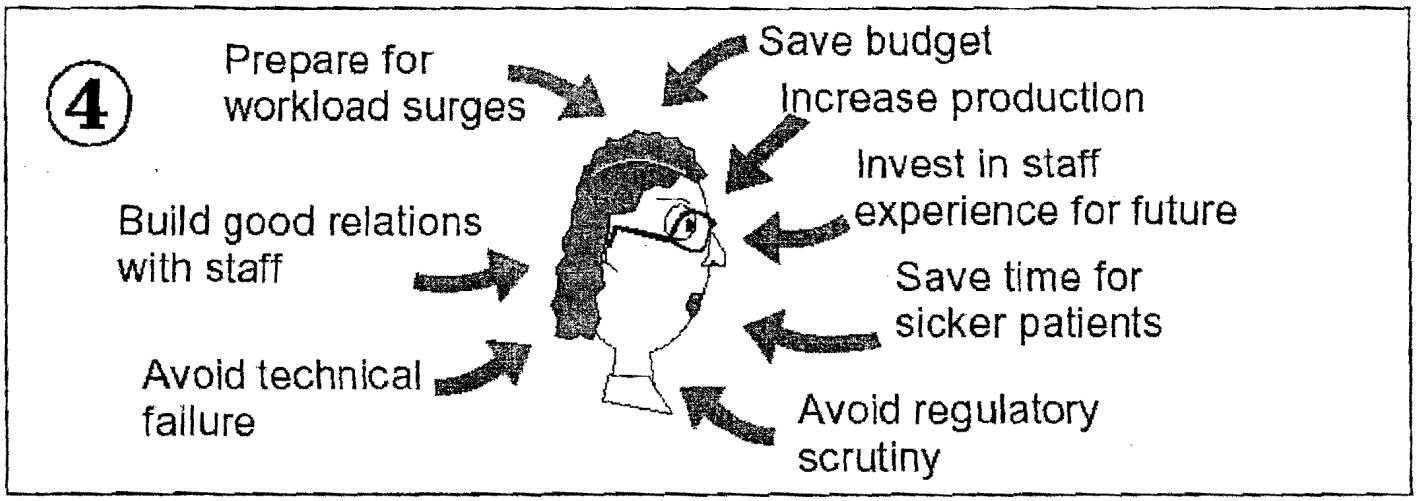


The perception-action cycle (Neisser 1976)




Management and Development
Organizations
Resources & Constraints
Goals
Conflicts
Obstacles
Hazards
Data
Behaviors
Coordinating
Knowledge
Mindset
Goals
Adapt
Anticipate
Accommodate
React
Cope
Evolving and escalating situations


3
Need to avoid being sued for malpractice
Need to maintain good relationships to other professionals (e.g. surgeons)
Need to protect patient safety
Pressure to reduce costs
Change surgery to outpatient, same day admission
Maximize preoperative workup and information
Maximize patient turnover
CONFLICT
CONFLICT
Avoid injury to the heart
Prevent the heart muscle from being starved for oxygen
keep heart muscle work low
provide oxygen to the heart muscle
keep heart rate low
keep blood pressure low
keep blood pressure high
keep oxygen saturation high
keep oxygen carrying capacity of blood high
CONFLICT


4
Prepare for workload surges
Save budget
Increase production
Invest in staff experience for future
Build good relations with staff
Save time for sicker patients
Avoid technical failure
Avoid regulatory scrutiny

II. The Technical Work in Context Maxim

Progress on safety depends on understanding how practitioners cope with the complexities of technical work.

Corollary IIA. Look for Sources of Success

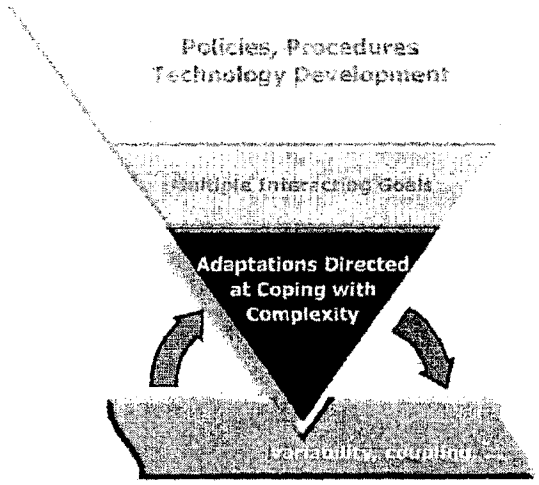
To understand failure, understand success in the face of complexities.

Corollary IIB. Look for Difficult Problems

To understand failure, look at what makes problems difficult.

Corollary IIC. Be Practice-centered -- Avoid The Psychologist's Fallacy

Understand the nature of practice from practitioners' point of view.



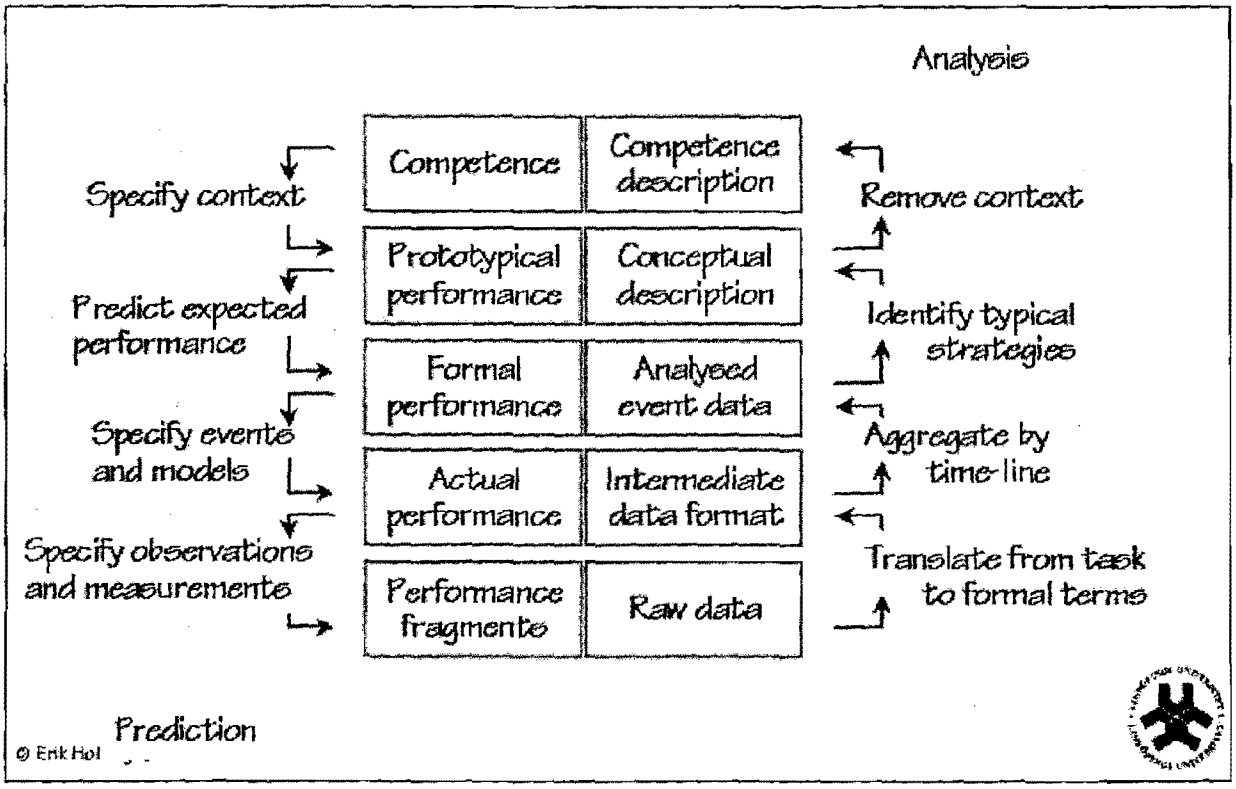
Critical Incidents were marked by unanticipated variability, under- or over- adaptation (1984)

Type A. continued to follow a plan when changing circumstances demanded adaptation

often failures to revise assessment as situation changed

Type B. attempts to adapt were incomplete

often missing side effects of change in replanning



File: patient safety talks CAIB Brief 4-28-03

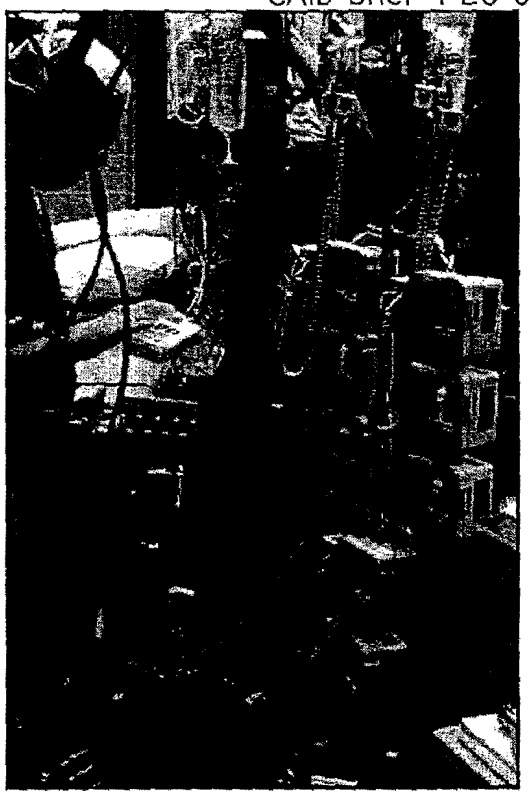
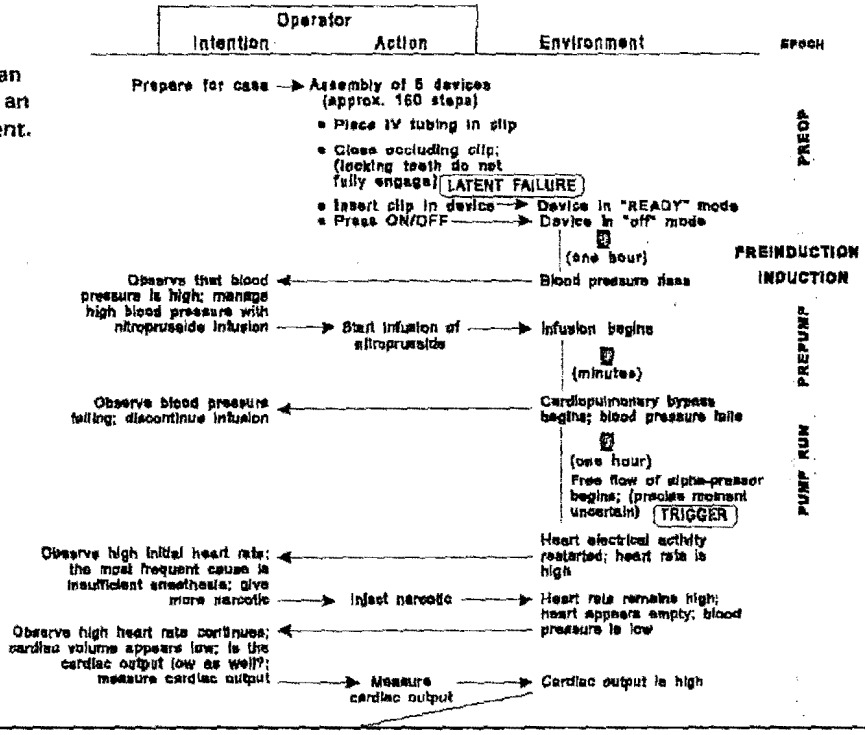
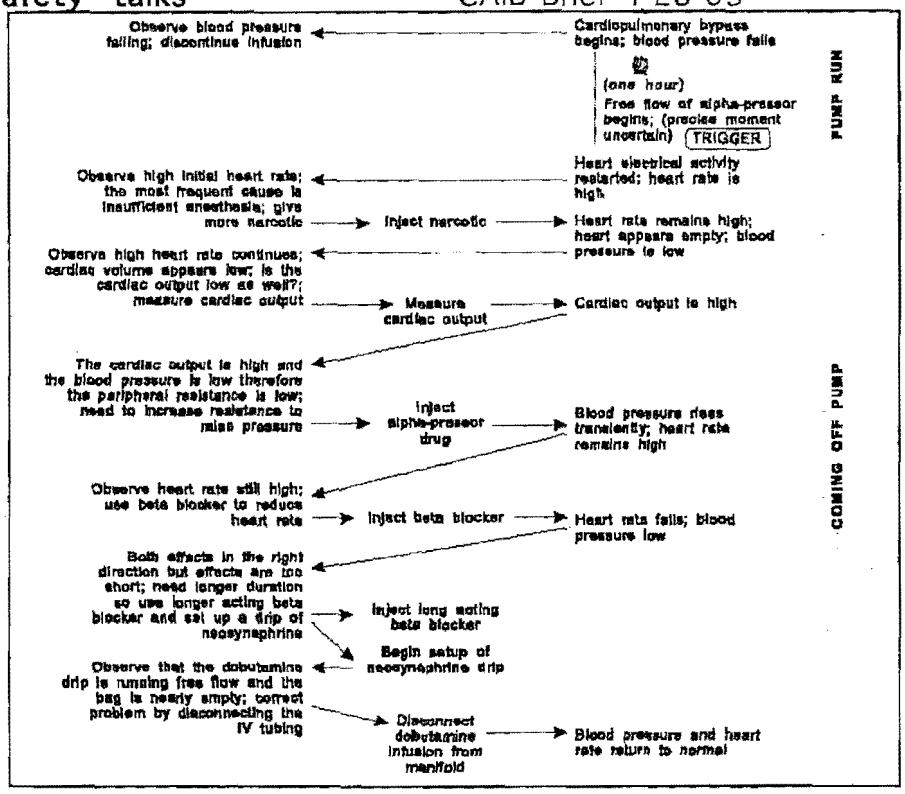


Figure 5. Protocol describing the interaction between anesthesiologists and an infusion device during an operating room incident.

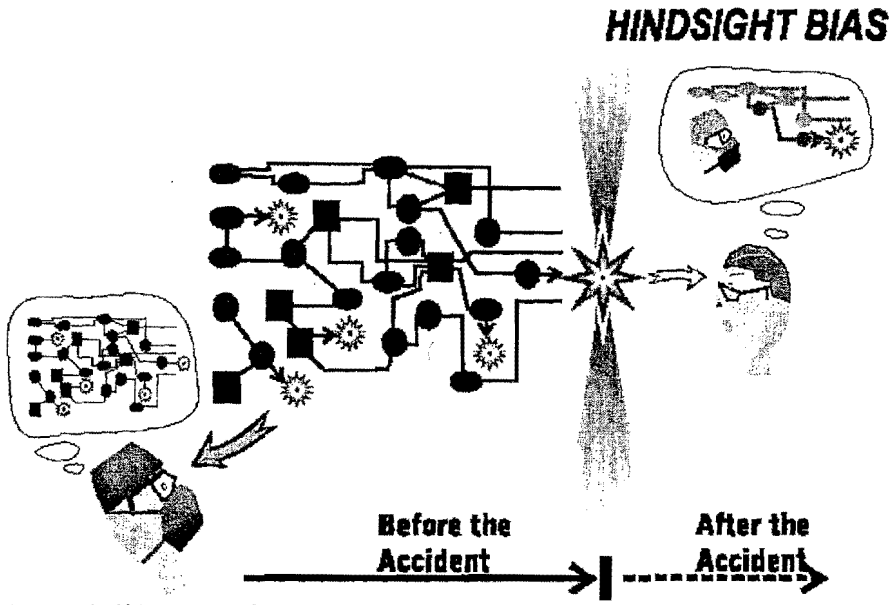


ile: patient safety talks CAIB Brief 4-28-03



Script

Figure 2. Hindsight does not equal foresight. Knowledge of outcome biases our judgment about the processes that led up to that outcome.



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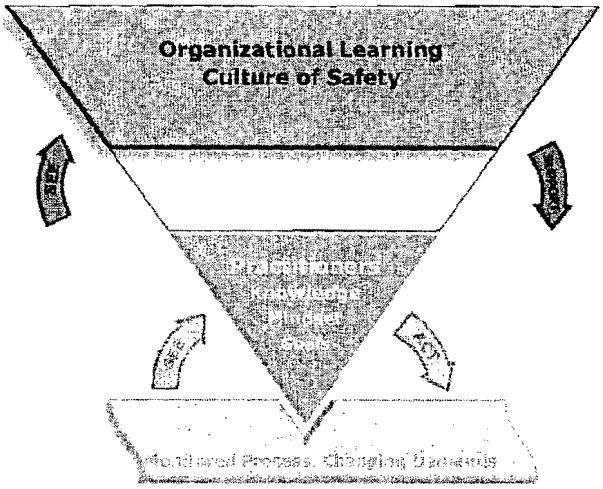
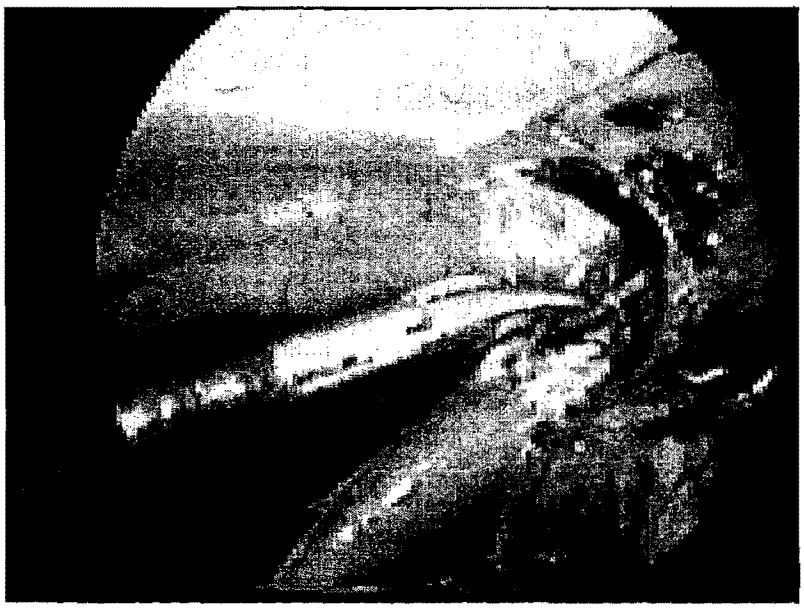


Nine Steps to Move Forward on Safety

1. Pursue Second Stories underneath the surface to discover multiple contributors.
2. Escape the hindsight bias.
3. Understand work as performed at the sharp end of the system.
4. Search for systemic vulnerabilities.
5. Study how practice creates safety.
6. Search for underlying patterns.
7. Examine how change will produce new vulnerabilities and paths to failure.
8. Use new technology to support and enhance human expertise.
9. Tame complexity through new forms of feedback.



Doings things safely is ongoing

strategies sensitive to paths toward failure, but

- partial awareness of potential paths
- since the world is changing, the potential paths are changing
- coping strategies can be weak or mistaken
- overconfidence
- miss side effects of change

need to invest in monitoring changing paths and potential

The law of stretched systems:
every system is stretched to operate at its capacity; as soon as there is some improvement, for example in the form of new technology, it will be exploited to achieve a new intensity and tempo of activity.

Weick's Hallmarks of High Reliability Organizations

~ preoccupation with failure

~ reluctance to simplify interpretations

~ sensitivity to operations

~ commitment to resilience

~ deference to expertise

The future seems implausible.

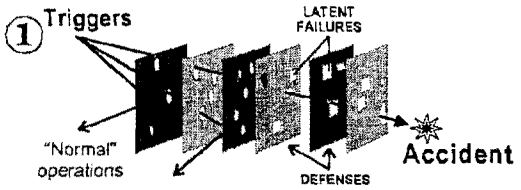
The past seems incredible.

Create Foresight

Anticipate the changing shape of risk,
before anyone is injured.

CL A brief look at the New Look in complex system failure, error, and safety

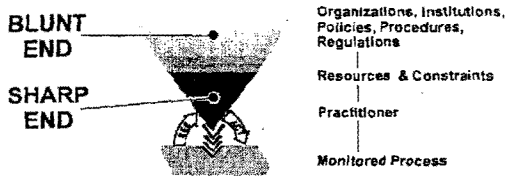
① Triggers



Modified from Reason, 1990

Complex systems fail because of the combination of multiple small failures, each individually insufficient to cause an accident. These failures are *latent* in the system and their pattern changes over time.

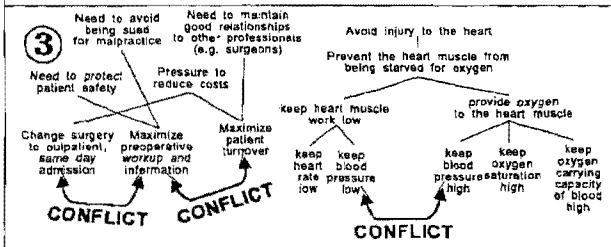
② BLUNT END / SHARP END



Modified from Woods, 1991

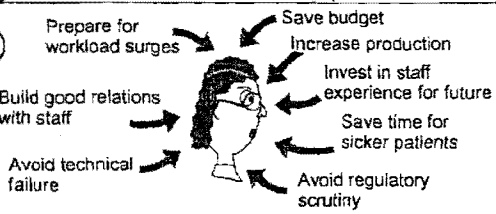
Practitioners at the *sharp end* of the system interact directly with the hazardous process. The resources and constraints on their technical work arise from institutional, management, regulatory, and technological *blunt end* factors.

③



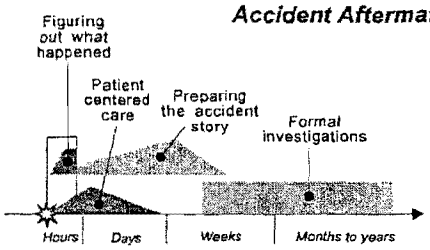
Competing demands, dilemmas, conflicts, and uncertainty are the central features of operations at the sharp end. Technical and organizational conflicts overlap and interact.

④



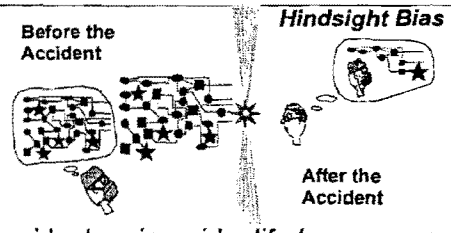
Work at the sharp end inevitably encounters competing demands for production and failure-free performance. Action resolves all dilemmas. Successful operations are the rule. Failure is rare.

⑤ Accident Aftermath



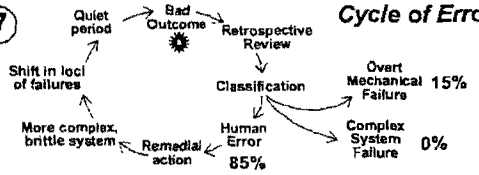
Accident/incident investigation normally stops with error. Sterile incident collections result. Learning halts. End of story.

⑥ Hindsight Bias



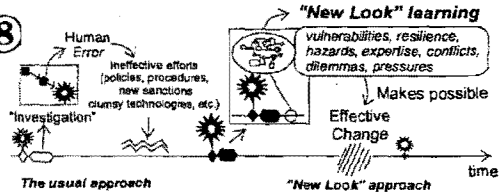
Post-accident reviews identify *human error* as the 'cause' of failure because of *hindsight bias*. Outcome knowledge makes the path to failure seem to have been foreseeable - although it was not foreseen.

⑦ Cycle of Error



Organizational *reactions to failure* focus on human error. The reactions to failure are: blame & train, sanctions, new regulations, rules, and technology. These interventions increase complexity and introduce new forms of failure. Cycle repeats.

⑧ "New Look" learning



People make safety. Improving safety depends on understanding the details of technical work, how success is usually achieved, and how failure sometimes occurs. Effective change follows.

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The New Look at Error, Safety, and Failure: A Primer for Health Care

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Institute for Ergonomics
The Ohio State University

Richard I. Cook
Cognitive technologies Laboratory
University of Chicago

September 16, 1999

The "New Look" at Error

The usual judgment after an accident is that human error was the cause. In other words, human error is the stopping point for an investigation and ends the learning process.

However, just as recent celebrated accidents in medicine have directed attention to patient safety, previous highly visible accidents in other industries, such as power generation and transportation drew attention to issues surrounding the label "human error" (e.g., Three Mile Island in 1979; the capsizing of the Herald of Free Enterprise in 1982; various aircraft accidents). The intense interest in these accidents led to sustained, cross-disciplinary studies of the human contribution to safety and accidents.

To make sense of these accidents, as well as other less celebrated cases, researchers found a second, multi-faceted story hidden behind the label of human error that revealed patterns about how systems fail. Going *behind* the label human error points the way to effective learning and system improvements. In other words, the label human error should be seen as starting point for investigation.

The result of research that pursues the "second" story has been a "new look" at the human contribution to safety and to failure.

Multiple Contributors

Traditionally, error analysis has focused on identifying the cause. However, one basic finding from "new look" research is that accidents in complex systems only occur through the concatenation of multiple small factors or failures, each necessary but only jointly sufficient to produce the accident (see Figure 1). Often these small failures or vulnerabilities are present in the organization long before a specific incident is triggered. All complex systems contain such "latent" factors or failures, but only rarely do they combine to create the trajectory for an accident.[2]

It is useful to depict complex systems such as health care, aviation and electrical power generation as having a sharp and a blunt end (Figure 2). At the sharp end, practitioners interact with the hazardous process in their roles as pilots, spacecraft controllers, and, in medicine, as nurses, physicians, technicians, pharmacists and others. At the blunt end of the health care system are regulators, administrators, economic policy makers, and technology suppliers. The blunt end of the system controls the resources and constraints that confront the practitioner at the sharp end, shaping and presenting sometimes conflicting incentives and demands.

CMM006-0099

Creating Safety
Traditionally, accident analysis has focused on individuals as unreliable components. The search for a cause typically stopped at the human or group closest to the accident who was determined, after-the-fact, could have acted in another way and in a way which we now believe would have led to a different outcome. The response to this verdict has been interventions to protect the system from erratic human behavior.

However, the more researchers have looked at success and failure in complex work settings, the more they realize that the real story is how people learn and adapt to create safety in a world fraught with hazards, tradeoffs, and multiple interacting goals (Figures 3 and 4).

When we look at the role of sharp end practitioners in various research investigations, we see that people make safety in the face of the hazards that are inherent in the system. System operations are seldom trouble free. There are many more opportunities for failure than actual accidents. Groups of practitioners pursue goals and match procedures to situations, but they also resolve conflicts, anticipate hazards, accommodate variation and change, cope with surprise, workaround obstacles, close gaps between plans and real situations, detect and recover from miscommunications and misassessments. In these activities practitioners at the sharp end block potential accident trajectories. In other words, people actively create safety when they can carry out these roles successfully (Figure 8).

Safety research tries to identify factors that undermine practitioners' ability to do this successfully. Research has examined how people, individually, as groups, and as organizations, create safety through investigations of how expertise is brought to bear in non-routine situations, how people cope with multiple pressures and demands before an accident draws attention to their practice, and how some organizations achieve "high reliability."

Feedback and Recovery from Incipient Failure
The "new look" at human error has shown that robust, "high reliability" individuals, teams, systems, and organizations are able to recognize systemic vulnerabilities and how situations evolve toward hazard before negative consequences occur.[6] This means that processes involved in detecting that a situation is heading towards trouble and re-directing the situation away from a poor outcome is critical to safety--the concepts of error tolerance, detection and recovery. Evidence about difficulties, problems, and incidents reveals information about the underlying system – systemic vulnerabilities that can create or propagate trajectories toward failures.

"High reliability" organizations also value such information flow, use multiple methods to generate this information, and then use this information to guide adaptive and constructive changes without waiting for accidents to occur.

Hindsight Biases
The hindsight bias is one of the most reproduced research findings relevant to accident analysis and reactions to failure (Figure 6). Knowledge of outcome biases our judgment about the processes that led up to that outcome.

In the typical study, two groups of judges are asked to evaluate the performance of an individual or team. Both groups are shown the same behavior; the only difference is that one group of judges are told the episode ended in a poor outcome; while other groups of judges are told that the outcome was successful or neutral. Judges in the group told of the negative outcome consistently assess the performance of humans in the story as being flawed in contrast with the group told that

the outcome was successful. Surprisingly, this hindsight bias is present even if the judges are told beforehand that the outcome knowledge may influence their judgement.

Hindsight is not foresight. After an accident, we know all of the critical information and knowledge needed to understand what happened. But that knowledge is not available to the participants before the fact. In looking back we tend to oversimplify the situation the actual practitioners faced, and this tends to block our ability to see the deeper story behind the label human error.

Researchers use methods designed remove hindsight bias to see the multiple factors and contributors to incidents, to see how people usually make safety in the face of hazard, and to see systemic vulnerabilities before they contribute to failures.

Organizational Factors in Failure

Traditionally, accident analysis has focused on the sharp end. However, the more researchers have looked at success and failure in complex work settings, the more they realize that the real story is how resources and constraints provided by the blunt end shape and influenced the behavior of the people at the sharp end -- organizational factors. Reason summarized the results: "Rather than being the main instigators of an accident, operators tend to be the inheritors of system defects... Their part is that of adding the final garnish to a lethal brew whose ingredients have already been long in the cooking" (1990, p. 173).

Creating Cultures of Safety and Learning

When hindsight bias leads to the judgment human error, organizational learning stops. Accountability degenerates into search for a culprit (blame) and threats of punishment follow in the mistaken belief that this will repair a fallible human component (Figure 7).

Research on safety culture show that open flow of information about vulnerabilities is the lifeblood of safety. In other words, blame and learning are in conflict.

What is ironic is how two conflicting notions can co-exist. Health care, like other settings, as they begin to understand the research results, calls for learning based on open information flow, but at the same time still perseveres in the pursuit of culprits. Rather than confront the conflict and develop new models of accountability with high openness to information on potential failure, they try to have it both ways.

A simple test of a safety culture is to examine what happens after a failure or other event creates an opportunity to learn about how safety is made and sometimes broken. Are calls for action focused on the "other"? – those people are not as careful, well intentioned, motivated, knowledgeable, etc. ..., as I am. Are proposed changes just those that other groups should make? There is this curious belief that because I am well intentioned, motivated in my role, I am immune from the processes that contribute to failure for other people.

The basic driving force to create a safety culture is the need to demonstrate that the goal of all, blunt end and sharp end, is learning to make the system work better. Sharing new knowledge and the willingness to act on this knowledge, especially when it conflicts with economic and other goals, is fundamental to a culture of safety. In other words, safety is not a commodity, but a value.

Interestingly, in this learning process people and organizations are learning not simply about those <u>other</u> people, groups, practices, institutions, or external processes. Rather learning about

safety is signaled when they are learning about themselves, about their role in the multiple processes that contribute to safety in health care, about their models of how safety is made and sometimes broken.

Creating confidence and buy-in across all stakeholder groups is essential for progress on safety. All parties must see a visible commitment to learn and improve by the organization.

Side Effects of Change

Health care systems exist in a changing world. The environment, organization, economics, capabilities, technology, and regulatory context all change over time. Even the current window of interest and opportunity to improve patient safety are mechanisms for change. This backdrop of continuous systemic change ensures that hazards and how they are managed are constantly changing.

The general lesson is that as capabilities, tools, organizations and economics change, vulnerabilities to failure change as well -- some decay, new forms appear. The state of safety in any system is always dynamic, and stakeholder beliefs about safety and hazard also change. Progress on safety concerns anticipating how these kinds of changes will create new vulnerabilities and paths to failure even as they provide benefits on other scores.

For example, new computerization is often seen as a solution to human performance problems. Instead, consider potential new computerization as another source of change. Examine how this change will affect roles, judgments, coordination. This information will help reveal side effects of the change that could create new systemic vulnerabilities.

Typically, it is the complexity of operations that contributes to human performance problems, incidents, and failures. Changes, however well-intended, that increase or create new forms of complexity will produce new forms of failure, in addition to other effects.

Armed with this knowledge we can address these new vulnerabilities at a time when intervention is less difficult and less expensive (because the system is already in the process of change). In addition, these points of change are opportunities to learn how the system actually functions and sometimes mal-functions.

Another reason to study change is that health care systems are under severe resource and performance pressures from stakeholders. First, change under these circumstances tends to increase coupling, that is, the interconnections between parts and activities, in order to achieve greater efficiency and productivity. However, research has found that increasing coupling also increases operational complexity and increases the difficulty of the problems practitioners can face. Second, when change is undertaken to improve systems under pressure, the benefits of change may be consumed in the form of increased productivity and efficiency and not in the form of a more resilient, robust and therefore safer system.

To move forward, one simply strategy is:

> Examine how unintended effects of economic, organizational and technological change can produce new systemic vulnerabilities and paths to failure.

Future success depends on the ability to anticipate and assess the impact of change to forestall new paths to failure.

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Methods for Studying Human Performance

Questions about patient safety, fundamentally, are questions about human performance – how do we influence for example, expertise, control of attention, team work, human-computer cooperation, organizational learning. The target is to understand how practitioners accomplish their goals in the face of a variety of difficulties, complexities, dilemmas and tradeoffs and how this usually successful process breaks down. Inquiry on these topics is focused on understanding what factors create complexity and how people in different roles coordinate to cope with complexity.

The methods used in this work come from Cognitive Science and Engineering (protocol analysis, cognitive work analysis), Anthropology (ethnography), and other fields outside of medicine. Health care does not normally use these methods to examine human performance, cooperative activity and organizational dynamics. Furthermore, the very character of these methods is quite different from methods typically deployed in medical and epidemiological research. Building the "story" – charting the process of how the problem is recognized and solved -- is a core and effortful activity that precedes statistical aggregation of the resulting patterns.

Ultimately, this is an issue about how to combine two families of knowledge – one family concerns different areas of health care knowledge and experience and the other family concerns different areas of knowledge about human performance.

Fundamentally, patient safety is as much a human performance topic as it is a medical topic. Success will come from interdisciplinary efforts using methods to understand and enhance human expertise in the context of diverse and changing health care settings.

CMM006-0103

A New Approach to Accident Analysis

Prof. Nancy G. Leveson

Aeronautics and Astronautics
MIT

Presentation to the CAIB May 28, 2003

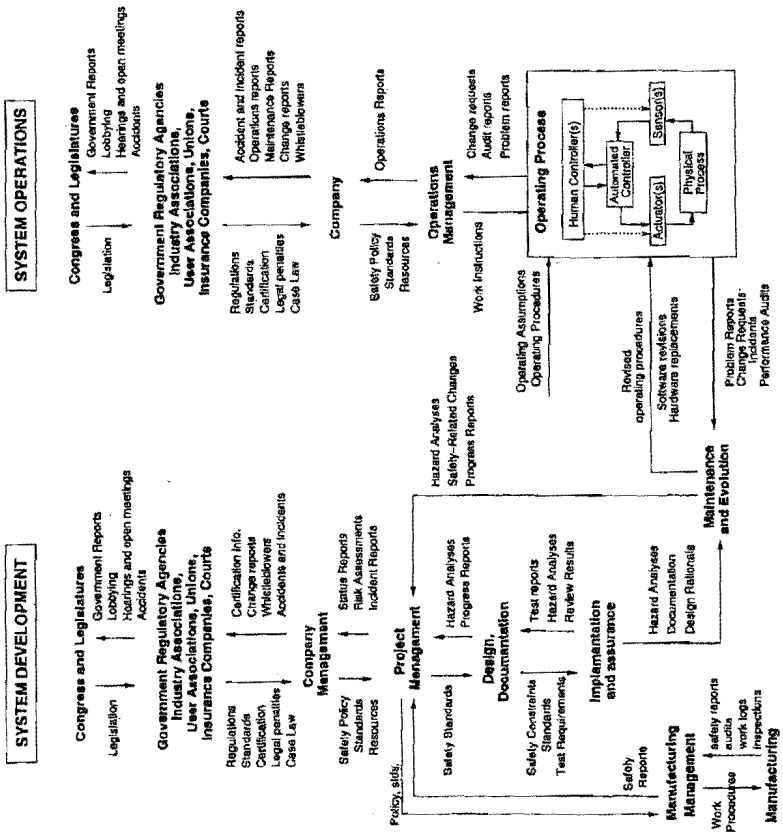
STAMP (Systems–Theoretic Accident Modeling and and Processes)

- Based on ideas from systems theory, systems engineering, cognitive engineering, and control theory.

- Accidents result from inadequate enforcement of safety constraints on
  - Development
  - Manufacturing
  - Operations

- Accidents occur when component failures, external disturbances, and dysfunctional interactions not adequately handled.

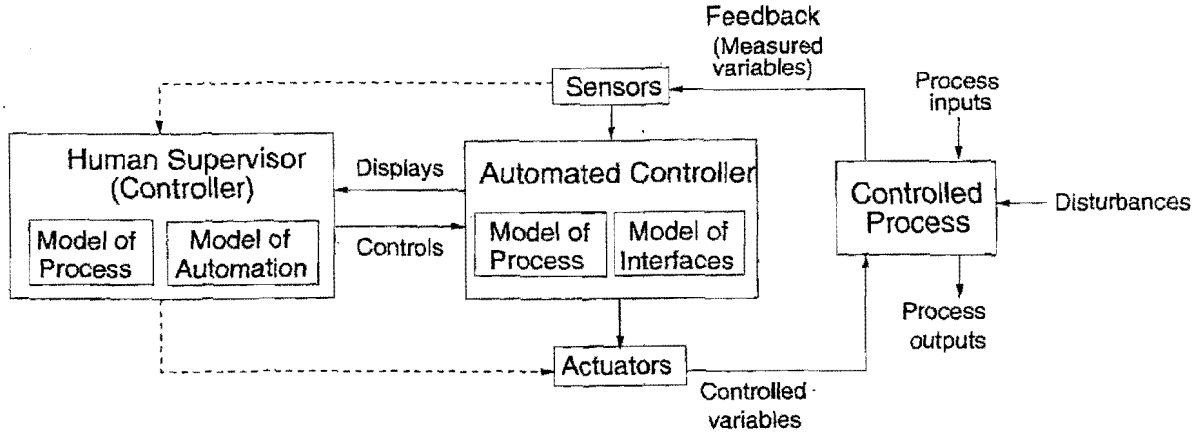
- Accident analysis: Determine why the controls were inadequate to maintain constraints on safe behavior (and thus why events occurred)



STAMP (2)

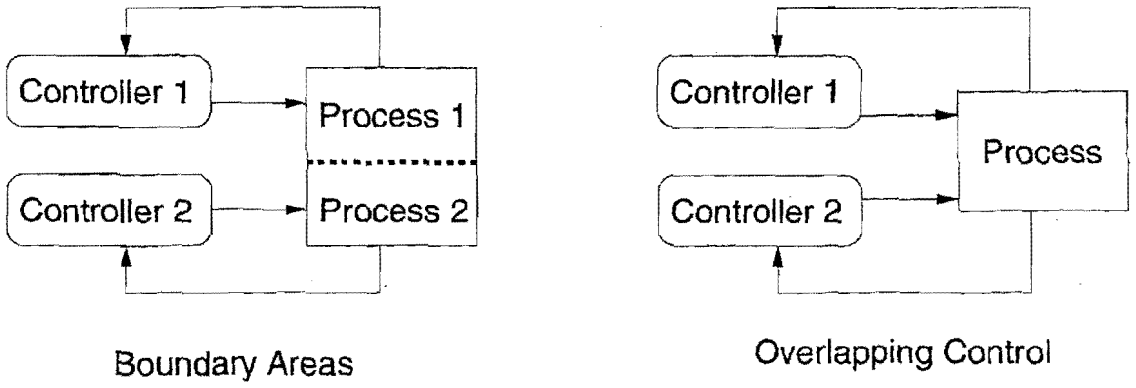
- System is a dynamic process that is continually adapting
  - to achieve its ends
  - to react to changes in itself and its environment
- Include physical components, people, organizational, societal structures
- Organizational and engineering control structure must limit system behavior to safe changes and adaptations
- Safety control structure changes over time
  - "Migration toward an accident"
  - Asynchronous evolution

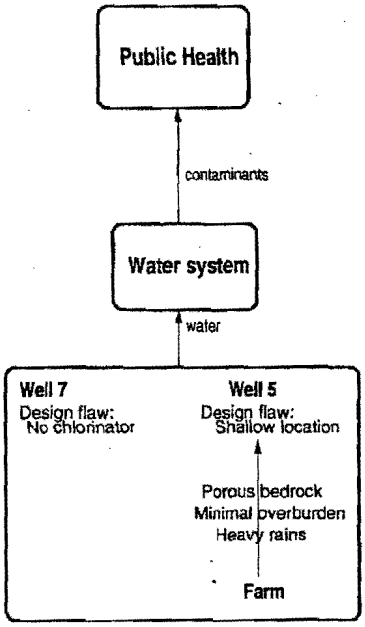
Process Models

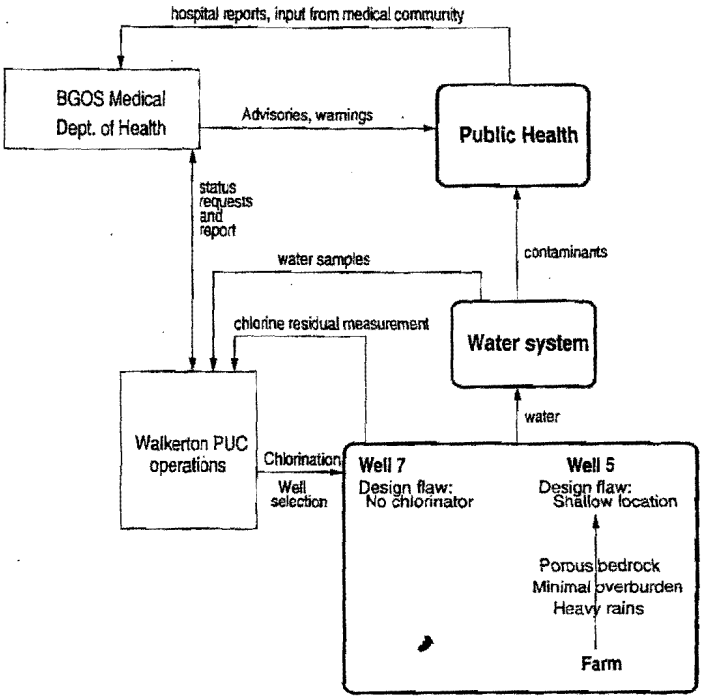


- Accidents often result from inconsistencies between models and actual process state.

System accidents may involve inadequate coordination:




Public Health
contaminants
Water system
water
Well 7
Design flaw:
No chlorinator
Well 5
Design flaw:
Shallow location
Porous bedrock
Minimal overburden
Heavy rains
Farm

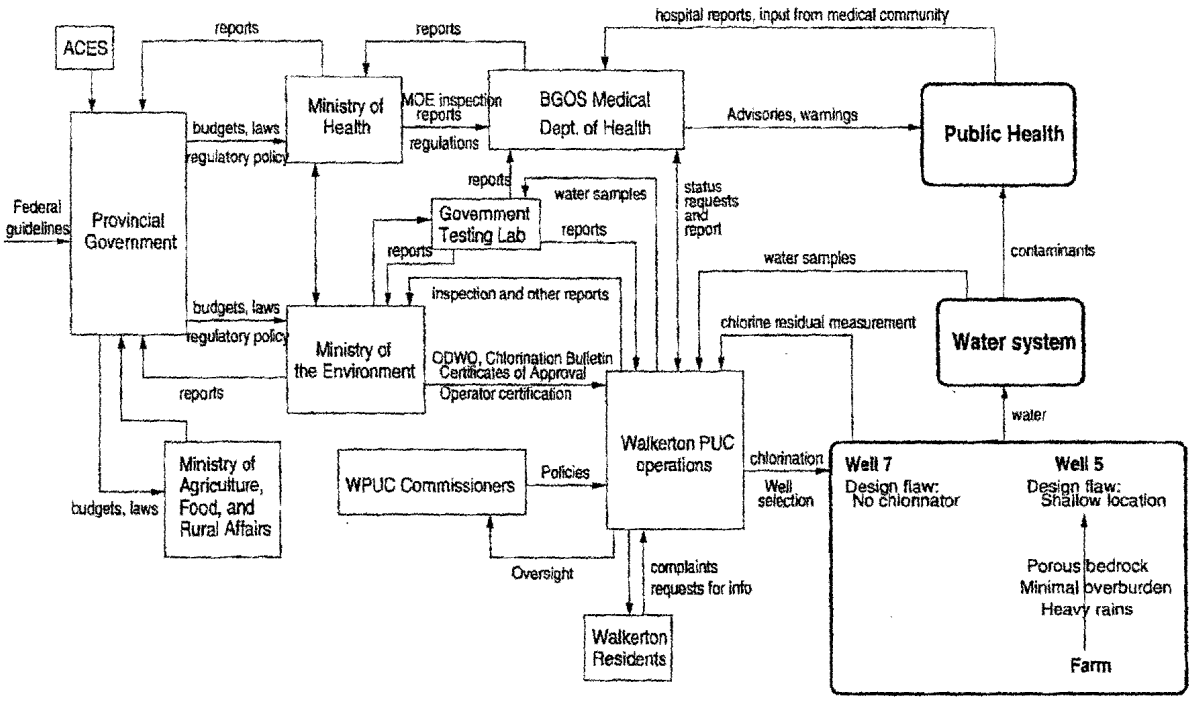

hospital reports, input from medical community
BGOS Medical
Dept. of Health
Advisories, warnings
Public Health
status
requests
and
report
water samples
contaminants
chlorine residual measurement
Water system
water
Walkerton PUC
operations
Chlorination
Well
selection
Well 7
Design flaw:
No chlorinator
Well 5
Design flaw:
Shallow location
Porous bedrock
Minimal overburden
Heavy rains
Farm

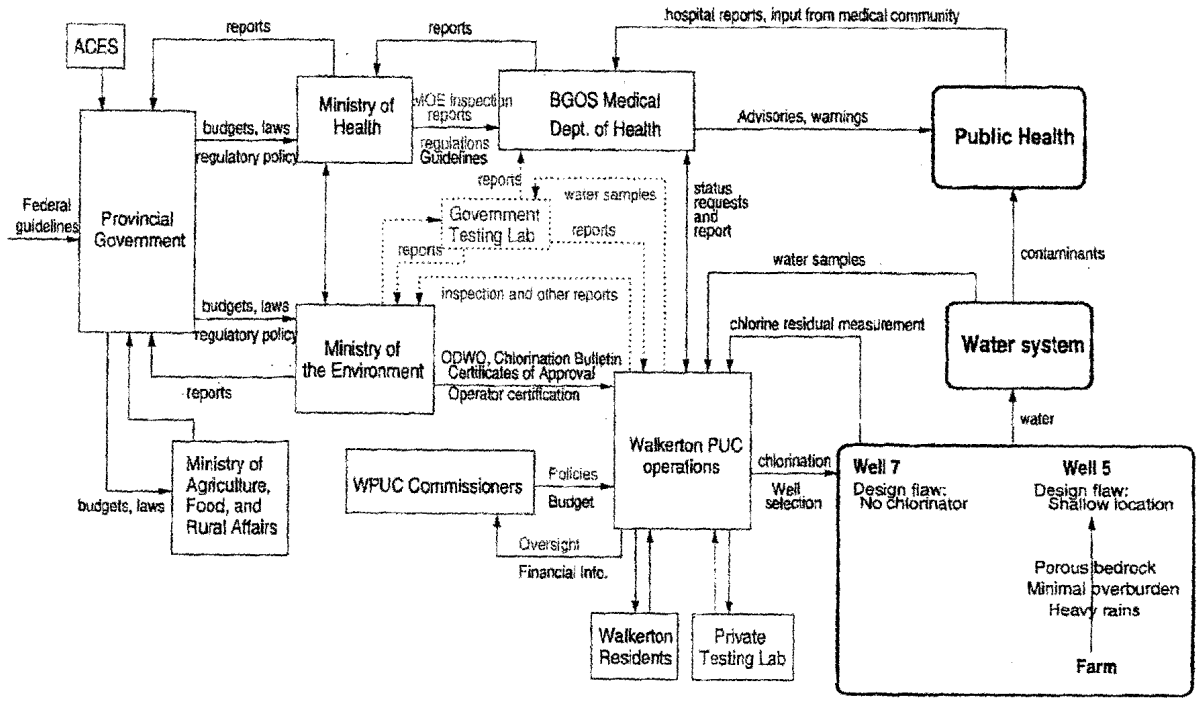
System Hazard: Public is exposed to e. coli or other health-related contaminants through drinking water.

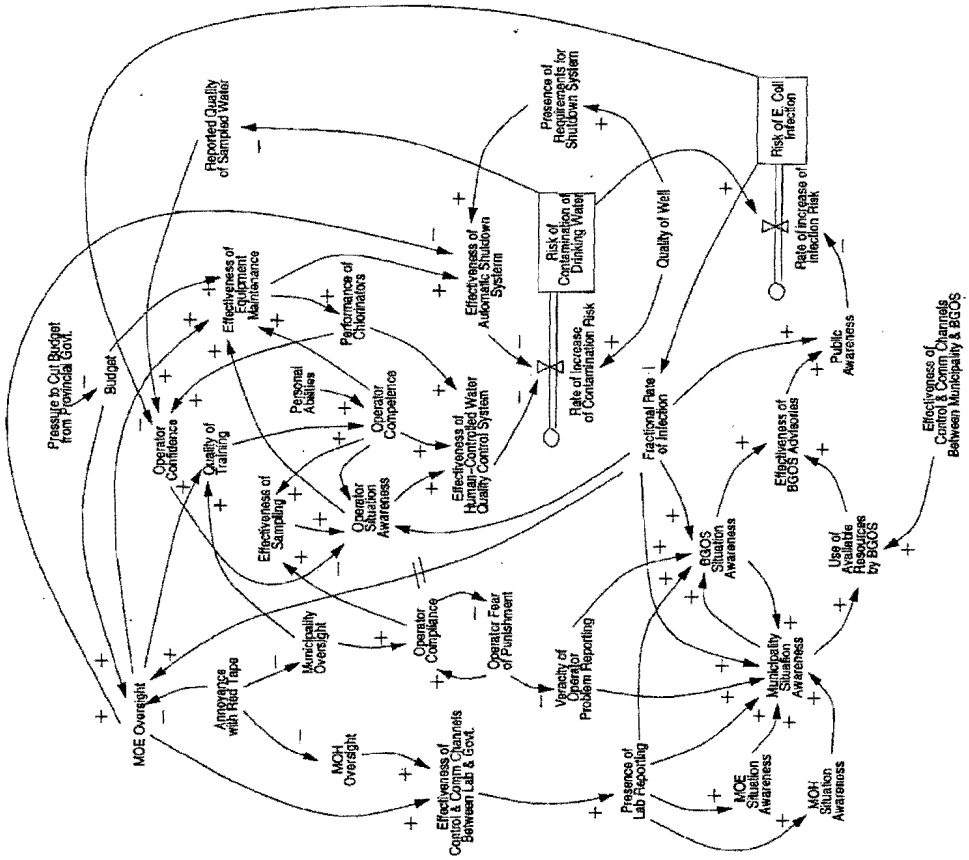
System Safety Constraints: The safety control structure must prevent exposure of the public to contaminated water.

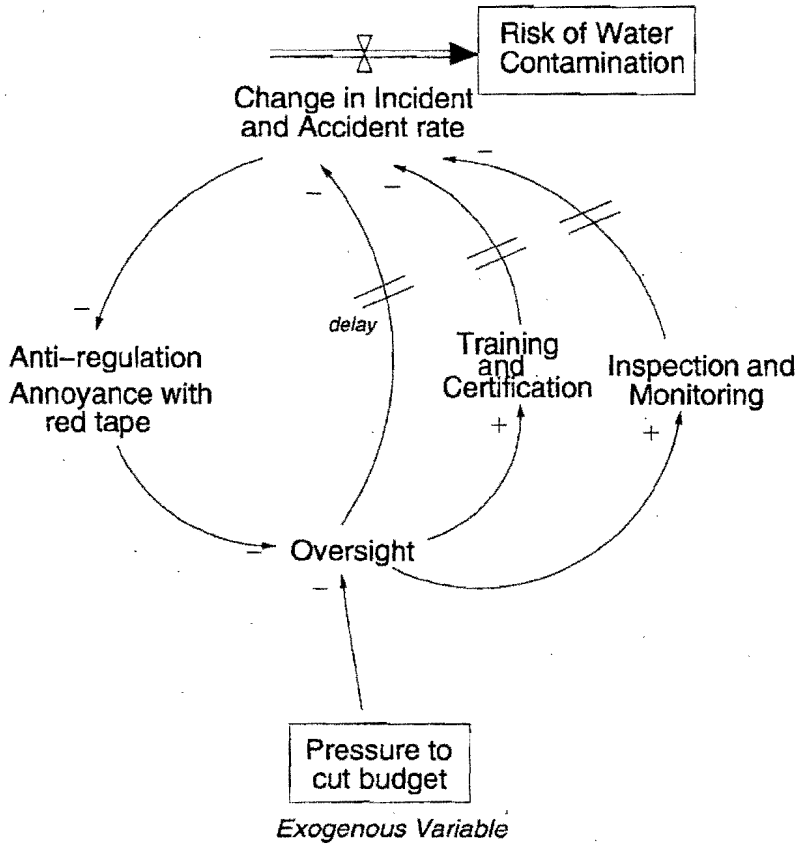
(1) Water quality must not be compromised.

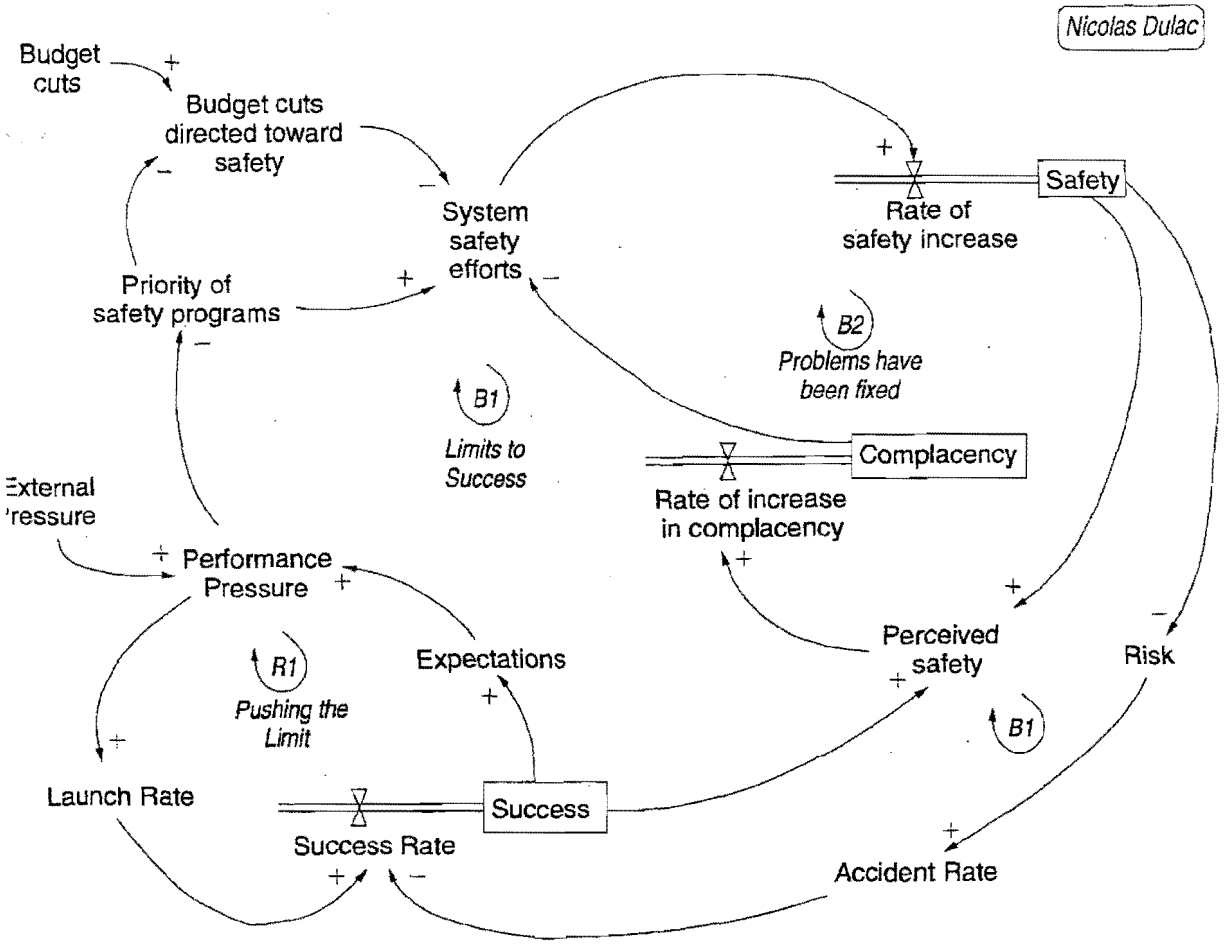
(2) Public health measures must reduce risk of exposure if water quality is compromised (e.g., notification and procedures to follow)






Pressure to Cut Budget from Provincial Govt.
Budget
MOE Oversight
Operator Confidence
Reported Quality of Sampled Water
Effectiveness of Equipment Maintenance
Quality of Training
Annoyance with Red Tape
Municipality Oversight
MOH Oversight
Effectiveness of Sampling
Personal Abilities
Performance of Chlorinators
Operator Competence
Operator Situation Awareness
Operator Compliance
Effectiveness of Control & Comm Channels Between Lab & Govt.
Effectiveness of Automatic Shutdown System
Effectiveness of Human-Controlled Water Quality Control System
Operator Fear of Punishment
Veracity of Operator Problem Reporting
Presence of Lab Reporting
Presence of Requirements for Shutdown System
Risk of Contamination of Drinking Water
Rate of Increase of Contamination Risk
Quality of Well
Fractional Rate of Infection
BGOS Situation Awareness
MOE Situation Awareness
Municipality Situation Awareness
MOH Situation Awareness
Risk of E. Coli Infection
Rate of Increase of Infection Risk
Public Awareness
Effectiveness of BGOS Advisories
Use of Available Resources by BGOS
Effectiveness of Control & Comm Channels Between Municipality & BGOS


Risk of Water Contamination
Change in Incident and Accident rate
delay
Anti-regulation Annoyance with red tape
Training and Certification
Inspection and Monitoring
Oversight
Pressure to cut budget
Exogenous Variable



Local (BGOS) Medical Dept. of Health

Safety Requirements and Constraints:

- Provide oversight of drinking water quality.
- Follow up on adverse drinking water quality reports.
- Issue boil water and other advisories if public health at risk.

Context in Which Decisions Made:

- Most recent water quality reports over 2 years old.
- Illness surfacing in communities outside Walkerton
- E. coli most commonly spread through meat.

Inadequate Control Actions:

- Advisory delayed.
- Advisory should have been more widely disseminated.
- Public health inspector did not follow up on 1998 Walkerton inspection report.

Mental Model Flaws:

- Thought were receiving adverse water quality reports after privatization.
- Unaware of reports of E. coli linked to treated water source.
- Thought Stan Koebel was relaying the truth.

Coordination:

- Assumed MOE was ensuring inspection report problems were resolved.

Provincial Government

Safety Requirements and Constraints:

- Establish regulatory bodies and codes of responsibilities, authority, and accountability
- Provide adequate resources to regulatory bodies to carry out their responsibilities.
- Provide oversight and feedback loops to ensure regulatory bodies are doing their job adequately.
- Ensure adequate risk assessment is conducted and effective risk management plan is in place.
- Enact legislation to protect water quality.

Context in Which Decisions Made:

- Anti–regulatory culture.
- Efforts to reduce red tape.

Inadequate Control Actions:

- No risk assessment or risk management plan
- Privatized laboratory testing of drinking water without requiring labs to notify MOE and MOH of adverse test results. (Privatizing without establishing adequate governmental oversight)
- Relied on guidelines rather than legally enforceable regulations.
- No regulatory requirements for agricultural activities that create impacts on drinking water sources.
- Water Sewage Services Improvement Act ended provincial Drinking Water Surveillance program
- No accreditation of water testing labs (no criteria established to govern quality of testing personnel, no provisions for licensing, inspection, or auditing by government).
- Ignored warnings about deteriorating water quality.
- No law to legislate requirements for drinking water standards and reporting requirements.
- Environmental controls systematically removed or negated.

Feedback:

- No monitoring or feedback channels established to evaluate impact of changes

Steps in a STAMP analysis:

1. Identify
   - System hazards
   - System safety constraints and requirements
   - Control structure in place to enforce constraints
2. Model dynamic aspects of accident:
   - Changes to static safety control structure over time
   - Dynamic processes in effect that led to changes
3. Create the overall explanation for the accident
   - Inadequate control actions and decisions
   - Context in which decisions made
   - Mental model flaws
   - Control flaws (e.g., missing feedback loops)
   - Coordination flaws

STAMP vs. Traditional Accident Models

- Examines interrelationships rather than linear cause–effect chains
- Looks at processes behind changes rather than snapshots
- Identifies basic patterns so can:
  - Leverage those factors that can produce major effects rather than simply responding to events themselves
  - Not just react to accidents and impose controls for a while but understand why controls drift toward ineffectiveness over time and
    - Change those factors if possible
    - Detect the drift before accidents occur

Safety Metrics
Leading and Trailing Indicators
Lessons Learned

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Presentation made to the Columbia Accident Investigation Board
Johnson Space Center, NASA, Houston, Texas
April 28, 2003

Is our safety performance getting better or worse?

- How can we answer this question?
- Extreme events occur infrequently.
- If extreme events are used to judge the performance, the system becomes self-defeating

CMM006-0113

There is no way to tell unless we screen, evaluate, and correlate (measure) performance influencing factors

Safety Performance Measurement Using Indicators

Indicator ≡ Observed Variable

Indicators becomes valuable when looked at over a period of time or as a trend

Trend analysis looks at an indicator or a series of indicators over a period of time to observe if there is a general sustained movement of the time series upward, downward, or if there is no discernible pattern

Limitations of Indicators

1. Trend analysis requires a significant amount of data. Otherwise, stochastic or random phenomena may create a biased picture.
2. Comparison of variables requires normalization of the data.

Leading Indicators

- *An upstream measure that characterizes the level of hazard control; measurement of activities toward risk reduction prior to occurrence of incidents.*

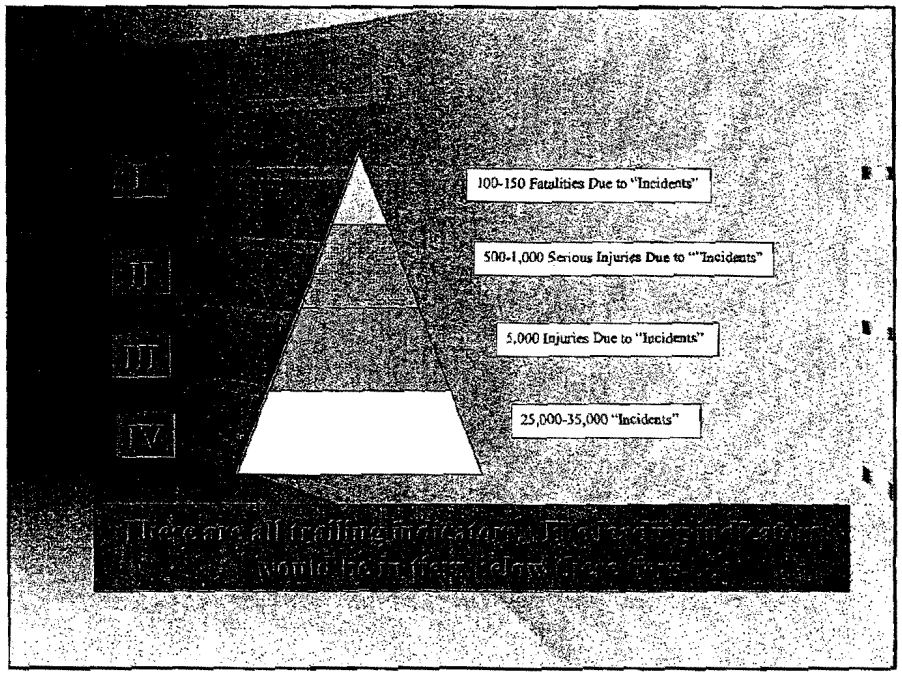
Trailing Indicators

- *Downstream measures; Measurement of the outcomes of safety and health efforts. These indicators reflect failure of the system to manage hazards.*

Example

Incident Definition for Chemical Industry

An incident is the sudden unintended release of or exposure to a hazardous substance, which results in or might reasonably have resulted in deaths, injuries, significant property or environmental damage, evacuation or sheltering in place.



The underlying causes for incidents in all the tiers are usually the same

Example Scenario

- Release of 500 pounds of flammable gas
- Consequences could vary and thus the incident could be categorized in any one of the four tiers
  - Tier IV: None
  - Tier III: Minor injury
  - Tier II: Serious injuries
  - Tier I: Fatalities

What does that mean?

- Need to broaden our definition of incidents
- Need to keep the definition of incident limited to process incidents
- Personnel safety (e.g., trips and falls) should be dealt with separately
- Lessons learned from Tier IV incidents could very well be used to eliminate Tier I incidents
- These are all trailing indicators

Then what?

- Now we have trailing indicators
- We still need to look at leading indicators
- How do we identify those leading indicators

Leading Indicators

- Varies according to activity and mission of the organization
- Examples of leading indicators
  - Proactive near-miss reporting, investigation, and action
  - Configuration management
  - Emphasis on inherently safer design
  - Effective application of risk assessments
  - Deferred maintenance
  - Repetitive maintenance
  - Faults detected by inspection and testing
- Need careful analysis of organizational mission and activities involved to determine all appropriate leading indicators

Hierarchical Approach

➔ Safety Culture

➔ Management Systems

➔ Procedures, Technology, etc.

Safety Culture

- Varies according to activity and mission of the organization
- Very difficult to identify objective characteristics
- Some known characteristics
  - Involvement and commitment of highest level personnel
  - Open communication at all levels of the organization
  - Everyone's responsibilities and accountabilities regarding safety is clearly defined and understood
  - Safety is second nature
  - Zero tolerance for disregard of management systems, procedures, and technology
  - Information systems allow all parties access to design, operational, and maintenance data

Summary

1. The need to have appropriate trailing indicators to measure safety performance
2. Use of leading indicators to influence the trailing indicators
3. Taking a hierarchical approach
4. Defining and implementing a program to help establish the appropriate safety culture

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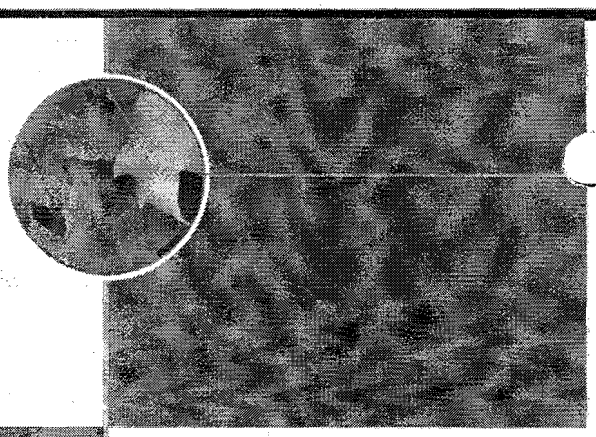
Environmental, Health and Safety Report 2001 Highlights

CMM006



Intel's Environmental, Health and Safety Policy

Intel Corporation and its subsidiaries are committed to achieving high standards of environmental quality and product safety, and providing a safe and healthful workplace for our employees, contractors and communities.

We will comply with all applicable regulatory requirements as a minimum, and implement programs and processes to achieve greater protection, where appropriate. We will work with stakeholders to develop responsible laws, regulations and innovative programs that provide safeguards for the community, the workplace and the environment while providing flexibility to meet the needs of our business.

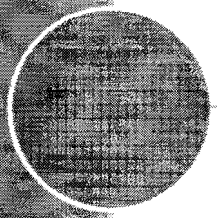
We seek a healthful and safe workplace, free of occupational injury and illness. We emphasize individual responsibility for safety by all employees and at all levels of management. We expect employees to report potential safety hazards and issues, and be involved in implementing solutions. We will not conduct any operations or market a product without adequate safeguards. To maintain a safe work environment, employees are prohibited from possessing or using illegal drugs on Intel premises or reporting to work under the influence of illegal drugs or alcohol.

We are committed to conserving natural resources and reducing the environmental burden of waste generation and emissions to the air, water and land. Through continuous improvement methodologies, we will develop environmentally compatible products and processes. We will strive to be leaders in reducing, reusing and recycling, and will ensure that any wastes remaining are properly disposed of in a safe and environmentally sound manner.

We will be a responsible member of the communities in which we live and work. We will continue to expand our knowledge and understanding of the effect of our operations on safety, health and the environment. We are committed both to continuous improvement in our operations and to sharing the knowledge that we gain with our employees, customers, suppliers, the communities in which we live and work, the scientific community, government and industry.

We will establish and maintain appropriate controls, including periodic review, to ensure that this policy is being followed.

Craig R. Barrett
Chief Executive Officer
Policy established 1991, last revised March 1998.



Intel sells scrap wafers to the solar industry, which recycles them into solar cells. Since 1999, solar plants have converted 3 million Intel wafers into 2.4 million solar cells.

We provide employees with ergonomic tools as part of our commitment to a healthful and safe workplace, free of occupational injury and illness.

At Intel, we are actively involved in improving the health and safety of our local communities, as well as their environments.

"Intel's work in the EHS arena is the same as our performance in the marketplace. We have worked hard to become global leaders in EHS. This commitment is integrated throughout the corporation from the executives to every employee." — Craig R. Barrett, Chief Executive Officer

Excellence in Our EHS Programs

The American novelist John W. Gardner once described excellence as "doing ordinary things extraordinarily well." At Intel, our goal is to integrate EHS excellence into all aspects of our business. To achieve this goal, we use our Design for Environment, Health and Safety philosophy to consider EHS issues early in the development process, rather than relying on end-of-the-pipe solutions. For instance, we work with our equipment suppliers to design safety and environmental features into our manufacturing tools, so that they are safe for our employees and have minimal environmental impacts. We partner with our materials suppliers to select chemical processes that are more benign to human health and the environment. We design and build factories that are safe and use fewer natural resources. And we train, educate and motivate our employees to maintain safe behaviors and reduce our collective impact on the environment. In short, we are doing ordinary things extraordinarily well. This section includes a few examples.

World-Class Safety

Despite the lowest injury and illness rate in the semiconductor industry—and possibly the lowest rates in any industry—we continue to improve our illness and injury prevention performance. In 2001, we reduced our already world-class OSHA recordable rate by an additional 33% to 0.19 injuries per 100 employees. Said another way, Intel's safety performance is about 4,500% better than that of the average U.S. manufacturing company. These numbers are more than statistics: in human terms, they represent the prevention of injury and illness to thousands of employees and contractors each year, which makes Intel one of the safest places to work on the planet.

Wafer Recycling

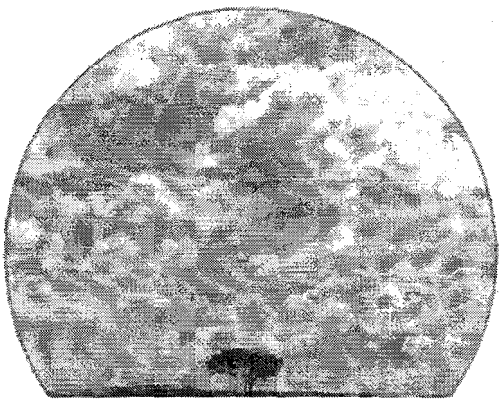
Intel sells scrap wafers to the solar industry, which recycles them into solar cells. These cells convert solar energy into electricity, thereby providing a reliable, renewable energy source. Since 1999, solar plants have converted 3 million Intel wafers into 2.4 million solar cells. These cells, in turn, have the capacity to generate approximately 11.4 million kilowatt-hours of emission-free power each year. Producing a similar amount of energy with fossil fuels would generate more than 11,000 tons of greenhouse gases per year. For additional information, visit *www.intel.com/intel/other/ehs/R_R_Initiatives.htm*.

Energy-Efficient Products

In 1999, Intel introduced its Instantly Available Personal Computer (IAPC) technology, which allows a PC to power down to a "sleep" mode of 5 watts or less when not in use and then become fully operational again in less than 10 seconds. In 2001, numerous PC manufacturers introduced IAPC technology to the global marketplace. PCs equipped with IAPC technology, such as the new Intel® Pentium® 4 processor-based PCs, consume as much as 71% less energy per year than PCs without IAPC technology. Intel received a Technical Innovation award and a Clean Air Excellence award from the U.S. EPA's Energy Star® program, a government/industry partnership dedicated to saving consumers money and protecting the environment.

Water Management

Water is one of our most valuable natural resources, and it is also a vital ingredient in semiconductor manufacturing. Worldwide, Intel uses about 5.6 billion gallons of water a year to manufacture and assemble our microprocessors. To put this in perspective, one wafer fabrication facility (or "fab") alone uses about the same amount of water daily as a typical golf course in the southwestern United States. Intel is committed to conserving and reusing water. We're pleased to report that in 2001, approximately 2.5 billion gallons of our total water came from on-site, reused sources. Reusing water whenever we can significantly reduces the amount of fresh water that we need, thus making it available to the local community and the surrounding environment.



We are committed to conserving natural resources and reducing the environmental impact of our products, processes and operations.

Excellence in Our Communities

Our leadership and dedication to EHS excellence is not confined to our employees and our operations. We are actively involved in improving the health and safety of our local communities, as well as their environments.

Philippines Projects

Spearheaded by their Intel Involved team, the Philippines site continued to lead community involvement initiatives on several fronts in 2001: providing free medical and dental services to residents of its neighboring communities in Makati and Cavite; conducting safety and health campaigns to provide information on home safety, community safety, nutrition, family planning and healthcare; educating students and teachers on safety and environmental issues; planting more than 500 trees; and actively contributing to local traffic safety improvements by installing visible roadway signs and street lighting, and donating other safety equipment.

Education Web Sites

In 2001, Intel worked with Conservation International to create an educational Web site, Investigate Biodiversity, that allows high-school students to look over the shoulders of scientists on exotic eco-research. The site takes students into ecological hotspots—places where human intrusion is threatening the natural balance. To view the Web site, visit *http://investigate.conservation.org*.

Intel has also launched a series of "Explore the Last Great Places" Web sites with The Nature Conservancy. Aimed at 7th- to 9th-grade science students, the first site featured a tour of Southern Arizona's Upper San Pedro River Basin. A second Web site, which focuses on the Berkshire Taconic landscape in New England, will launch in 2002, and other sites are expected to follow. To view these Web sites, visit *www.lastgreatplaces.org*.

EHS Excellence Confirmed

We work hard on our EHS performance, and we are pleased to report that our performance has been recognized by government agencies and institutions around the world. During the past five years, Intel has received more than 50 awards recognizing our EHS leadership. Similarly, in the selective, socially responsible investment category, we are a sought-after investment and a key holding in several funds.

U.S. EPA Recognition

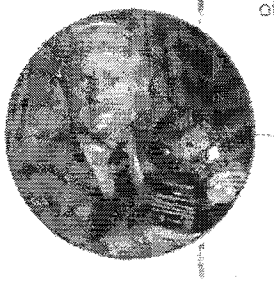
In a speech delivered on January 9, 2002 in Chandler, Arizona, U.S. EPA Administrator Christie Whitman, citing Intel's leadership under Project XL (eXcellence and Leadership) and Intel's success in reducing PC energy consumption, made the following statement: "It's no surprise why Intel has become a corporate leader in environmental stewardship—and one of the EPA's greatest partners."

Green Cross Safety Medal

The National Safety Council awarded Craig Barrett, Intel's chief executive officer, its highest award for safety: the Council's 2001 Green Cross for Safety Medal. Dr. Barrett received the award for his exemplary commitment to workplace safety and corporate citizenship. Alan C. McMillan, the council's president and CEO, said Barrett's business operating philosophy represents the kind of "top-level commitment to worker safety and health, environmental stewardship and community service that every company would do well to emulate."

Akira Inoue Award

Craig Barrett received the Semiconductor Equipment and Materials International (SEMI) 2001 Akira Inoue Award for Outstanding Achievement in Environment, Health and Safety in the Semiconductor Industry. "We commend Craig Barrett for his vision, leadership and effectiveness," said Stanley T. Myers, president and CEO of SEMI. "In addition to mandating environmental, health and safety performance at the world's largest chip-manufacturing company, Dr. Barrett is a forceful proponent of responsibility throughout the semiconductor industry."



Craig Barrett accepting the Akira Inoue Award

Message From Craig Barrett

This is our eighth consecutive Environmental, Health and Safety (EHS) Report. This year we have made significant changes to the report's format. The primary change is that we have moved most of our content to a Web-based version of the report (www.intel.com/go/ehs), which reduces the environmental impact of publishing a large report and allows for a more in-depth and interactive review of our EHS performance. Despite this change in focus and format, we still include all of the indicators and metrics that we have traditionally used to gauge our progress.

Our company, and our industry as a whole, experienced many changes in 2001. Even as we continued to expand our operations and our production, we faced extremely challenging economic conditions. It was a terrible year for the semiconductor industry, and most companies struggled to maintain profitability. Intel's own revenues dropped 21% from 2000. Despite this negative economic climate, our EHS performance actually continued to improve—often beyond the goals we set in 2000. Such sustained performance has been recognized year after year by award committees around the world as well as fund managers who consistently select Intel as a socially responsible investment.

We are strategically poised to emerge from this difficult period, and we look forward to continuing our efforts with our local, regional and global stakeholders to improve EHS excellence, both within our own facilities and in the industry at large. Indeed, our goal at Intel still is to have a positive social and economic impact on our employees, our suppliers, our communities and our stakeholders, while reducing our footprint on the local and global environment.

Here at Intel, we believe that producing our products in a safe and environmentally sensitive manner is an integral part of our business success. Because of that, we work hard to reduce the emissions from our factories, to minimize our use of natural resources, and to maintain a work environment in which our employees and contractors remain free of injuries and illnesses.

Craig R. Barrett

Craig R. Barrett
Chief Executive Officer

CMM006-0126

Goals, Targets, Indicators

Intel has been driven by three long-range strategic goals for environmental, health and safety (EHS) performance:

- Be an environmental, health and safety leader in our communities and our industry.
- Prevent all injuries in the workplace.
- Reduce the environmental footprint of our products, processes and operations.

We also develop short-term goals for EHS improvement against which we measure our performance.

New and Ongoing Targets for 2002 and Beyond

- Continue to lead the world in employee health and safety performance.
- Recycle 45% of the chemical waste generated from our worldwide facilities.
- Recycle 60% of the solid waste generated from our worldwide facilities.
- Reduce volatile organic compound (VOC) emissions per unit of production for the sixth consecutive year.
- Offset at least 25% of our total incoming fresh water supply needs with reclaimed water and more efficient systems.
- Incorporate energy-efficiency design requirements into our design and procurement processes.
- Register all of our semiconductor facilities worldwide to ISO 14001.
- Continue the development of lead-free product technologies.
- Purchase 30% recycled content paper for all U.S. copiers and printers.

If you have questions or comments, contact:
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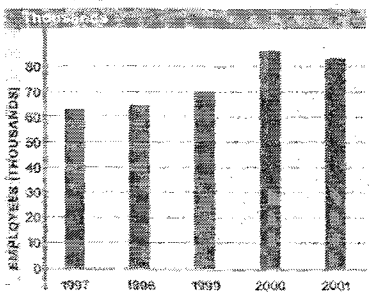
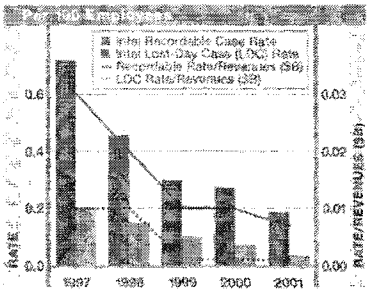
Intel Employees Worldwide



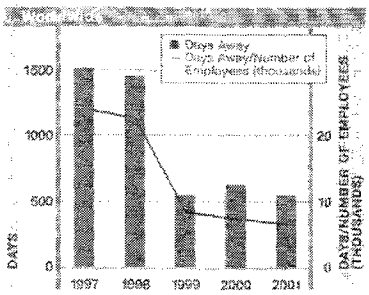
In 2001, Intel had 83,400 employees worldwide.

Intel Recordable and Lost-Day Injury Case Rates



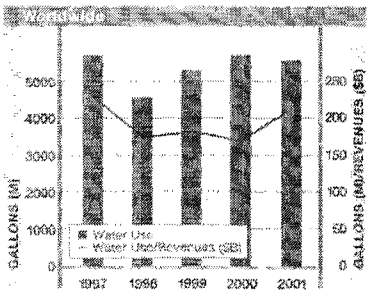
Intel is setting the benchmark for world-class safety performance. We benchmark our performance across all industries as well as with the leading semiconductor manufacturers.

Days Away From Work Due to Injury or Illness



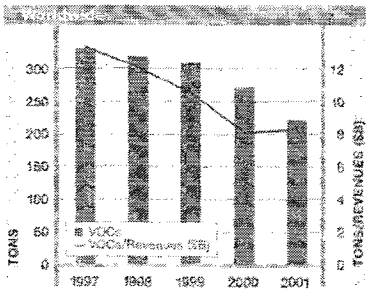
Active case management by Intel occupational health nurses worldwide, as well as the early reporting of symptoms, have reduced the number of days employees are away from work due to an injury or illness.

Water Use (millions of gallons per year)



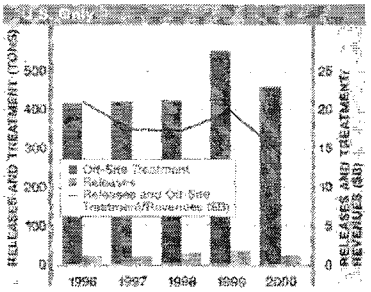
Intel's worldwide water use has been increasing at a rate less than our production growth. In 2001, Intel used approximately 15.3 million gallons per day. This level is approximately in line with water use in 1997. Numerous conservation projects at Intel sites worldwide contribute to the management of water use.

VOC Emissions (tons per year)



Aggregate volatile organic compound (VOC) emissions continue to be reduced, and the reduction for 2001 was more than 18%. Our success is due to the maturation of Design for Environment, Health and Safety initiatives. None of Intel's manufacturing facilities emits VOCs at levels greater than 100 tons per year, the level the U.S. EPA defines as a major source in most cities.

SARA Title III Releases and Off-Site Treatment (tons per year)



The U.S. EPA's Toxic Chemical Release Inventory lists several hundred chemicals for which companies are required to report releases to the environment. Intel's reportable releases to the environment decreased by approximately 40% in 2000, primarily due to production changes at several U.S. manufacturing sites. When we review the data normalized to production, usage decreased by approximately 21% overall. The 2001 data will be reported to the EPA on or before July 1, 2002.

CMM006-0127

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Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
April 29, 2003
These Minutes Contain No Sensitive Data

Purpose: Non-Destructive Evaluation Briefing to the CAIB

Date: 29 April 2003 **Time:** 1600- 1800

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

Orbiter RCC Inspection Plan and Future Non-Destructive Inspection Options.

Background - Mr. Roe reported that NASA has two teams assigned to determine the work required before Return To Flight (RTF): the Problem Resolution Team (PRT) and the UA (Unexplained Anomaly) Tiger Team. The PRT is working from a technical perspective to determine the cause of the accident and develop the mitigation plan. The Tiger Team is chartered to determine the steps to take in the event the exact cause cannot be determined.

Questions and comments are summarized below.

Mr. Hubbard asked about the vintage of the RCC specimens.

Answer - The two flight panels are recent; everything else was used for the 1st flight certification except for some "Type A" and "Double Type A" panels that were added after the 6th flight of OV-102. They will look at all three layers--sealants, silicon carbide coating, and substrate.

Mr. Hubbard asked about the maximum quantity and location of coating area that can be lost.

Answer - When they make the calculations they assume they lost all the coating but not the substrate. They always make the calculation for panel nine. Assuming a high inclination, heavy weight entry they predict that they will get to the backside (IML) coating of panel 9 at approximately 100 seconds prior to the TAEM (Terminal Area Energy Management) maneuver, which would indicate that if you had any kind of aero load on that panel you could potentially break through the carbon substrate. However, if you lose the sealant and the silicon coating it is still survivable.

MGen Deal asked for details on the break down inspection.

Answer - The orbiter will be completely stripped down at OMDP, which is nominally after every 8 flights. They will remove all RCC panels and verify that attachment hardware and attach location points are corrosion free.

MGen Deal - All visual?

Answer - Yes, against the OMRS (Operations and Maintenance Requirements and Specifications) ML06010002. The inspectors are advised to do a visual—with areas of interest looked at with 10x magnification.

MGen Barry - Tactile?

Answer - Panels are physically pushed to see where convective mass loss has manifested itself to such a degree that you can actually degrade the bond line of the silicon carbide coating. If oxidation is bad enough you can break the coating.

MGen Barry - What are the pinhole limits?

Answer - The break point is .040 mils. The pinholes stabilize at .020, and then they jump way beyond. The concern is getting a localized region of oxidation, which could inhibit the adherence of the silicon carbide. Inspections are done on all panels except those going back for refurbishment.

MGen Barry - How did they perform measurements?

Answer - They use a magnified loop with a .040 circle on the reticle.

Mr. Wallace - What is the difference between internal and internal micro inspection?

Answer - Micro inspection is a contingency visual inspection done whenever you have access to the backside of the panel, using the same ML06010002 criteria. Micro means visual from 3 ft or less.

MGen Barry - What is the time frame (for destructive inspection of panels)?

Mr. Roe - It is in discussion, we anticipate late this summer.

Mr. Wallace - Why select panel 16R versus something around panel 9?

Answer - Panel 16R experiences the highest structural loads, 10L experiences high thermal loads

MGen Barry - Why not dry ultrasound scan?

Answer - Through-transmission C-scan is the same as wet scan, and is far superior to the dry scan. Therefore you do not need to do the dry scan.

100% NDE inspection means it is the same as when the panels were first built. It is performed to see if there were any manufacturing defects that escaped initial screening or grown and propagated into something that would be unacceptable.

Mr. Buzzard - When will the program decide whether or not to perform additional RCC inspections prior to RTF?

Mr. Roe - Depends on the extent of the RTF activity. The program must consider all the activity and do what-if type risk trades.

MGen Barry - Are you going to do thermography, tomography or any other new techniques on every panel before returning to flight?

Mr. Roe - They assembled a team of NDE experts from around Government and they are expediting the process. They may be doing thermography or something else (on a non-interference basis). If they can develop and certify a better technique in 6-8 months that can save some time —then they will move on to that. If not successful in 6-8 months then they will use existing techniques.

Mr. Wallace - Are you using the same testing technology as originally used?

Answer - Ultrasound is the baseline for looking at attenuation, density, or porosity levels. X-rays are used predominantly in the radiuses and the corners to look at ply separations or delaminations or voids.

Mr. Hubbard - Restating Mr. Wallace's question—what is the gold standard to establish the state of health of these materials?

Answer - X-ray, ultrasound, and eddy current

RAdm Turcotte - Isn't CT (Computer Tomography) the gold standard?

Answer - It really depends on what you are looking at—if you are looking at the density of the RCC then ultrasound is the technique to use. Eddy currents measure coating thickness. Ultrasound will not pick up voids in the corners—there is too much mass.

RAdm Turcotte - Is the single shot X-ray that you have down there—is that up to speed with current CT techniques?

Answer - My opinion is that anything we can find we can find with x-rays

Mr. Pye stated that it is his understanding that NASA saw something funny on 16R using thermography and they were going to use CT to see what they really have.

Response - The CT itself and the real-time x-ray are similar technologies; it is just how you review the data.

MGen Barry - I thought we were going to do the ultrasound, x-ray, and eddy current. Then do thermography to start building a baseline. If any one of those presented a problem—then we would do tomography, which we all understand takes 100 hours per panel.

Mr. Roe - Thermography and CT will be performed on a non-interference basis. These techniques will not be a constraint to flight because they have not been approved by the program for RCC use.

MGen Barry - What does it take?

Mr. Roe - Need to establish a standard and a formal certification program, which they are in the process of doing right now in parallel. The NDE team will hopefully expedite that process. If the techniques become certified in a timely manner then they will go with it if they think it is better. In the meantime, they are uncomfortable with using uncertified test methods to rebaseline the hardware.

Mr. Buzzard - (re: reluctance to do CT and thermography) Ralph's argument is not about having time to do it. Without standards I do not understand if I have an anomalous piece of material or a good piece of material. Further, he does not want to get into a debate about 'thermography says this is anomalous but my other three NDE techniques say all is good'. And then, do I fly that panel or do I not fly that panel? Until the NDE team comes back and says 'here are your standards, now you can use it, you are certified', or unless somebody proposes that the three techniques are not satisfactory, I do not want to put an uncertified technique into the mix.

Mr. Hubbard - Do the current vendor methods together establish a baseline for the known array of defects, and does thermography add anything to that, or is thermography well enough understood that you can interpret the results?

Mr. Babish - Are the production NDE methods appropriate for aged RCC? How do panels age?

Answer - We have RCC with various levels of degradation. Panels age by convective mass loss, which is preferential to the silicon carbide-carbon interface on the outer surface of the part. That is also a function of subsurface porosity and temperature, and that varies all over the place.

Mr. Hubbard - Action to establish modes of aging/degradation, and whether or not the three existing technologies are adequate?

Mr. Pye - The three experts that we talked to agree that vendor technologies are from the eighties.

Mr. Buzzard - What is wrong with existing techniques, other than that they are old?

Dr. Osheroff - My concern is about delaminations and recrystallization—is anything going probe these areas?

MGen Barry - Can NASA stand up and say that the three factory techniques are adequate for both production and aged RCC?

Answer - The factory defects are similar to aged effects, with the delaminations etc.

MGen Barry - Has anybody used these techniques on carbon-carbon?

Mr. Hernandez - The Air Force Research Lab (AFRL) is the only group that works on carbon-carbon--but not RCC.

Dr. Osheroff - Thermography can pick up delaminations. I do not think the other techniques can do that.

Mr. Hernandez - Ultrasound can do that.

Mr. Babish - If aging causes a lot of little holes vice larger ones that are caught the factory, does this indicate anything? We need to look at all the data together to make sure that we understand the trends.

Mr. Benz - The loss rate is too small to detect oxidation.

Mr. Roe - The three techniques will not measure mass loss. They will rely on math models and destructive testing. Using the factory standards on the aged stuff is actually more conservative.

Mr. Johnson - No technique has been used more on RCC than the three techniques here. Because of that, the technical maturity is outstanding and it beats anything in the field.

The CAIB and NASA then began moving towards agreement that if any of the three original techniques detects something then they would do a CT. The discussion on NDE techniques was then tabled.

MGen Barry - What about certification of inspectors?

Answer - Level three at a minimum in Dallas. If they did thermography they would get assistance from KSC since they have the experience.

MGen Barry - What is the timeline on all three orbiters?

Mr. Ojeda - One year for a complete orbiter from start to the time to launch.

Mr. Pye pointed out that the scope of RFI B1-000133 includes the composite structures, which they just discussed, the mechanical mounting assemblies, and the front spar backup structure enclosure panels, which they did not address in their presentation.

Answer - The mounting assemblies and enclosure panels fall under detailed inspections V09AJ.050 and 080, which include corrosion inspection (all visual). Since all fracture critical parts were dye-penetrant inspected at manufacture, and analysis of flight loads has shown that they have been operating well within limits, they will not do any additional dye-penetrant inspection.

Mr. Roe - NASA will resubmit the data package with the attach hardware included.

Foam Impact Test Readiness Review (TRR) Presentation – Dan Bell, Impact Test Team Lead

Mr. Bell stated that separate TRRs would be conducted prior to the test of each article (Main Landing Gear Door (MLGD) acreage, wing acreage, RCC, & Carrier Panel).

Mr. Hubbard noted that the waterfall schedule showed overlaps. For example, the wing acreage test on the left side of panel 2 overlaps with the TRR for the RCC test. Since RCC has priority he assumes that they will make the necessary adjustments.

Mr. Bell replied that the TRR has nothing to do with actual test dates. They can be testing wing acreage panels and still have a TRR.

Mr. Hubbard then expressed concern that these two events will consume some of the same people

Mr. Bell replied that the TRR could be supported remotely from Southwest Research. However, since RCC has priority they will slip any test article testing as required to accommodate RCC activities.

Mr. Hubbard then asked if the four fiberglass panel tests scheduled prior to the test of the actual RCC panel are required or notional.

Mr. Bell replied that the number of fiberglass tests is notional at this time. If the concern is about schedule—as long as there are no hiccups they can get multiple shots in a day. Further, reducing the number of shots from 4 will not expedite RCC testing.

Mr. Wilde stated that the impact analysis team is looking at determining specific test objectives for the fiberglass tests. The intent is to determine worst case loading transferred to the fittings and the panel.

Mr. Bell noted that investigators from Sandia Labs, NASA Marshall (MSFC), Univ. of Texas, and the Boeing Debris Team have each made predictions on the extent of tile damage resulting from impact tests #1 & #2, and these predictions are wide-ranging. For example, Sandia Labs predicts that the tile coating will be damaged (no depth), and the Classic Crater model predicts 70 cu. inches of damage. The structures community performed similar analysis and concluded that the impacts would cause no damage--because the maximum load at any point was predicted to be only 20% of design capability.

Mr. Hubbard - When will I get a test procedure to review and sign?

Answer - Possibly that evening—next day at the latest.

With that, Mr. Hubbard acknowledged the efforts of the Impact Test Team and concluded the meeting.

The meeting was adjourned at 1800

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. For
Executive Secretary
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Major General Barry	CAIB	281-283-7526
Dr. Osheroff via telecon	CAIB	281-283-7511
Dr. Hallock	CAIB	281-283-7518
Mr. Hubbard	CAIB	281-283-7517
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mike Boulavsky	Recorder	281-280-8062
Mr. Buzzard	CTF	281-283-8412
Steve Schmidt	CAIB Staff	281-283-7539
Dave Lengyel	CAIB Staff	281-283-7581
Mike Francis	CAIB	281-283-7574
Doug White	USA	281-282-2879
Ralph Roe	NASA	281-483-3307
D.R. Pye	CAIB IAST	281-283-7549
Chuck Babish	CAIB	281-283-7840
John Shannon	CTF	281-483-0716
Bo Bejmuk	Boeing	281-723-1973
W.D. Reeves	USA-OE	281-282-2608
Steve Poulos	JSC/EC	281-483-9108
J. Halsell	JSC/MA	281-244-8973
F. Benz	JSC/EA	281-483-3319
F. Delgado	JSC/ER	281-483-9077
T. Griffith	CTF	281-244-5813
Rob Ellison	KSC/AA	321-867-3135
Jose M. Hernandez	JSC/EA	281-483-6074
Jim Smiley	CAIB	281-283-4575
Michael Conley	CTF	281-483-6511
Ruth Harrison	CTF	281-483-8550

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 05, 2003
These Minutes Contain No Sensitive Data

Purpose: Briefing to Group 1 on JSC, MSFC, KSC and USA Safety and Mission Assurance

Date: 05 May 2003 **Time:** 0830 - 1230

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting are attached.

There were no action items generated from this meeting.

MGen Barry convened the meeting at 0830 and introduced Mr. Bill Harris of the NASA Space Shuttle Program Office (SSPO).

Mr. Harris' basic presentation was on metrics as related to the Space Shuttle Program (SSP). Prior to presenting his main topic, he gave an overview of the topics of discussion for the meeting. These included his presentation of the Space Shuttle Program S&MA organization. Following this would be presentations from United Space Alliance (USA), Kennedy Space Center (KSC) Ground Operations, Johnson Space Center (JSC) Safety, Reliability and Quality Assurance Office, and the KSC Safety, Health and Independent Assessment (SH&IA).

SPACE SHUTTLE PROGRAM SMA BRIEFING (Mr. Harris Briefing)

Mr. Harris then began by reviewing the SSP SMA Organization beginning with the Office of Space Flight at NASA Headquarters that is directed by the Associate Administrator for Space Flight, Mr. William Readdy. The Space Shuttle Program Office (SSPO) is located at Johnson Space Center. Also, General Michael Kostelnik, the Deputy Associate Administrator for International Space Station and Space Shuttle Programs reports directly to Mr. Readdy. The Space Shuttle Program Office (SSPO), located at JSC is managed by Mr. Ronald Dittemore, reports directly to General Kostelnik at NASA Headquarters.

Within Mr. Dittemore's organizational structure, there are five managers to include the following:

- Linda Ham – Manager, Space Shuttle Program Integration. Functions include
  - Mission Management Team
  - Payload Safety Review Process
  - System Safety Review Process
  - Mishap Investigation Team

- Wayne Hale – Manager, Launch Integration. Functions include
  - Flight Readiness Review Process
  - WEBCASS (Problem Reporting and Correction Action [PRACA] database)

- William Harris – Manager, Space Shuttle Program SMA. Functions include
  - SMA Requirement Office of Primary Responsibility
  - Oversight of NASA and Contractor S&MA
  - Technical Monitor Representative for USA Prime Contract

- Lee Norbraten – Manager, Space Shuttle Program Development who oversees the Service Life Extension Program (SLEP) previously known as Shuttle Safety Upgrades.

- Joyce Rozewski – Manager, Space Shuttle Logistics. Functions include
  - Industrial Engineering for Safety. This is the SSP Program Office's version of maintainability. This is an effort to identify those improvements which are "low dollar", but which are structured around safety in the industrial complex.
  - Process Control Working Group (more of a quality function).

Mr. Harris then noted that the Space Shuttle Systems Integration Office managed by Mr. Lambert D. Austin reports directly to Mr. Dittemore.

The Mission Operations Director, the Crew Office, Flight Crew Equipment (FCE) and Extra Vehicular Activity (EVA), located at JSC report directly to the JSC director, but functionally report to the SSPO.

Marshall Space Flight Center Organization (Mr. Harris Briefing)

The Marshall Space Flight Center Director is Mr. Art Stephenson who reports directly to Mr. William Readdy of the Office of Space Flight at NASA Headquarters. Mr. Alex McCool is head of the Space Shuttle Projects Office and reports directly to Mr. Dittemore; however, the office is defined under a Marshall directive. The project managers for the solid rocket boosters (SRB's), Redesigned Solid Rocket Motor (RSRM), external tanks (ET's) and the Space Shuttle Main Engine (SSME) report directly to Mr. Stephenson and report functionally to Mr. McCool. The Marshall Space Flight Center S&MA Office is under the direction of Amanda Goodson, and she reports directly to Mr. Stephenson. The other prime contractors associated with the Space Shuttle Program are managed here within the S&MA perspective. All projects elements are functionally responsible to the Space Shuttle Program.

MGen Hess raised another question concerning Mr. Alex McCool, head of the Space Shuttle Projects Office and located at the Marshall Space Flight Center. He noted that he is "hardlined" to the Space Shuttle Project Office, but functionally aligned to JSC and the projects. MGen Hess asked what is his main role, and Mr. Harris stated that he is functionally responsible to Mr. Dittemore for integration of activities at Marshall. MGen Hess then asked, "he works directly for Mr. Dittemore, but is the program guy stationed at Marshall"? Mr. Harris stated that the office code and job description are defined by the Marshall Space Flight Center Director, Mr. Art Stephenson, but Mr. McCool's assignment is directly administered by Mr. Dittemore.

Kennedy Space Flight Center Organization (Mr. Harris Briefing)

Before beginning this discussion, Mr. Harris clarified, after questions from MGen Barry, that there is a functional relationship between the Systems Integration Office managed by Mr. Lambert Austin and the SSPO managed by Mr. Alex McCool. The Systems Integration Office functions in direct support to Mr. Dittemore, but they do have some integrated products that require support from the elements normally supporting Mr. Dittemore. In these instances, they work through Mr. Austin to Mr. Dittemore.

The Kennedy Space Flight Center is under the direction of Mr. Roy Bridges. The Space Shuttle Ground Operations is directed by Mr. Mike Wetmore who reports directly to Mr. Bridges. The SRQA manager, Mr. Bill Higgins, works directly for Mr. Bridges. Both the Kennedy Space Flight Center and the Space Shuttle Ground Operations have a functional relationship to the Space Shuttle Program Office.

The Space Shuttle KSC Integration Office, supported by Mr. Randy Segert, reports directly to Mr. Dittemore of the Space Shuttle Program Office at JSC. Individuals in the Integration Office have office codes basically defined by KSC and they are "KSC badged".

Mr. Harris also clarified that, from a safety perspective, he has SMA responsibility over the solid rocket boosters (SRB) even though they are a Marshall program, under USA on jobs and contracts and are made at KSC.

SMA Metrics (Mr. Harris Briefing)

A large number of management processes are in place and most all are measured in some manner. In terms of safety, there are leading and lagging metrics. A lot of information comes to this program from many different people expressing different ideas with something called a metric. This is categorized as "leading" or "lagging", or it is related to personnel or flight hardware, etc.

- Leading indicators are analyses. These are indices of what we can expect for performance. Design margins, in terms of hardware, different certification, testing and verification processes, when measured and plotted, or trended, are leading indicators in terms of flight readiness and flight safety.

- Lagging indicators are measurements "after the fact". In many cases, a lagging indicator from a previous mission is the leading indicator for the next mission.

Metrics Usage: Many of the metrics we develop strictly measure performance. For example, how good is a contractor or organization doing? How good are we doing as a program for a given product? Many of the other metrics give us an indication of how healthy the fleet is, and then other indications are mission-by-mission specific. The mission specific metrics are where we see a lot of effort going towards a flight readiness review process.

When we go into metrics, very seldom is it for safety. Usually the concerns are personnel, flight hardware and environment. In personnel, we look for knowledgeable skills, morale and motivation as well as the relationships between culture, human factors and suitability. Flight hardware items include flight and ground design margins and the technology accompanying it. Environment includes the operational environment as well as political and organizational effects.

As data emerges from a program, how can we determine from the data that we have a safe program? We put it into different categories and assure that there are measurements that address each category. Again, we must have personnel as a leading index, personnel as a trailing index, personnel before flight, personnel between flight, etc.

We require metrics to be utilized in all aspects of management and expect it to be corrected and analyzed as presented to us as forums and reviews meet. It is presented as a cross-section of material that flows through the program and projects on a daily basis. Metrics are not a finished product, but a continual activity that is always under continuous review for relevance.

Program level safety is presented to NASA Headquarters who provide requirements for oversight to this organization. Information presented includes the following:

- Set of OSHA type measurements to include mishaps, incidents classified as to cost categories of property damage between $1,000 and $25,000. Incident prevention tries to capture involvement and forthcoming ideas. It is represented on all contractor workforce summaries. This does not address NASA civil servants.

- Program Management Council: This is the most senior body to which Mr. Dittemore reports. The SSPO periodically presents a package of expected metrics.

- Risk Management Structure: High-level report to NASA HQ of cost schedules technical management issues. Program management is treated separately.

Mr. Harris then presented some metric examples.

- Erosion of Skills: What is the potential impact, the action planned, and what are the results? Under the 'action planned', if it is something his organization can handle, then a commitment is usually made. If it is beyond the capability of his organization, it is open for discussion at the PMC.

- Mr. Harris then went through an example, the Boeing relocation from Huntington Beach to Houston. He discussed how the metrics are used, how issues are mitigated, and how plans developed and reported out.

Process Escape: A process escape is any error that passed a quality check and went undetected. Example: If an item goes through a process of quality checks and passes, but fails in the final check it is defined as a process escape. Something that gets into flight and is later found to be anomalous that was not detected earlier (perhaps no inspection or check) will be considered a process escape. It may result in a new inspection being added. Process escapes can include management, budgeting, and

schedules – not just the hardware process. There are thousands of variations of the final check. An example of a non-process escape was given by a NASA employee in the audience. She stated that, if during a scheduled quality inspection at KSC, a NASA Quality Control Inspector found something wrong, that error is not considered to be a process escape because the inspection was scheduled and is a part of the process. On the other hand, if an item was closed out, say, in the High Bay and then, for some reason, had to be reopened on the pad, and we found some debris or other foreign object, that would be a process escape because we had gone through the entire process (including final inspection). Mr. Harris gave a narrow definition of process escape: Any incident that occurs in a process that was not "as designed".

Audits include a number of different items such as International Standards Organization (ISO) certifications, Aerospace Safety Advisory Panel reviews or any other external group audits. Audits are considered a more formal disciplined approach.

Mr. Harris then presented a summary of the foam loss anomaly on the STS-112. He presented the track record in terms of dates, action items and corrective actions.

MGen Hess asked if there were reports similar to the book provided to him listing Orbiter problems (provided at an earlier briefing) on other projects within the program. Mr. Harris stated that if there were any, he had not received them. MGen Hess than asked if there were any integrated safety efforts across projects. Mr. Harris said this was correct (no examples were cited). Mr. Harris concluded his presentation and introduced Mr. Russ Turner of the United Space Alliance (USA).

UNITED SPACE ALLIANCE PRESENTATION (Mr. Turner Presenting)

Mr. Turner provided a presentation on USA Certification of Flight Readiness process, performance measurement, and Safety, Quality and Mission Assurance (SQ&MA). He also introduced Mr. Dick Beagley who is the vice president of the USA SQ&MA organization.

Mr. Turner described the responsibilities and organization of USA and Mr. Beagley's organization. Mr. Beagley does have some line activities such as doing inspections, but his primary task is to essentially function as an independent assessment activity to verify that the organization is meeting its commitment.

Process owners have an overview of processes such as engineering and manufacturing. They have accountability for three things:

- Making sure people have a solidly defined career path
- To make sure that we have world-class processing activities. Do we do engineering well? How are we getting best practices bench marked against other companies?
- To make sure we have the right tools to support those process activities.

Mr. Turner Discussed the "Safety is our Responsibility" concept to keep the public, flight crews, employees and hardware safe. There is a significant amount of focus on behaviors, processes and systems. Open "reporting" and communication is key. Much effort goes toward providing

management access to personnel at the working level. USA emphasizes taking action and closed-loop accountability.

The USA CEO has ultimate safety and quality accountability. The manager of SQ&MA reports to the Office of CEO/COO and is independent from the program organizations. Internal Auditing reports to Office of CEO/COO. Safety and quality performance reviews are briefed to CEO/COO. The CEO/COO sign flight readiness statements as well as affirming readiness at NASA Level 1 FRR. The program manager does a separate affirmation in Mr. Dittemore's chain of command about his readiness.

Mr. Turner then discussed the company's flight readiness certification program. Each of the eight USA elements such as SRB's performs their own readiness preparation process. That includes participation with their own NASA technical management representative (TMR). In the case of SRB, it means starting at Level 5 with the Marshall organization and working up through that readiness process. There are some extra steps they go through to support the Marshall process before coming together in USA.

Mr. Turner stated that material often covered at the USA Flight Readiness Review (FRR) is not covered at the NASA level 1 FRR. The Technical Management Representatives (TMR's) decide what items should be taken forward to the higher level reviews. If the TMRs did not include something that USA thought was critical, this would be discussed with them. USA performs at a lower level of detail than what ultimately rolled up for review by the board.

A brief discussion was conducted as to the type of USA organizational elements that support the flight readiness reviews for NASA, USA and USA's SQ&MA.

MGen Hess asked Mr. Turner to compare the thickness of USA and NASA FRR materials (length of time/content of FRR briefings). Mr. Turner said thickness is generally the same in terms of technical content, but because of NASA's overview of the mission, theirs is longer. The primary driver is Orbiter material. MGen Barry asked about the timing of the two FRRs. Mr. Turner answered that they usually happen within a week of each other.

MGen Barry stated that the number of Government Mandatory Inspections Points (GMIPs) has gone from 44,000 to 8,000. He then asked if there have been reviews to determine if that is the correct number. Mr. Turner responded by describing an incident regarding a missing washer that occurred on a Shuttle ferry flight. The story exemplifies eliminating redundant, ineffective inspections. The goal is to make the inspections effective, not to get rid of inspectors.

MGen Barry asked if there were periodic review of GMIP numbers. Mr. Wetmore explained the NASA review process. Currently, there is not an ongoing review process to reduce GMIP numbers. There is a process where engineering, if they experience a problem, evaluate whether adding quality inspections will correct the problem. Mr. Beagley stated that after review there was a realignment of non-critical inspections.

Mr. Beagley stated that USA was working on new techniques for supplier audits. USA has historically performed compliance audits but rarely has had an opportunity to observe hardware being

built, i.e., process audits. Process audits are very involved and do present some costs to the suppliers and sometimes disrupt their business a bit during the audit. USA has completed two pilot projects doing the major process audits and has found them to be useful. Audits usually cause some business disruption, so a compromise has been reached. USA goes in to a supplier and observes the hardware being processed. An audit is not scheduled unless there is a piece of flight hardware going through the facility. The goal is to secure program approval to concentrate on process audits and move farther away from compliance audits. USA wants to make process audits the primary focus.

MGen Barry asked if there had been any major findings. Mr. Turner responded that he would have to check but the only thing that came to mind was a configuration management issue on dry lubricated versus lubricated pump.

Mr. Turner mentioned that USA had just completed 150 independent ISO audits with only 2 minor findings.

BGen Deal asked if the data regarding industrial safety was strictly USA data. Mr. Turner replied that it was and that the data in Mr. Harris' charts were for the entire Shuttle program.

Mr. Turner then briefed the only Type B Mishap in company history. This dealt with the event of the Remote Manipulator System when it was struck by a work platform. This incident caused around $300,000 worth of damage.

Mr. Turner discussed worker overtime and stated that the variability in hours expended is driven by launch schedules and may end up "going red" due to expenditures for the STS-107 accident. There were many people who were paid significant amounts of overtime out in the fields of East Texas who don't normally get such pay.

MGen Hess asked if it was a corporate decision not to use overtime during the holidays. Mr. Turner stated that he could not answer that question and that decisions regarding the launch manifest drive the overtime. He also stated that launching on 7 January versus 2 January would have impact overtime. Maj Gen Hess then asked if the 4.2% overtime was budgeted and Mr. Turner responded in the negative.

In discussing the timeliness metric, Mr. Turner pointed out that one item had been missed for STS-117 launch that was missed, and that this metric will remain red until launch.

Mr. Turner pointed out on the next several slides that Boeing had been having some problems with delivery timeliness on studies concerning upgrades and modifications to the Orbiter. They have been behind on a couple of studies, but the expectation is that they will recover.

Mr. Turner then moved on to a discussion of quality metrics and that he believed the "First Time Quality" metric was the metric to be utilized.

Mr. Turner then discussed processing mistakes made by their technicians. This is called a workmanship problem report (PR) and occurs when a technician damages something such as a nicked wire. USA has a requirement to be below 23 PR's per flow hours. Flow hours are nominally 575,000

per flow but can go as high as one million. The most common cause of a PR is simply a mistake by a technician. The second most common cause is when process is poorly designed causing errors to be made. He stated that the Orbiter was designed to fly, not to be processed.

MGen Barry then stated that the Board had just gone through a Work Authorizing Document (WAD) review at KSC, MSFC, and Palmdale. MGen Barry believes there are lessons to be learned from WAD reviews. He then asked if there are any metrics on WAD reviews within the USA process. Mr. Turner said there was. MGen Barry stated that there is a concern that the metrics on WADs are not catching all errors.

Col Nakayama asked whether processing debris was tracked and if there was a metric. Mr. Turner replied in the affirmative. Col Nakayama then asked how debris compared with foreign object debris (FOD) tracking, and Mr. Turner stated he would have to look and have an answer to the board.

MGen Barry stated there were concerns about the definition of FOD versus processing debris. Mr. Craig Clokey said he would provide an input on USA's process. MGen Barry then stated he had a concern that greater NASA involvement in FOD prevention beyond GMIPs might be warranted.

Mr. Turner completed his portion of the briefing by covering the safety and quality culture at USA. Safety and quality is all about people being motivated to do the right thing. Mr. Turner and Mr. Beagley take a personal interest in all aspects of USA's program. Mr. Turner stated that safe operations are USA's number one focus. A number of examples were given as to how the safety program is conducted by USA.

Mr. Turner also made very positive comments on contract consolidation on how it has reduced costs and improved efficiency. He described improvements which have accrued to the program from integrating such items as non-conformance reports and FEMA/CILs into a single integrated process where in the past there had been up to 27 separate processes which were not integrated.

MGen Hess asked for an example of an independent assessment that affected USA operations. Mr. Beagley stated that there are two aspects to these assessments; one is proactive for all Certification of Flight Readiness (CoFR) elements while the other is reactive for problem investigations and resolutions. One example was providing an assessment of technology issues with the Cockpit Avionics Upgrade. MGen Hess wanted clarification on the difference between a separate assessment and an independent assessment. Mr. Turner says independence is gained by reporting directly to the CEO and maintaining a separate budget.

SHUTTLE PROCESSING MISSION ASSURANCE AND SURVEILLANCE PRESENTATION (Mr. Wetmore Presenting)

Mr. Michael Wetmore, TMR for Ground Operations, made this presentation.

He stated that his organization has 380 direct report employees and another 130 civil servant employees from support organizations. He then gave a detailed description of his organization.

Safety and Mission Assurance is embedded in all tasks for ground operations.

MGen Barry asked how Mr. Wetmore and Mr. Harris go together on the TMR for the SFOC contract. Mr. Wetmore then described his relationship as a Technical Management Representative (TMR) with Mr. Harris. He stated that authority is divided in accordance with the statement of work and the work breakdown structure. Mr. Wetmore said that Mr. Harris owns the requirements and that Mr. Harris sub-delegates to Mr. Wetmore to perform surveillance.

Mr. Wetmore then said surveillance begins at landing and continues throughout the whole flow process to launch. He stated that NASA provides insight over the work of approximately five thousand contractor employees. Mr. Wetmore provided a definition of in-family tasks as activities that have been previously experienced, analyzed and are understood. In-family tasks are categorized as critical and non-critical tasks. The critical tasks are activities that must be performed correctly to assure safety of the public, flight, processing personnel, flight hardware facilities or ground support equipment. Anything that is not classed as in-family is considered out-of-family, so it is typically those things not seen or experienced before hand are classified as out-of-family. Surveillance is performed on both in-family and out-of-family events. As soon as an event is classified as out-of-family, it requires oversight meaning the contractor cannot go forward with a disposition without the approval of NASA engineering and Mr. Wetmore. Insight equates to observing the contractor whereas oversight would mean the contractor could not make a move without NASA.

MGen Barry asked when the next GMIP review would take place. Mr. Wetmore stated that none is currently planned but that the CAIB report may influence that.

Mr. Wetmore described the processes that the engineering organizations perform in preparation for the CoFR. Col Nakayama asked how observations and reviews were selected. Mr. Wetmore answered that they are selected by each systems engineering group going through the planned work in their section to determine which items would be critical to that flow. It is a risk-based assessment and not random sampling.

Mr. Wetmore also described the NASA process of oversight surveillance that includes approval of "out-of-family" problem disposition, changes to launch and landing procedures, changes to requirements, procedures for new requirements, and design of launch site equipment.

Mr. Wetmore defined the "big 3 errors" used to categorize metrics used for CoFR preparation. The big 3 are 1) safety, 2) potential for hardware damage and 3) requirements implementation changes. His organization created a form and database for tracking called Processing Insight and Trend Analysis (PITA).

Mr. Wetmore provided a description of the Safety and Mission Assurance (S&MA) organization and that it consisted of around a 105 personnel. He described the processes S&MA used for CoFR preparation. Their responsibility is the handling of the 8500 Government Mandatory Inspection Points (GMIPs).

Col Nakayama asked if there were any audits or assessments of work paper. Mr. Wetmore answered that the PITA database is one source of information on the adequacy of the documentation. Some

GMIPs might call for audits periodically. Ms. Harrington responded that an initiating event might be a concern that a process is not being followed properly. MGen Barry expressed that audits and assessments were an area of concern to the Board.

Col Bair stated that the Air Force has an intentional rather than an ad hoc program. He is concerned that NASA's program is more ad hoc. Col Bair stated that every year there will be "x" number of inspections done. BGen Deal said, "You probably ought to break out what that 75 people do because that's not the number of people on the floor. You've got people going out to the vendor, etc." Mr. Wetmore responded that the 75 personnel do not include those that go to the vendor. They are in a separate group. The 75 include the people that cover three shifts a day to those areas in ground operations such as the Vertical Assembly Building.

Mr. Wetmore described the metric dealing with overtime and how it was tracked. He mentioned that there was an average of 4.2% overtime rate. Overtime rate varies in the various organizations. It is 0% in a lot of the administrative organizations and 20% in some of the processing organizations. Maximum overtime deviations and violations are tracked to ensure that no individual is overstressed. Mr. Wetmore also provided details on the work rules as related to stressing the work force. Dr. Bluford said "I would assume that when you trim that data, you come up with some recommendations for improvements ('I need more time to do this. I need more people to do that'). I assume that's part of the process in order to try to reduce the amount of overtime." Mr. Wetmore stated that NASA looks at the data and evaluates hours, work schedules, skills, location of spikes and then makes a determination.

Mr. Wetmore then began discussing the logistics organization. He stated that oversight is performed on an exception basis. There are about 26 NASA personnel looking at about 1000 contractor personnel. Metrics used by the logistics organization are primarily performance metrics and not safety metrics. They are also looking for any process instability. Metrics also looks for significant cannibalization of parts that would put risk into the system. Late part deliveries would also put pressure on the system. While discussing the logistic organization's CoFR preparation activities, Col Bair asked about the process for testing of parts that have been sitting on the shelf for years. Ms. Terry Keeney answered that NASA has been examining this issue to determine if changes are needed. She stated that there is Problem Resolution Team involvement on what is the right level of testing and review. There are several issues being worked.

When logistics gets ready to certify items for flight readiness verification, they are going to verify a long list of items.

Mr. Wetmore summarized the Shuttle processing flow. Col Nakayama referenced the previous chart and asked how much of the information (e.g. a particular GMIP issue) developed during the flow is pre-announced. He gave an example in the case of a GMIP. When one gets to a certain point in the WAD, a NASA inspector is needed. That is pre-announced. It is known they are coming to inspect. If, for example, engineering was going to do an in-depth observation of critical procedures path, is that pre-announced? Does everyone know what the areas of interest are that engineering is going to be observing? Mr. Wetmore answered that all inspections are pre-announced in a pre-published plan. Everyone in the process flow is aware of NASA's involvement and the time of involvement.

Mr. Wetmore described the responsibilities of KSC supporting organizations for Launch Readiness Reviews (LRR). Dr. Bluford asked if there was a security check involved somewhere in this process. Mr. Wetmore answered that institutional organizations verify that the Security Plan is adequate and implemented properly.

BGen Deal asked about infrastructure readiness. Mr. Wetmore responded that if there were facility issues they would be brought out at the LRR but they are normally covered in day-to-day activities. The Facility Systems Division handles these issues. The Spaceport Services Office would address other issues such as roof problems.

Mr. Wetmore moved on to discuss the GMIP process, how inspection requirements were determined, the approval process, and the inclusion of inspection data into the Work Authorizing Documents (WADs). MGen Barry discussed N-Stamps, where there seems to be a process that you give contractor time to correct a problem and it is not logged as an N-Stamp. Col Nakayama related USA and NASA activities to T-Stamp, Q-Stamp, and N-Stamp reviews and expressed concerns that UYSA and NASA do not collect metrics on the results of first time quality inspections. Mr. Beagley answered that USA quality is around 98-99%, so the number of items is not significant. There needs to be an understanding that GMIPs are not a serial process but many activities occurring simultaneously. Mr. Bill Higgins stated that there are no problems that are fixed without all the appropriate paper at all levels. Mr. Wetmore added that there is as much likelihood of a USA inspector rejecting work as there is of a NASA rejection. The occurrence of USA performing the work and documenting it, then NASA withholding its stamp is very low.

MGen Barry said there was enough anecdotal and interview evidence regarding the lack of metrics on NASA insight on rejection and rework rates to cause concern. He observed that there needed to be a healthy tension in order to cause the "Cooperate and Graduate" syndrome about which the Board is concerned. MGen Barry indicated the inspection issues raised by the board would come under Other Significant Issues and not be associated with the Columbia mishap.

MGen Barry noted the lateness and rearranged the agenda to delay the presentation of the JSC personnel to another day.

Mr. Wetmore provided information on Ground Operations involvement in STS-112, 113, and 107 external tank (ET) foam events. His organization performed some film review and provided findings to the MMT and design centers. For STS-107, external review by KSC identified the debris strike, the ET Project identified the probable weight, integration identified the transport mechanism, and Orbiter Project performed damage assessment. KSC listened to the damage assessment but were not polled. Had they been polled they would have concurred with the damage assessment.

Dr. Bluford asked if there was follow-up work (i.e. GMIP) on STS-112 and 113. Mr. Wetmore responded that if the External Tank Project had determined that any additional work were desired it would have been up to the design centers to generate the requirements. Mr. Wetmore's organization cannot self generate a GMIP as they are requirements which originate at the design centers.

MGen Barry asked why the PRCB did not list the ET foam events as an In-Flight Anomaly. Mr. Wetmore responded that the normal disposition of an IFA is to assign an action to the PRCB as part

of the closed loop accounting process. It was proposed as an IFA and then turned into a PRCB action to the design center which is nominal procedure, and whether it is continued to be tracked as an IFA is almost incidental because it is put into a closed loop requirement structure. MGEN Barry asked if foam shedding from the previous flight would normally be carried in the STS-107 FRR. Mr. Wetmore responded that carrying the issue forward to the next FRR would normally be done. After a brief discussion of the procedures with MGen Barry, Mr. Wetmore said he would be glad to check into the procedures for the final tracking of quality.

Col Bair asked if there is work force mobility from S&MA and the work force. Mr. Wetmore answered that there was some mobility from the contractor side into NASA, but there was no mobility on the NASA side unless the inspectors choose to pursue another career path. Mr. Beagley referred to low attrition in the work force for USA and more mobility. USA inspectors primarily come out of the technician work force and USA does have a lot of growth opportunity.

KSC SAFETY, HEALTH AND INDEPENDENT ASSESSMENT (SH&IA) DIRECTORATE (Mr. Toledo Presenting)

Mr. Oscar Toledo made this presentation. He described the functions of SH&IA and the organization structure put in place to support those functions. He stated that SH&IA has 64 people assigned with some contractor support.

Mr. Toledo described the change in organizational structure based on the "KSC 2000" reorganization. Mr. Toledo's group went from a centralized approach to distributed S&MA.

Mr. Toledo described the three-tiered approach SH&IA utilizes for safety and mission assurance utilizing independent assessment, insight/oversight, and self-monitoring. Mr. Toledo also described the variety of reviews that SH&IA supports during a mission flow. Mr. Toledo then showed several charts with examples of observations, findings, and recommendations associated with assessments and audits performed on STS-112, 113, and 107. No recommendations were made for STS-113 and for STS-107 the focus was on the payload.

A member of the audience asked how much time the SH&IA people focused on the Shuttle program. Mr. Toledo said there are 13 personnel assigned (eight civil servants and five contractors) with augmentation as required. The same member of the audience then asked how much of his funding actually comes from the Shuttle program and how much of that was for contractors. Mr. Toledo stated that his funding comes from NASA Headquarters Code Q for the contractors. Mr. Toledo completed his portion of the presentation.

This was the last question from the Board.

MGen Barry then requested that the representatives from Johnson Space Center return on another day and adjourned the meeting at 1230.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

For

Attendees are as follows:

NAME	ORG.	PHONE
Major General Barry	CAIB	281-283-7526
Major General Hess	CAIB	281-283-7512
Brigadier General Deal	CAIB	281-283-7507
Dr. Ride	CAIB	281-283-7503
Col Bloomfield	CAIB	281-483-7809
Mr. Shannon	CTF	281-483-8412
Mr. Choban	Audio	281-283-7591
Mr. Hartman	Recorder	281-280-8033
Dave Lengyel	CAIB Ex. Secretary	281-283-7525
Col Dave Nakayama	CAIB Gp I	281-283-7835
Col Tim Bair	CAIB Gp I	281-283-7521
Jack Lehman	CAIB Gp I	281-283-7842
Dwayne Day	CAIB Gp 4	281-283-7588
E.J. Ripma	CTF	281-483-8574
J.D. Wetherbee	JSC/NA	281-244-8918
Jerry Holsomback	JSC/NA	281-244-7956
Yolanda Marshall	JSC/NA	281-483-2422
Don Hammel	KSC/PH	321-867-0803
Jean Flowers	KSC/PH	321-861-9304
George Jacobs	KSC/PH	321-861-3964
Bill Higgins	KSC/PH	321-861-7901
Russ DeLoach	KSC/PH	321-861-4123
Doug Whalin	USA S&MA	321-867-8585
LtCol Don White	CAIB Gp 2	281-283-7570
Maj David Kral	CAIB Gp 2	281-283-7571
Oscar Toledo	NASA/KSC	321-867-1460
Pam Zeitler	NASA/KSC	321-867-0834
Terry Keeney	NASA/KSC	321-861-5382
Capt John Schmidt	CAIB Gp 2	281-283-7820
Kelly Beck	CTF	281-483-8448
Clare Davy	CAIB/USAF	281-283-7841

Russ Turner	USA/CEO	281-286-4207
Dick Beagley	USA/SQMA	321-861-3528
Craig Clokey	USA/SQMA	281-212-6236
Bill Harris	NASA/SSPO	281-483-0480
Mike Wetmore	NASA/KSC	321-867-4343
Ruth Harrison	CTF	281-483-8550
Mike Francis	CAIB Gp I	281-283-7574

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 07, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 07 May 2003 **Time:** 1230 - 1610

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the DOJ CDS Database.

There were seven action items generated from this meeting.

Admiral Gehman convened the meeting at 1230.

Mr. Hubbard, supporting via telecon from Southwest Research in San Antonio, advised the Board that he would likely drop off of the meeting around 1330-1400 due to testing scheduled to take place. The foam testing will be going to 8 degrees impact angle today. The more important discussions of what items should be considered for the RCC impact testing will be addressed at another time.

Dr. Osheroff, supporting via telecon, verified that a summary from Mr. Hubbard would be provided after the test today.

Admiral Gehman stated that he had a number of board process issues on the agenda today:

- What Return To Flight (RTF) issues should be dealt with?
- What is the schedule for testing and analysis?

Mr. Lengyel listed the nine items at the conclusion of the working scenario brief yesterday via the groupware. This allows the Board to "neck down" and focus on what testing and analysis that needs to get done. The Admiral stated that there are two questions before the Board:

- What is the time frame for doing these things? Is it critical that they get done before the report is written? If so, when do we need them completed?
- Who will be appointed the point of contact?

Report Writing Discussion

Admiral Gehman advised the Board that many members of Congress have asked if the report could be completed by the time Congress recesses by the first of August.

Mr. Wallace stated that 1 August was a reasonable internal goal, but he is less comfortable making it an external commitment. The Admiral agreed with Mr. Wallace.

Mr. Tetrault stated that there will probably be a couple of tests that will be outstanding at that particular point, but he did not see any tests on which the report would hinge. These are things that need to be done to close out. He thought that these items could be written around and added later.

The Admiral stated that he thought Group 1 and 2 still have more work to do. He did not believe they are currently ready.

The Admiral stated that the report was not scenario dependent. If they use the rest of the month of May to complete some writing in Houston, and then shift to Washington DC in the first week in June to start writing very seriously, this would give the board the entire month of July for editing. He thought this was a fairly reasonable goal, but would defer to the Board.

MGen. Barry raised a concern about the time needed to get to a publisher. He suggested backing out two weeks, which would move the due date to 15 July.

Mr. Wallace stated that he thought that they needed to account for unforeseen time impacts to the schedule.

Mr. Hubbard expressed a concern about a block of time for discussion and coming to a consensus among the Board. The technical issues may be straightforward, but the things for the other two-thirds of the report may be quite contentious.

Dr. Osheroff reminded the Board that he is committed to being in Germany for ten days in June. He expressed concern about interacting with the Board while he was abroad.

Admiral Gehman stated that they have found a technical answer to allow every member of the Board to edit text remotely in a secure way via the internet. He does not see any problem with Dr. Osheroff being gone for ten days.

The Admiral then stated that he would like to have as an internal goal of having the report ready by 1 August.

Key Testing and Analysis Events

Admiral Gehman then directed the focus of the meeting to the Group session presentation, which had a list of key testing and analysis events that the Board wants to get done to help write this report. He would like to put some names beside them along with a timeframe. This would identify the limiting factors and allow the Board to get this testing done or go out and get this done independently. The key testing and analysis events with the assigned Point of Contact (POC) are:

- Completion of foam impact testing at Southwest Research – POC is Mr. Hubbard

  Mr. Hubbard added that in the first week of June, they will be testing RCC panel 6 and around June 20, they would be testing RCC panel 9.

  The Admiral stated that he had two questions.

  1) He asked if he could count on Group 3 writing other analysis results while waiting for foam testing to be completed. Mr. Hubbard assured the Admiral this would be occurring concurrently.
  2) What is the impact on the Board of a "big time" delay possibly due to technical problems? Should they hold up the report for that? Mr. Tetrault stated that this should not hold up the report, they could make it a Return

To Flight (RTF) issue. Mr. Hubbard stated that he thought that you could write ninety plus percent of the report. The Admiral suggested writing some parameters to give to the Stafford Task Force to follow up on.

Dr. Osheroff pointed out that the strong expectation is that the RCC panels will get broken and he did not regard these tests as a Return To Flight issue.

The Admiral then pointed out that it is highly likely that we will never be able to prove that the foam broke a hole in the leading edge of the Orbiter. We will be able to prove that it was possible, but will probably never come up with any evidence to prove that on launch of STS-107 that the foam strike broke a hole in the front edge of the Orbiter wing. We will be able to conclude it with some words like most probable, most likely, maybe or possible. Our report is not dependent on us proving that fact. The report is not scenario dependent.

Mr. Hubbard highlighted that the CAIB charter asks us to look at the most probable cause. To say that this is not scenario dependent seems to him to be abrogating part of our charter.

The Admiral responded that he did not want to diminish the significance of the foam testing in any way. Then the board continued on with identifying key testing and analysis tasks and members who primarily responsible.

- Aerothermal analyses to correlate off nominal heating trends in left fuselage sidewall and left OMS pod heating observed in the MADS data. POC – Dr. Widnall. Dr. Widnall had an issue with getting NASA on track to provide a plan on the thermal analysis test plan, which resulted in an identified action to set up a meeting as listed at the end of these minutes.
- Instrumentation wire burn-through arc jet tests and thermal analyses to support the timing of observed instrumentation failures. POC – Mr. Tetrault. Dr. Widnall had a concern that the temperatures being used (1800 degrees) should be closer to 5000. She later amplified that she wanted to see a realistic arc jet test. Mr. Tetrault agreed with Dr. Widnall's comment, and stated that the issue he had is that it is hard to envision that a jet coming through at the expected angles in areas 7 or 8, whether it is the T-seal or not can get to the wires back by the wheel well. It is an unexplained item at this point.
- Instrumentation circuit analyses or testing to confirm the failure signatures observed in the data. POC – Dr. Hallock.
- Hypersonic wind tunnel testing and aerodynamic and structural analyses to explain aerodynamic off-nominal roll and yaw moments observed in flight data. POC – Dr. Widnall.
- Thermal analysis of RCC panel 9 clevis and spar temp sensor responses to support or refute flight data. POC – Dr. Widnall. Mr. Tetrault questioned the need for this item. Dr. Widnall suggested using this item to estimate the size of the hole in the wing.

- Arc jet testing and/or analysis of previous arc jet testing to determine feasibility of RCC erosion observed in several key pieces of RCC panel 8/9 debris. POC – Mr. Tetrault. Mr. Buzzard asked if this test was critical to writing the report. Admiral Gehman responded that he did not believe so.
- Continued forensics testing and analysis of significant recovered debris. POC – Mr. Tetrault
- ET foam dissection and cryo-pump testing. POC – BGen. Deal. BGen Deal reported that ET dissection is essentially done. The cryo-pump testing should be completed at MSFC by the end of May.
- Testing of the bolts/LESS structure (added by R Tetrault during group discussion). POC – Mr. Tetrault/MGen. Barry
- Policing of the details of the fault tree closeout. POC – Dr. Hallock

Dr. Widnall asked if return to flight recommendations from the CAIB would all be technology recommendations or will process and other considerations be included. Mr. Wallace, MGen Barry, and Admiral Gehman all indicated their agreement that the return to flight recommendations not be limited to technology but will address technical issues as well as anything else that needs to be included. Admiral Gehman cautioned against fixating recommendations on an on-orbit repair system when other recommendations regarding fixing processes, the PRACA system, the anomaly/waiver system, and other issues might lessen the ascent risk.

Mr. Tetrault expressed a concern that the drawing system of the Shuttle is the worst system he has ever experienced in his 30 years of engineering. Every time that he has looked at a drawing it has been wrong. If the shuttle is going to be run for another 18 years, and this is a system that is not on CAD/CAM, all of the changes should be implemented. Group 1 should be looking at the drawing system and making some recommendations.

Dr Widnall expressed a concern that they are receiving PowerPoint presentations versus technical papers and there are a lot of holes.

Mr. Schmidt brought up issue of extended activity for Dr. Linda Pate-Cornell of her tile report. Dr. Widnall volunteered to close the loop with Dr. Pate-Cornell.

Return to Flight

Admiral Gehman stated that two issues have been sent to NASA so far concerning Return To Flight.

Mr. Tetrault brought up the need for two different avenues (or buckets) for Return To Flight:

- High risk acceptance criteria
- Long term for 7 people

This concept brought up a spirited discussion in which Dr. Ride and Dr. Bluford endorsed a one-bucket system emphasizing that there was not enough momentum in the current political arena to differentiate between flying a minimum crew versus a full crew. The Admiral proposed that the

Board needed to evaluate the safety of the shuttle vehicle and forget about the International Space Station (ISS). Maj. Gen. Hess suggested that the Board was being too prescriptive.

Dr. Widnall questioned whether all recommendations for RTF were going to be technology. The Admiral responded that it could be whatever they wanted.

The Admiral then asked the Board if they distinguished between future flights to the ISS or Hubble. The Board should not get hung up on these details. The Admiral is concerned that the Board is falling into the same trap that we accused others of. That is fixing the symptom in front of your face and not fixing the organization, the process. We are deluding ourselves by thinking that on-orbit inspection and repair will solve the problem.

Dr. Osheroff questioned what is the problem.

Admiral Gehman responded that NASA has evolved into an institution that cannot sense when changes are occurring. They are not able to sense when they have tiny faults and are trying to predict when a bigger one is going to get you or they are not able to sense that an aging Orbiter has different characteristics than a young Orbiter. They are not able to adapt to the environment.

Dr. Widnall added that NASA treats anomalies as data, and that data becomes a justification for the next flight.

Admiral Gehman stated that you have something, which continuously goes wrong with the system. It is not designed to operate that way. You get away with it a number of times. You convince yourself that you can get away with it for a couple of more times and then sooner or later it bites you. This promotes the question, what else is out there? The Admiral then offered two questions:

- Are you organized to detect these things, and are you organized to report them, are you organized to make sure top management knows about them?
- Or, are you organized to suppress them through bureaucratic means? And that is this PRACA business, and an anomaly is not an anomaly if we have seen this before. All independence has been taken out of the system – the engineers are not independent anymore, the safety guys are not robust enough.

MGen. Hess stated that if you do not assume that you can get rid of the risk over time, then you just get used to it.

The Admiral stated that it is within reach of this Board to achieve a state at which we can prescribe a system of checks and balances and organizational attitudes and cultures, which would at least be on the lookout, at least are sensitive when a snake is lying in the garden.

Dr. Logsdon questioned that when Bryan O'Connor was here with the Board did he talk about the robustness of the NASA S&MA system from his perspective. Admiral Gehman answered that he did not in detail or specific terms. Dr. Logsdon and Maj. Gen. Hess are planning on talking to Mr. O'Connor next week.

MGen. Hess asked if the Board was going to entertain a recommendation on how they are currently organized for Human Space Flight. Admiral Gehman responded yes, maybe. MGen. Hess stated that when you start to walk down through all of the various lines of communications, it is this posse that is in charge of this thing and he thinks that they will never become organized from a risk management structure when it is that diverse.

Admiral Gehman put the question to the Board if anybody would comment on what would be a good way to search databases or search documents to see if we could come up with an example of another time when the machine was talking to us and we decided to live with it. Harry McDonald did this by going through the PRACA system. He came up with a couple of cases where he thought more attention should have been paid to some of these faults. But the PRACA was so hard to use and not kept up.

Dr. Ride suggested talking to some people who have been around for a while and see if we get six or seven ideas and research them briefly through the database.

Dr. Widnall asked if the whole Board could get a senior level briefing, because this will turn out to become an important issue for us. This resulted in an action for Bryan O'Connor to brief the Board.

The emphasis of the meeting then shifted to the RTF section of the Groupware appended to these minutes.

Admiral Gehman stated that another astounding thing is (regarding Return To Flight discussion) that there are hundreds and hundreds of inspectors conducting these 8500 GMIPs and they do not keep any records.

Capt. John Young's issues on Return To Flight were not covered because of time constraints.

The Admiral then brought up report writing. Next Friday the Board will start analyzing the outline of the report. An outline of the report was handed out for the Board for advanced reading. The Admiral intends to accomplish this during the regular Friday 1230 meeting.

The Admiral suggested that the next public hearing be in June when the Board has moved to Washington DC.

This meeting concluded at 1610.

Identified Actions

1) Frank Benz to come over for aero-thermal analysis test plan, etc. with Dr. Hallock & Dr. Widnall

2) Action to Dr. Widnall to examine tile report from Dr. Linda Pate-Cornell to evaluate whether additional activity is required or whether focus has changed.

3) Action to Executive Secretary to set up a briefing by Brian O'Connor to come to Board and brief on safety organization, budgets, manpower, etc.

4) Action to Steve Wallace to become acquainted with NASA activities involving On-Orbit Inspection and Repair, or have Paul Hill come over and brief.

5) Action to Steve Wallace for an RFI on briefing from NASA on Safe Haven

6) Action to Executive Secretary to draft letter for the Admiral's signature regarding closing out fault trees earlier.

7) Action to MGen Hess to examine PRACA and the waiver system to identify critical items that are continually waived in order to continue operations.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Major General Hess	CAIB	281-283-7512
Dr. Hallock	CAIB	281-283-7518
Brigadier General Deal	CAIB	281-283-7507
Mr. Hubbard via telecon	CAIB	281-283-7517
Dr. Logsdon	CAIB	202-994-7292
Dr. Osheroff via telecon	CAIB	281-283-7511
Dr. Ride	CAIB	281-283-7503
Mr. Tetrault	CAIB	281-283-7509
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Buzzard	CAIB	281-483-8412
Dr. Guy Bluford	CAIB	281-283-7813
Mr. Shannon	CTF	281-483-8412
Mr. Choban	Recorder	281-483-4890
Dave Lengyel	CAIB Ex. Secretary	281-283-7525
Steve Schmidt	CAIB	281-283-7577
Dwayne Day	CAIB Gp. 4	281-283-7588
Mr. Griffen	OSB SMA	480-585-8039
Lt. Col. Woodyard	CAIB	281-283-7565
Howard McCurdy	CAIB Consultant	202-885-6236
Les Reingold	CAIB	281-283-7539
Dennis R. Jenkins	CAIB Gp. 4	281-283-7589

CAIB Input Session on RTF Preliminary Recommendations (Group Outliner)

Potential CAIB Inputs on RTF (Return to Flight) Recommendations

An independently-led bottom-up review of the Quality Planning and Requirements Document (QPRD) for KSC SFOC operations -- focused on the NASA Quality Assurance manning, GMIPS re-look, and discrepancy tracking.

An independently-led bottom-up review of the Quality Planning and Requirements Document (QPRD) for MAF ET production -- focused on the DCMA Quality Assurance manning and GMIPs re-look.

Redesign of the ET bipod ramp (already in work by NASA). **
NDE of the foam on the ET -- focusing on the flange and PAL ramp area.

Ensuring 2-person operations in all close-out/final configuration areas (specifically, two ET foam spraying areas which aren't mandated today).

NASA must closeout the fault tree before return to flight. ** (or look for ways to communicate this appropriately)

(Re)Evaluation of public risk during launch/reentry

NASA Inputs on RTF (Return to Flight) Recommendations **=general agreement that this is a candidate for interim RTF recommendation

Understand history of foam loss, debris generation on the ET, SRB and SSME and identify source of debris.

Determine the root cause and corrective action resolution of loss of foam on ET bipod ramp area flange. **

Investigate entry options after repair of TPS to minimize thermal impact to Orbiter

Determine if there are other materials which FALGRO does not have data for

Investigate and evaluate ground assets to view launch activities. Camera locations and capabilities for day and night. **

Investigate location and specification of ET camera (possibly 2). **

Recommend schedule for Destacking SRB short stacks to allow hardness testing of the ETA rings

Develop inspection technique and options to reach bottom of vehicle and repair technique both while docked to the ISS and when undocked. (on orbit repair)

Steve Wallace will investigate current status

John Young Inputs on RTF (Return to Flight) Recommendations

Orbiter Bottom Damage Protection

Space Shuttle Flow Processing Upgrades

Treating Tile Damage by Debris and/or MMOD as an IFA

Orbiter Bottom Damage Repair

Delete the Return-to-Launch-Site (RTLS) Abort Mode

Incorporate OI-30 and Other Software Safety Upgrades

Lengthen the Transatlantic Landing Abort Selection Delay

Transatlantic and Contingency Abort Landings Using GPS Navigation

Additional Transatlantic Abort Landing Sites Selection

Potential CAIB Observations

Independent security review for MAF security needs (manning, 4WD vehicles, NVGs

NASA Code Q review of KSC NASA Safety Office responsibilities and manning.

FOD and housekeeping procedures and process review at KSC.

FOD and housekeeping procedures and process review at MAF.

Infrastructure concerns (MAF roof, KSC VAB roof, launch pads, and more).

Return KSC's closed loop NASA discrepancy system.

NASA management training and education programs.

Training programs for NASA quality engineers, process analysts, and quality assurance specialists.

Astronaut workcenter visits.

A CRATER-type tool based on material science/physics

A better MADS system with more sensors (Shuttle "blackbox" equivalent)

Verification that Shuttle wing does not have any <100 flight life fracture criticality items

Telemeter RSRM anomalous thrust oscillation data (0-60 Hz).

Telemeter umbilical photos instead of using film.

Safe Haven on ISS for Shuttle Crew.
Steve Wallace wil investigate/write RI for briefing

Reanalysis of MMOD Threat based on modified arc jet testing.

Recertification of Shuttle design basis.

Evaluation of "workpaper" (WADS, etc.) errors.

Group discussion points during review of outline

May be unique issues relative to the space station and its implication (this is a different situation that Challenger)

Do we open the door to two RTF scenarios (short term/long term)?

May difuse the level of focus/impact if we allow for 2 scenarios (Ride)
Less than a full flight contingent might keep the focus on (Tetrault)
Concern of what you might accomplish with minimal crew (3)...(Buford)
Can options be developed to avoid need for RTF on Space Station prior to full crew support complement Ride)
Look at the space station from a future value standpoint, not an previous invested value standpoint (Gehman)

Will we really be able to say that the Shuttle is 'safer than it has ever been' to fly when RTF occurs?

There should not a differentiation in the Board's view between number of crew on board...safe is safe.

Do we make a distinction between space station travel and non relative to in flight repair?

Is NASA organized to detect and deal with the next 'whisper' (beyond the current RTF dialogue): Implication: is resolving THAT issue a RTF issue?

We should focus on HOW to listen to the whispers/signals...not try to list all of the current whispers that may be out there...

Do we need to renormalize the public perception/awareness/recognition of the risks of space flight? (and in doing so, re-clarify/review the waivers that are outstanding...)

Can we find an other scenario where 'the machine is talking to us' (either current or prior)

Should ensure that we assess current activities underway by NASA and endorse/support those (we may have others...

Input on Requirements for Re-entry Analysis and Testing (Group Outliner)

Completion of RCC and tile impact testing at Southwest Research Institute

CAIB POC: Hubbard
NAIT POC: Frank Benz
Test Location: SWRI, San Antonio, TX
Current Schedule Status: June (comments attached)

First week in June for Panel 6
June 20 Panel 9
Panel 8/9 could move up to second week

Threats (comments attached)

Test scenarios could be impacted by initial test/process
Do not anticipate that this will hold up report activity
Could be some transition activities/actions that would go over to the Stafford group
The foam issue is already a RTF issue

Aerothermal analyses to correlate off nominal heating trends in left fuselage sidewall and left OMS pod heating observed in the MADS data

Include the forward sensors in the analysis

CAIB POC: Widnall
NAIT POC:
Analysis Location:
Current Schedule Status: (comments attached)
Threats (comments attached)

Instrumentation wire burn-through Arc jet tests and thermal analyses to support the timing of observed instrumentation failures

CAIB POC: Tetrault
NAIT POC:
Test Location:
Current Schedule Status: (comments attached)
Threats (comments attached)

Need to increase temperature on tests

Instrumentation circuit analyses or testing to confirm the failure signatures observed in the data

CAIB POC: Hallock
NAIT POC:
Analysis/Test Location:
Current Schedule Status: (comments attached)
Threats (comments attached)

Hypersonic wind tunnel testing and aerodynamic and structural analyses to explain aerodynamic roll and yaw moments observed in flight data

CAIB POC: Widnall
NAIT POC:
Test Location:
Current Schedule Status: (comments attached)
Threats (comments attached)

Thermal analysis of RCC panel 9 clevis and spar temp sensor responses to support or refute flight data (Estimate of size of hole/breach...implication on day 2 event)

CAIB POC: Widnall
NAIT POC:
Analysis Location:
Current Schedule Status: (comments attached)
Threats (comments attached)

Hole size is important...
Can it be simulated?
Need order of magnitude...20 inch or 120 inch? T-seal or RCC panel?

Arc jet testing and/or analysis of previous arc jet testing to determine feasibility of RCC erosion observed in several key pieces of RCC panel 8/9 debris

CAIB POC: Tetrault
NAIT POC:
Test Location:
Current Schedule Status: (comments attached)
Threats (comments attached)

May take a while...

Continued forensics testing and analysis of significant recovered debris

CAIB POC: Tetrault
NAIT POC:
Test Location(s):
Current Schedule Status: (comments attached)
Threats (comments attached)
High priority

ET foam dissection

CAIB POC: Johnny Wolfe (primary), Larry Butkis/BG Deal
Make BG Deal the CAIB POC, footnote Wolfe and Butkus as Support Staff POCs
NAIT POC: Darrell Deweese (MSFC)/Steve Holmes (MSFC)/Eugene Sweet (MAF)
Make Frank Buzzard the NAIT POC, footnote Darrell Deweese (MSFC)/Steve Holmes (MSFC)/Eugene Sweet (MAF) as NASA Staff POCs
Test Location: MAF
Current Schedule Status: (comments attached)
ET-120 dissection complete (bipod ramps, flanges), analysis in work
ET-124 dissection complete (bipod ramps/flanges), analysis in work
ET-94 dissection complete (bipod ramps, flanges, PAL ramp), analysis at work
Dissection plan in work for ET-118/119/121/122/123/125
Threats (comments attached)
Chemica physical analyses of observations (due to large numbers of observations & analytical tests)

ET cryopumping testing

CAIB POC: BG Deal, with staff support from Johnny Wolfe and Larry Butkis
Make BG Deal the CAIB POC, footnote Butkus and Wolfe as Support Staff POCs
NAIT POC: Frank Buzzard, with Lee Foster (MSFC)/Steve Gentz (MSFC)/Rich Wright (MAF) as NASA Staff POCs
Make Frank Buzzard the NAIT POC, footnote Lee Foster (MSFC)/Steve Gentz (MSFC)/Rich Wright (MAF) as NASA Staff POCs
Test Location: MSFC
Current Schedule Status: (comments attached)
Checkout in progress
Testing scheduled for May 13-22
Threats (comments attached)
Hardware/facility mods at MSFC to permit multiple tests/day (specifically cryogenic plumbing)

Testing of the bolts/LESS structure (added by R Tetrault during group discussion)

CAIB POC: Tetrault/Barry
NAIT POC:

Test Location(s):
Current Schedule Status: **(comments attached)**
Threats (comments attached)

Aerothermal: include forward sensors

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 09, 2003
These Minutes Contain No Sensitive Data

Purpose: Pre-Launch, Launch, Insertion (PLI) Review

Date: 09 May 2003 **Time:** 0900 - 1200

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

Admiral Gehman opened the meeting at 0900 hours by outlining the agenda for the morning session which consisted of a review of the Pre-Launch, Launch, Insertion (PLI) material. Admiral Gehman noted that the material to be presented contained information previously reviewed by the Board and contained minimal new information. The intent of the briefing was to capture the PLI information in a "package" similar to the entry scenario materials.

The briefing consisted of 18 topical sections composed of a total of approximately 460 charts, most of which were presented very quickly and without discussion among the audience. Only a small subset of the charts resulted in discussions. Those discussions are summarized by the appropriate section below.

Left Wing Leading Edge Support Structure (LESS) (OMM to Flight): Orbiter Service Life

Several of the charts in this section contained information on fatigue structure. Dr. Widnall asked for a definition of this terminology. The response was that the spectra information was used to establish the service life.

The summary findings for this section stated that while 50% of the root bending moment data is missing, the review of the existing data indicated that the fatigue spectra margins were adequate. Admiral Gehman commented that the fatigue spectra margins may be adequate for the Shuttle but would not be viewed as adequate in the airline industry.

Reinforced Carbon-Carbon (RCC) Design and Aging: RCC Mission Life Capability

The recommendation in this section was to conduct additional testing to verify predicted mass loss rates and the corresponding reduction in mechanical properties. Dr. Widnall requested that Mr. Glenn Millar be kept in the loop for that additional testing.

RCC Design and Aging: RCC Maintenance

As part of the background to this section, the inspection accept/reject criteria was presented as including flaking of Type A sealant is acceptable when the depth is less than 0.015 inches. Admiral Gehman commented as to the difficulty of an inspector determining that flaking gap.

Bipod Design, Manufacture, and Handling: External Tank (ET)-Foam Production

During the discussion of ET-Foam Production, Dr. Osheroff offered cautions on the accuracy of the plug pull tests. The tests can provide different results from pulls in the same area. The Board agreed that these tests should be revalidated.

Bipod Debris: ET-Foam Launch-Ascent

Among the recommendations for this section were that NASA should consider eliminating a foam-covered ET from the Space Transportation System. This recommendation was considered to be unrealistic by the Board.

Certification of Flight Readiness (CoFR) Process: Foam Disposition: Program Requirements Control Board (PRCB), CoFR, Flight Readiness Review (FRR), Mission Management Team (MMT)

This section included findings that in spite of confirmed ET foam loss on 62 of 80 missions since STS-1, ET foam loss was dispositioned as "no safety of flight" or "acceptable risk". Several Board members including Dr. Osheroff, Dr. Widnall, and Mr. Tetrault commented that the decision that any size of foam loss was not a safety of flight issue was not based on adequate engineering analysis. Admiral Gehman inquired as to whether dispositioning of the foam issue over the most recent nine flights was a topic at the FRR's. The response from the speaker was negative.

Launch Video Analysis

In the interests of time, this video was skipped.

Integrated Ascent Analysis: Design/Mods/Manufacturing Structures-STS-107 Orbiter Recorder Ascent Data

In this section, the findings indicated that STS-107 wing front spar temperature sensor measurements compared to previous seven missions showed unusual activity. Admiral Gehman requested that each of the teams agree as to the significance of the data presented.

CRATER Analysis: Ascent Impact Analysis

This section included a review of the CRATER analysis. Dr. Widnall observed that there was no need to polish the CRATER analysis as all that could be gained from a physics standpoint had already been obtained. The focus now should be on the cultural and process implications. The Board agreed with this observation.

General Comments:

The Board discussed that group 1 and group 3 were not generally on the same page regarding their expectations for the PLI presentation. However, all concluded that this was not a significant problem to be concerned with going forward.

Identified Actions

- None identified.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 09, 2003
These Minutes Contain No Sensitive Data

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff	CAIB	281-283-7511
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Dr. Widnall	CAIB	281-283-7579
Mr. Cooke	CAIB	202-329-8844
Steve Schmidt	CAIB	281-283-7577
Larry Hartley	Recorder	281-280-8062
Johnny Wolfe	CAIB	281-283-7543
Larry Butkus	CAIB	281-283-7839
Mike Francis	CAIB	281-283-7574
John Mulholland	Boeing	281-853-1738
Don McCormack	NASA	281-483-1267
Allen Peterson	Boeing	281-853-1608
Andy Foster	NC/GHG	281-244-1961
Scott Altman	NASA	281-244-2228
Tom Martin	NASA	281-244-7126
Bob Ess	NASA	281-483-0180
Larry Purtle	Boeing	281-226-5975
Rodney O. Wallace	NASA	281-483-3904
Rick Burgess	CAIB	281-283-7566
Tim Poaur	CAIB	281-283-7521
Ron Gress	CAIB	281-283-7532
Jim Arnold	CAIB	281-283-7589
Chuck Babish	CAIB	281-283-7840
Jeri Bryant	USA	281-483-5558
Wayne Gotch	NASA	281-483-8554
Bruce Darling	CAIB	281-283-7504
Gene Grush	NASA	281-483-8499
Joyce Seriale-Grosh	NASA	281-483-4542
John C. Melcher	NASA	281-244-6427
John Redding	USA	281-483-2668
Jeff Kling	USA	281-483-0677
Phil Engelauf	NASA	281-483-4416

Greg Byrne	NASA	281-483-0500
Elizabeth A. Fountain	NASA	281-483-5257
John Kennedy	NASA	281-483-8942
Rob Ellison	NASA	281-867-3135
Jim Kennedy	NASA	321-867-2355
Leroy Cain	NASA	281-483-0705
Doug White	USA	281-282-2879

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 09, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 09 May 2003 **Time:** 1230 - 1815

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA web site.

CAIB Report Outline

Admiral Gehman stated that the objective of the meeting was to take previously agreed upon final report chapters and start filling in content descriptions down to the first level of detail (bullets). As the Board members went through this exercise they were to decide the following: Does the subject belong in the report? Does it warrant a "big" (comprehensive) or "little" narrative? Is anything missing? He then emphasized the importance of documenting comments using the Group Systems tool to prevent useful comments from disappearing "into the ether."

Admiral Gehman next stated that the format of the report would not be proscribed until the outline is finalized, and then he presented two alternatives for developing the report narrative:

1. Groups would write rough narratives that would be "polished up" later by the writers/editors
2. Groups would provide data sheets with facts and discussion but leave the narrative to the writers

Les Reingold (Lead Editor) stated that he would prefer that the groups provide the narratives because in doing so they have bounded the size of each section. He also asked that the groups provide background material that is linked to the narrative.

The Board agreed that the groups should write their own rough narratives to maintain process control and ensure that the intent, tone, and spirit of the message cannot be misconstrued. They also agreed to establish group/individual "ownership" of the report content.

With that, Dr. Bluford led the rest of the Board thru a detailed review of the report outline.

This meeting was adjourned at 1815.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 09, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Dr. Logsdon via tcon	CAIB	202-994-7292
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Dr. Osheroff	CAIB	281-283-7511
Dr. Bluford	CAIB	281-283-7813
Mr. Hubbard	CAIB	281-283-7517
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Tetrault	CAIB	281-283-7509
Mike Boulavsky	Recorder	281-280-8062
Dave Lengyel	CAIB Staff	281-283-7581
Chris Kirchhoff	CAIB Staff	281-283-7821
Steve Schmidt	CAIB Staff	281-283-7577
Dennis Jenkins	Grp 4	281-283-7589
Les Reingold	CAIB Staff	281-283-7539
Rudy Gazarek	Grp Sys	281-283-7593

:

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 12, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 12 May 2003 **Time:** 1230 - 1515

The list of attendees is appended to the end of this report.

There were no action items generated from this meeting.

Admiral Gehman opened the meeting at 1230 hours by stating that the policy of the board is that once we come to a conclusion about any Return-to-Flight recommendation, we issue it right away so that NASA can get to work on it immediately. The Board has issued two interim recommendations in April:

1) It should be routine to take a picture of the Orbiter on every flight for good engineering and scientific principles.
2) There are certain parts of the Orbiter, which tend to age chronologically, not by flight. The RCC is one of them. There should be a more rigorous non-destructive evaluation of the aging process.

The board has a couple of other recommendations, which are not quite ready yet. The Admiral stated that they would like to hear Capt. Young's viewpoints on what constitutes a Return-to-Flight Issue.

A copy of Capt. Young's Memo on Return-to-Flight (RTF) recommendations, which is discussed below, is appended to these minutes.

Capt. Young then began with his views on Return-to-Flight.

1) Orbiter bottom damage protection. A previous analysis showed that 17-18 % of the bottom is critical. If you lose a tile in these areas and get a burn through, you will damage the hydraulic lines, the cryo tanks, or the fuel cells. We are currently working on the TUFI tiles, but they shrink.

The Admiral interjected a question that they had been told two different stories about TUFI tiles shrinking. Mr. Hubbard responded that he had talked to the person who invented the TUFI tiles who said that they did not shrink unless they were overheated. Capt. Young stated that more use of TUFI tiles, especially around the doors of the wheel wells, would be a good idea because you just cannot get hot gas up in there. Someone else also suggested that NASA ought look at redundant thermal seals around the main landing gear and nose wheel door. During our first mission (STS-1), we had a gap filler hanging down and we got hot gas in the wheel well. We had 247 tiles replaced after this mission. The gear door was warped or buckled because of the hot gas exposure during STS-1. Capt. Young stated that he thought that it would be good to have TUFI tiles on the wing leading edges and the carrier panels. The Admiral stated that he understood that the TUFI tiles were heavier than the current tiles. Capt. Young responded that this would be a good area to use the additional weight.

2) Shuttle flow processes and upgrades.

The Admiral questioned Capt. Young if this recommendation should be put in the Return-to-Flight category. Capt. Young responded that this should be performed as quickly as possible. Capt. Young brought up the concern of independence regarding safety being performed by USA for "buying off" items.

Capt. Young then stated that there used to be four divisions of NASA KSC engineers with twenty-five in each division, now they have less than one-half of that number.

The Admiral offered that the board had looked at other organizations that have high-risk type of enterprises. Another model that works well is one in which the engineering department owns the technical specifications and waivers and not the program office. So, if a problem surfaces, the operational group, or program office, must come to the technical side to convince them of the validity of a particular preferred change. The question is: If NASA were to implement something like this, would this bring the whole program to a complete halt? Capt. Young responded that he thought it would for a while until it was organized properly. Capt. Young said that he thought an independent group should carry out these things.

3) Treating tile damage as an in-flight anomaly. Tile damage has never been taken very seriously.

Mr. Wallace asked if there were people or factions in the process who have a vested interest in seeing the number of in-flight anomalies go down? Capt. Young responded, "Oh sure, contractors get extra money to lower the number of in-flight anomalies". Mr. Wallace questioned Capt. Young; "So you create an incentive to under report in-flight anomalies?" Capt. Young responded that the Program Office has been bragging for years about how the in-flight anomalies have been dropping.

4) Orbiter bottom tile damage inspection and repair is being addressed at this time utilizing EVA. The question, which arose from this activity, is what is the amount of damage to justify an EVA fix. NASA is also looking at keeping the Orbiter on orbit. This would utilize another Orbiter to come up and rescue the crew.
5) Questioned the idea of Return-to-Launch Site (RTLS). The RTLS scenario is a high-risk scenario while there are possible alternatives such as an abort to east coast airfields. They could use what is called "fast separation" from the External Tank and land at an airfield if something like an engine failure occurred.
6) Safety upgrades – Software OI-30 load has 117 safety upgrades based on the abort panel studies. Capt. Young thinks that they should utilize speed brakes to be able to land at shorter airfields. Aerospace Safety Advisory Panel has recommended upgrading the shuttle computer for years. These are AP101s that first flew in A6 aircraft in 1966. They are now up to 250,000 words and they have single event upset capability incorporated into the software. Capt. Young stated that if NASA was going to continue to fly the shuttle for a number of years, they should change computers (General Purpose Computers (GPCs)).

Col. Bloomfield brought up an example of a current related activity and stated that the Cockpit Avionics Upgrades (CAU) for the shuttle does not break into the flight software to drive the displays. They use the flight software to feed other computers and these drive the displays. You do not break into the flight software, which we have twenty years of experience with.

Admiral Gehman speculated that there were probably several items that were not monitored on the Orbiter due to computing constraints.

Capt. Young addressed Admiral Gehman's speculation by stating that there were about 8200-telemetered items that were monitored on the ground but could not be monitored on-orbit because of computer limitations. A different computer would be very helpful during events like ascent and entry when you are moving so fast and you are not really talking to the ground. The Orbiter is completely dependent on the ground for landing if they lose one engine.

7) Lengthen the Transatlantic Landings Abort Selection Delay. You are always worried about the next engine failure and you can delay the transatlantic abort landing so that you are

completely covered for two and three engine failures during the ascent. If one engine fails, it is 7 seconds before the ground gets this information. It used to be that you had to abort TAL at 15 seconds after the engine has failed. This means that the ground has only looked at the data for 8 seconds to determine if the other two engines are nominal. If you select TAL you are headed across the Atlantic Ocean and at the next engine failure you are going to land in the ocean. If you lose the next engine you are definitely landing in the Atlantic Ocean. Col. Bloomfield added that by delaying the TAL selection you continue up the east coast and if you lose another engine you have the ability to get to a landing site on the east coast. One of the concerns is that if you lose an engine you may also lose communications and then you are in a bad situation.

8) Transatlantic Landings and Contingency Abort Landings Using GPS Navigation. The crews have agreed to land with zero-zero weather up the east coast. The only thing they have to do that with is the TACtical Air Navigation (TACAN) system and they ought to use the Global Positioning System (GPS) (3 string). They currently have only one string of GPS.

Col. Bloomfield added that at most of the major landing sites, such as KSC, they use the Microwave Landing System (MLS), which is very precise. It can be coupled to the autopilot system, which brings you right down to the runway. Most of the east coast landing sites do not have an MLS but have the less precise TACAN system. The GPS gives you a better capability and flexibility at other airfields.

Admiral Gehman asked if NASA had studied differential GPS. Capt. Young responded that they had differential GPS at the Cape and at White Sands that they are using. He stated that it was very precise in two horizontal axes but not as good in the vertical.

Capt. Young pointed out that the MLS does not work well during heavy fog and rain, which is where you want it to work.

Col. Bloomfield summarized that the premise is that if we lose one engine, the game plan is that we will turn around and come back to KSC or press overseas. Capt. Young's proposal is to take a hard look to avoid using the RTLS option in favor of east coast aborts.

Capt. Young stated that the program preferred the RTLS option so that they can get the Orbiter back to KSC. East coast aborts must also account for a heavier External Tank (ET) and fuel slosh.
A TAL abort reentry is more like a normal reentry. Capt. Young stated that they should plan for the worst and hope for the best.

9) Additional TAL Landing Site Selection. Capt. Young stated that he thought that additional TAL sites should be provided. A TAL reentry is similar to a normal entry except that you have a higher heat spike because of your type of entry.

Mr. Hubbard brought up the concept of modifying the shuttle arm to be utilized for tile inspection. Capt. Young stated that he thought this was currently being looked at.

Admiral Gehman asked Capt. Young if he thought the idea of having shuttle contingency capability available on the ISS was a good concept versus bringing up each shuttle flight. Capt. Young responded that he thought this was an acceptable idea.

The Admiral asked Capt. Young if he was on-orbit and was able to inspect an Orbiter, how would you decide or judge which damaged areas should be repaired? Capt. Young responded that this was a very

tough problem, and someone has to decide this. He continued by stating, "you need to know where is the nick, and is it over critical structure, and how big is it".

Mr. Tetrault mentioned the two recommendations that they have made with respect to addressing the on-orbit repair:

1) Have an analytical model that suggest what failures may occur
2) On-orbit repair system

Mr. Tetrault stated that these were originally thought to be unrelated but may need additional consideration on how these two are interrelated.

The meeting then transitioned from Capt. John Young's Return-to-Flight recommendations to the discussion of the upcoming move of the board to northern Virginia. Mr. Schmidt reviewed the office layouts of the Anser facility that the board will be transitioning to during the first week of June.

The Admiral then transitioned the discussion to the previously discussed Return-to-Flight items utilizing the Group Systems software, which is appended to these minutes.

Admiral Gehman brought up a line of investigation, which dealt with hypothetical on-orbit operations if it was known that there was a problem. There is a NASA team that is beginning to look at this scenario. This presents the board with all sorts of challenges. This could change bureaucratic oversight to negligent behavior. The Admiral wanted the board to be aware of this on-going activity being led by Mr. John Shannon.

The meeting was adjourned at 1515.

Identified Actions

- None identified

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

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Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mr. Buzzard	CAIB	281-483-8412
Col. Bloomfield	CAIB	281-244-2233
Steve Schmidt	CAIB	281-283-7577
Dr. Guy Bluford	CAIB	281-283-8062
Mr. Lengyel	CAIB	281-283-7581
Pete Choban	Recorder	281-483-4890
Capt. John Young	NASA	281-483-3897
Mr. Dennis Jenkins	CAIB Gp.4	281-283-7589
Les Reingold	CAIB	281-283-7539
Dwayne Day	CAIB Gp.4	281-283-7588
Jim Mosquera	CAIB/IAST	281-283-7546
Bill Sikora	CAIB Counsel	281-283-7564
Chris Kirchhoff	CAIB	281-283-7500

National Aeronautics and
Space Administration
Lyndon B. Johnson Space Center
2101 NASA Road 1
Houston, Texas 77058-3696

April 15, 2003

Reply to Attn of AC5-03-07

TO: CA/R. Cabana
DA/J. Harpold
EA/F. Benz
MA/R. Dittemore
NA/Y. Marshall
HQ/M/W. Readdy
HQ/Q/B. O'Connor

FROM: AC5/Associate Director (Technical)

SUBJECT: Space Shuttle Return-to-Flight Safety Upgrades

Background: The STS-107 accident has shown us once again that we are not as smart in real time as we think we are. The Space Shuttle is complex machinery and software. To keep the Shuttle operating safely the Space Shuttle Program needs to consider many things. For example, currently the Space Shuttle Program does not consider tile damage as an In-Flight Anomaly. Even though the Program over the years has automated many contingency abort procedures, the current Program does not support any mission operations work on Contingency Aborts. Because the Return-to-Launch Site (RTLS) Abort is certified, the Space Shuttle Program loves it even though the RTLS Abort is a very dangerous abort.

What We Need to Worry About: The enclosure is a detailed discussion of what we should upgrade to operate more safely. It is clear, because of the complexity and the aging of the total Space Shuttle system, we cannot accurately predict what bad things will happen next. Therefore the Space Shuttle Program needs to plan for the worst and hope for the best.

What Should be Fixed: The following are line items of the detailed discussions in the enclosure. It is a list of what we should do to return to safer operation of the Space Shuttle system.

1. Orbiter Bottom Damage Protection.
2. Space Shuttle Flow Processing Upgrades.
3. Treating Tile Damage by Debris and/or Meteoroids as an In-Flight Anomaly.
4. Orbiter Bottom Damage Inspection and Repair.
5. Delete the Return-to-Launch Site Abort Mode.

6. Incorporate 01-30 and Other Software Safety Upgrades.

7. Lengthen the Transatlantic Landing Abort Selection Delay.

8. Transatlantic and Contingency Abort Landings Using GPS Navigation.

9. Additional Transatlantic Abort Landing Sites Selection.

Conclusions: It is concluded that

1. In order to more safely perform our operation of the Space Shuttle, we must plan for the worst and hope for the best.

2. Work on these above issues should be accelerated to return the Shuttle to flight as rapidly as possible.

Recommendation: It is urgently recommended that NASA seriously consider all the above mentioned upgrades besides the obvious, which is the Orbiter Bottom Damage Protection mentioned as Number 1 under the heading "What Should Be Fixed".

These are complex technical matters, which I will be glad to discuss with anyone at anytime at 281-483-3897.

John W. Young

John W. Young

cc:

JSC
AA/J. Howell
AC/R. Stone
AG/J. Greene
CB/K. Rominger
CB/S. Altman
CB/J. Ashby
CB/M. Bloomfield
CB/C. Camarda
CB/F. Caldeiro
CB/K. Cockrell
CB/E. Collins
CB/R. Curbeam
CB/C. Ferguson
CB/M. Foale
CB/D. Gorie
CB/J. Grunsfeld
CB/K. Ham
CB/B. Jett
CB/J. Kavandi
CB/G. H. Johnson
CB/J. Kelly
CB/M. Kelly
CB/C. Hadfield
CB/S. Kelly
CB/T. Kopra
CB/P. Lockhart
CB/W. Lindsey
CB/P. Melroy
CB/A. Poindexter
CB/M. Polansky
CB/J. Reilly
CB/G. Reisman
CB/S. Robinson
CB/S. Smith
CB/S. Swanson
CB/T. Wilcutt
CC/K. Baker
CC/C. Hayes
CC/F. Marlow
CC4/S. Nagel
CC5/D. Mumme
DA8/M. Heflin
DA8/W. Hale
DA8/L. Cain
DA8/J. Shannon
DM/R. Epps
DT34/H. Lampazzi
EA/C. Schomburg
EG/D. Kanipe
ER/W. Guy
ER/D. Homan
MA/L. Ham
MA/M. Henderson
MB/D. Lengyel (CAIB)
MV/R. Roe
HS32/G. W. S. Abbey
NC/A. Foster
SX/E. Christiansen

Headquarters
HQ/AD/F. Gregory
HQ/QE/M. Kowalcski
HQ/QE/P. Rutledge

USA
USA482L/Yusef Johnson
USH100A/M. McCulley

Enclosure

Space Shuttle Safe Return to Flight Fixes

The following are detailed discussions of what should be fixed in order to improve the safe operation of the Space Shuttle:

1. **Orbiter Bottom Damage Protection:** Recommendation has been made to install an inconel "box" over the External Tank Bipod foam. Orbiter blankets, Kevlar netting, or other suitable restraining material has also been suggested. Redundant thermal seals around the main and nose landing gear wheel well doors have been recommended. As soon as practical we should put the new non-shrink TUFI tiles to replace the beveled tiles around the current single thermal seal. As soon as practical, these high strength tiles should also be installed below the Carbon-Carbon Wing Leading Edges in the bolted-on carrier panels.

2. **Space Shuttle Flow Processing Upgrades:** As we know, the number of independent NASA quality assurance technicians and NASA engineers has been significantly reduced. The Space Shuttle Independent Assessment team said these people should be there to provide second and third "sets of eyes" in flow processing. However, after a short beef-up of people, they have been significantly reduced again. In very complex development machines such as the Shuttle, independent checks and balances are vital. Further modern nondestructive evaluation flow checks should be implemented. These include the use of lasers, etc., to check fuselage, wing skin, and spars for cracks or corrosion. Investigation of new methods to check if the tiles are securely attached should be considered. Are the carrier panel bolts torqued correctly? Independent NASA quality technicians should do those checks. The thickness of the Wing Leading Edge Carbon-Carbon should also be checked as required, as it appears to degrade with time and exposure to the launch pad environment. Do these composites delaminate? Checks need to be made.

3. **Treating Tile Damage by Debris and/or Meteoroids (D&M) as an In-Flight Anomaly (IFA):** Tile damage caused by D&M after every mission should be treated as an IFA. Statistically the risk of getting unsuitable hits around the landing gear doors can be calculated for every mission. As we all know, pieces of debris and ice from the External Tank and its cryo lines have been hitting the Orbiter since the Tank was invented. D&M loss of vehicle statistics should be included in the Shuttle Mission Probalistic Risk Assessments. We can do many things to decrease our D&M losses. For example, a layer of Whipple Bumpers over the 576 bulkhead and around the cryo-tanks should be considered.

4. **Orbiter Bottom Tile Damage Inspection and Repair:** ACS-03-03 of February 11, 2003, Subject: An Operational Workaround, describes in detail what should be done to inspect and repair the bottom of the Orbiter. It has been stated that the Orbiter could also be accurately inspected using national assets. In any event, if the Obiter is docked to the

Space Station, it can be easily inspected. EVA crews could repair bottom damage with suitable materials. Mission Operations is currently developing this capability. With a suitably designed Orbiter Remote Manipulation System Arm extension, an independent flight such as the Hubble Space Telescope reservicing mission, could accommodate Orbiter bottom damage inspection and repair.

5. **Delete the Return-to-Launch Site (RTLS) Abort Mode:** Although certified, the RTLS is not a safe abort mode. The specification is that for 16% of the time it is OK for the Orbiter to hit the External Tank at separation. In 300 relatively recent Monte Carlo RTLS runs, the Orbiter only hit the Tank 21 times. Therefore, the RTLS Abort Mode meets specification. Further DARE reported that there is 1 chance in 38 that, at RTLS External Tank separation, we will lose control of the vehicle. With one or more additional SSME failures, RTLS has only fatal black zones and/or bail out zones. Clearly RTLS is certified to kill its users. When the first Main Engine fails, the Shuttle should use OI-30 Delta psi and turn to parallel the East Coast. It should use an East Coast Range-Velocity line to land as soon as possible - Beaufort MCAS, for example. Fast External Tank Separation will prevent the Orbiter from hitting the tank.

6. **Incorporate Software Safety Upgrades:** The OI-30 load should be installed as soon as practical. The many OI-30 upgrades will greatly improve our operation flexibility with respect to safety improvements. Based on the OV-102 loss, we have no clue as to when the next bad things can happen. Therefore, we must plan to accommodate the worst and hope for the best. For example, adaptive speed brakes below 3,000 ft. should be automated in software, as real wind shears below 3,000 ft. are difficult to accommodate in short field landings.

7. **Lengthen the Transatlantic Landings Abort Selection Delay:** As has been demonstrated repeatedly, TALs can be delayed until the high energy TAL to Gander at Mach 21.9 inertial. SSME power of 109% in many cases does not need to be selected if the TAL is late. However, it is common sense to spend as much time as practical to look at the health of the remaining two Space Shuttle Main Engines since they live in the same nacelle – the Aft Thrust Structure.

8. **Transatlantic Landings and Contingency Abort Landings Using GPS Navigation:** If the Orbiter is on a TAL trajectory paralleling the East Coast, a Gander Range-Velocity line will allow the Orbiter to land safely at any of six landing fields in Canada. Even in winter one of these airfields will have suitable weather. The use of 3-string GPS for navigation will allow the Orbiter to safely land in very bad weather. The flight crews have agreed to land in zero zero conditions instead of bailing out. The Canada TAL is faster and far cheaper return of the Orbiter than the across the Atlantic return of the Orbiter on the Shuttle Carrier Aircraft. All the entry range extension tricks should be played including launching late in the 51.6° inclination rendezvous window, eliminating the 30° prebank, closing the speed brakes which can gain up to 12 nautical miles range and using adaptive GPS navigated speed brakes to land on abort runways 7,000 ft. or less long.

9. <u>Additional TAL Landing Site Selection</u>: Rather than scrubbing for weather, additional overseas TAL sites should have TAL Range-Velocity lines. These include Shannon, Beja, LeTube, Rota and Casablanca. GPS navigation instead of MBLS can be safely used. It is more dangerous to scrub because of TAL weather than to launch because the alleged probability of a TAL is 1 in 530 or so.

CAIB Input Session on RTF Preliminary Recommendations (Group Outliner)

1. Potential CAIB Inputs on RTF (Return to Flight) Recommendations

1.1 NASA must closeout the fault tree before return to flight. **

Deliver memo (dated 11 MAy) from CAIB Chair to NAIT Chair on this subject. All board members have a copy.

1.2 An independently-led bottom-up review of the Quality Planning and Requirements Document (QPRD) for KSC SFOC operations -- focused on the NASA Quality Assurance manning, GMIPS re-look, and discrepancy tracking. **??

1.3 Backlog of unincorporated Engineering Orders (UEO) is significant and may impact the quality and timeliness of maintenance.

1.4 An independently-led bottom-up review of the Quality Planning and Requirements Document (QPRD) for MAF ET production -- focused on the DCMA Quality Assurance manning and GMIPs re-look.

1.5 NDE of the foam on the ET -- focusing on the flange and PAL ramp area.

1.6 Ensuring 2-person operations in all close-out/final configuration areas (specifically, two ET foam spraying areas which aren't mandated today).

1.7 (Re)Evaluation of public risk during launch/reentry

2. NASA Inputs on RTF (Return to Flight) Recommendations **=general agreement that this is a candidate for interim RTF recommendation

2.1 Determine the root cause and corrective action resolution of loss of foam on ET bipod ramp area flange. **

Redesign of the ET bipod ramp (already in work by NASA). **

2.2 Investigate and evaluate ground assets to view launch activities. Camera locations and capabilities for day and night. **

2.3 Investigate location and specification of ET camera (possibly 2).

2.4 Understand history of foam loss, debris generation on the ET, SRB and SSME and identify source of debris.

2.5 Investigate entry options after repair of TPS to minimize thermal impact to Orbiter

2.6 Determine if there are other materials which FLA-GRO does not have data for

2.7 Recommend schedule for Destacking SRB short stacks to allow hardness testing of the ETA rings

ETA ring hardness should have encompass the extreme thickness and density of a lawyer's head.

2.8 Develop inspection technique and options to reach bottom of vehicle and repair technique both while docked to the ISS and when undocked. (on orbit repair)

Steve Wallace will investigate current status

3. John Young Inputs on RTF (Return to Flight) Recommendations

3.1 Delete the Return-to-Launch-Site (RTLS) Abort Mode

Although certified, RTLS is not a safe abort mode. Utilize East coast aborts

3.2 Orbiter Bottom Damage Protection

Inconel box over, bipod foam, Orbiter blankets, Kevlar netting, redundant thermal seals, non-shrink TUFI Tiles, etc

3.3 Space Shuttle Flow Processing Upgrades

Additional NASA QA and engineering support, new NDE techniques, etc.

3.4 Treating Tile Damage by Debris and/or MMOD as an IFA

Tile damage caused by debris and/or MMOD(D&M) should be treated as an IFA. D&M should be part of Shuttle PRA. Addtional protection to orbiter should be considered.

3.5 Orbiter Bottom Damage Repair

National assests, EVA inspections and repair techniques

3.6 Incorporate OI-30 and Other Software Safety Upgrades

OI-30 software contains many safety features which will include additional operational flexibility

3.7 Lengthen the Transatlantic Landing Abort Selection Delay

TALs can be delayed until the hi-energy TAL to Gander at Mach 21.9 inertial

3.8 Transatlantic and Contingency Abort Landings Using GPS Navigation

Use of 3-string GPS for nav for Canadian abort sites (even in bad wx)

3.9 Additional Transatlantic Abort Landing Sites Selection

Rather than scrubbing for wx, additional overseas TAL sites should have TAL range velocity lines. GPS nav can be safely utilized (vice MBLS). It is more dangerous to scrub because of TAL wx.

4. Potential CAIB Observations

4.1 Independent security review for MAF security needs (manning, 4WD vehicles, NVGs

4.2 NASA Code Q review of KSC NASA Safety Office responsibilities and manning.

4.3 FOD and housekeeping procedures and process review at KSC.

4.4 FOD and housekeeping procedures and process review at MAF.

4.5 Infrastructure concerns (MAF roof, KSC VAB roof, launch pads, and more).

4.6 Return KSC's closed loop NASA discrepancy system.
4.7 NASA management training and education programs.
4.8 Training programs for NASA quality engineers, process analysts, and quality assurance specialists.
4.9 Astronaut workcenter visits.
4.10 A CRATER-type tool based on material science/physics
4.11 A better MADS system with more sensors (Shuttle "blackbox" equivalent)
4.12 Verification that Shuttle wing does not have any <100 flight life fracture criticality items
4.13 Telemeter RSRM anomalous thrust oscillation data (0-60 Hz).
4.14 Telemeter umbilical photos instead of using film.
4.15 Safe Haven on ISS for Shuttle Crew.

Steve Wallace wil investigate/write RI for briefing

4.16 Reanalysis of MMOD Threat based on modified arc jet testing.
4.17 Recertification of Shuttle design basis.
4.18 Evaluation of "workpaper" (WADS, etc.) errors.

5. Group discussion points during review of outline

5.1 May be unique issues relative to the space station and its implication (this is a different situation that Challenger)
5.2 Do we open the door to two RTF scenarios (short term/long term)?

May difuse the level of focus/impact if we allow for 2 scenarios (Ride)
Less than a full flight contingent might keep the focus on (Tetrault)
Concern of what you might accomplish with minimal crew (3)...(Buford)
Can options be developed to avoid need for RTF on Space Station prior to full crew support complement Ride)
Look at the space station from a future value standpoint, not an previous invested value standpoint (Gehman)

5.3 Will we really be able to say that the Shuttle is 'safer than it has ever been' to fly when RTF occurs?
5.4 There should not a differentiation in the Board's view between number of crew on board...safe is safe.
5.5 Do we make a distinction between space station travel and non relative to in flight repair?
5.6 Is NASA organized to detect and deal with the next 'whisper' (beyond the current RTF dialogue): Implication: is resolving THAT issue a RTF issue?

We should focus on HOW to listen to the whispers/signals...not try to list all of the current whispers that may be out there...

5.7 Do we need to renormalize the public perception/awareness/recognition of the risks of space flight? (and in doing so, re-clarify/review the waivers that are outstanding...)
5.8 Can we find an other scenario where 'the machine is talking to us' (either current or prior)
5.9 Should ensure that we assess current activities underway by NASA and endorse/support those (we may have others...)

Columbia Accident Investigation Board (CAIB)
Memorandum For The Record
May 13, 2003

Purpose: JSC Safety, Reliability, and Quality Assurance Briefing to Group 1

Date: 13 May 2003 **Time:** 0830 to 1045

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting are attached.

There were 3 potential requests for information generated from this meeting that are listed later in this report.

Ms. Yolanda Marshall, Director of System Reliability and Mission Assurance at JSC and selected members of her staff, provided the subject briefing to Group 1. Questions and significant comments during the briefing are documented below with a reference to the chart number that prompted the question or comment.

CHART	COMMENTS/QUESTIONS/DISCUSSION
6	Is there an SR&QA organization at Marshall Spaceflight Center (MSFC) and Kennedy Space Center (KSC)? ANS: Yes, but those organizations are called S&MA at each of those centers and JSC will adopt that nomenclature next month. BGen Deal added that there is a perception at KSC that United Space Alliance (USA) performs the quality function, not NASA, because NASA took the name out of the title.
9	What is done at each SR&QA site shown on the map? ANS: Huntington Beach – There is a delegation to Defense Contract Management Agency (DCMA) to insure that requirements are passed along to suppliers. Palmdale – The site is pretty much shut down as far as JSC is concerned except to examine records in response to CAIB requests. Some manufacturing still goes on for other Shuttle Program Projects. KSC – A new office to provide eyes and ears for JSC. WSTF – Mini-SR&QA staff to support testing and other activities.
10	The chart also includes the number of civil service and contractor employees.
11	MGen Barry asked which SR&QA employee sits on the MMT. ANS: Mark Erminger (is the permanent SR&QA MMT member). Mr. Harris added that the SR&QA chair on the MMT does not belong to either JSC or the Shuttle Program but to Code Q and Mr. Erminger's delegation comes to him personally from Code Q at Headquarters.
14	BGen Deal asked whether the surveillance activities were documented. ANS: When surveillance is performed there is a combination of responses.

	1. The Discrepancy Report System 2. A close call report which is normally addressed in a very short period of time a. Is there a sharing mechanism for close call reports? ANS: Yes, the recent use of medical syringes to dispense glue is a good example. b. Is sharing close call reports a professional courtesy or a formal process? ANS: The GIDEP alert timeline causes "unofficial" alerts to be sent out however, the recent episode of cracks in computer chairs demonstrates the effectiveness of this system.
20	BGen Deal asked how the decision is made to not do an assessment. ANS: Mr. Himel responded that there is a formal process in place that considers potential payoff to the program, available resources and other factors that are jointly considered by the Independent Assessment (IA) offices at HQ, JSC, KSC, and MSFC.
22 – 25	BGen Deal indicated that they would be requesting additional IA reports. Mr. Himel indicated the IA office will respond quickly and pointed out that JSC is the focal point for the IA Website.
22	There was a question regarding the program office closing the loop with the IA office in responding to IA reports. ANS: Mr. Himel responded that there is not a formal closed loop system but IA does bring forth recommendations for program office consideration and program office determination of a response. He indicated there was no way for IA to force a program to do something. Mr. Harris added that the program office has primary and secondary systems for dealing with IA recommendations and he always has the option of requesting a follow-on assessment from IA. Ms. Marshall added that it is the program responsibility to close the loop but IA does monitor to see if there is any change in program behavior in response to an IA report but that there was no formal closing of the loop.
28	Mr. Harris observed that while JSC has the design center responsibility, most of the hardware is bought by USA Logistics in Florida with the procurement chain being initiated by USA through Boeing to the actual supplier. He indicated there is an on-going dialogue discussing the quality implications of having the design center in Texas/California and the logistics function in Florida. MGen Barry asked if he could obtain the actual numbers of mandatory inspection points (MIP) for the pre and post-SFOC eras. ANS: Mr. Harris indicated it was difficult to easily differentiate between those eras. When USA came aboard with the SFOC contract they came in one level higher than their predecessor, Rockwell. USA essentially replaced the government quality function with a contractor function. When JSC was prime for Rockwell there were many government MIPs (GMIPs) but with USA assuming the government role the number of GMIPs went down.
30	MGen Barry asked if there was a process to reorder or reprioritize a Critical Items List (CIL). ANS: All items on a CIL are treated the same.

33	MGen Barry asked about how the CIL is evaluated for risk in light of the 700+ Orbiter CIL items and over 1600 CIL items in the integrated system. ANS: One analyzes risk and puts in processes or redesigns to minimize risk. Mr. Harris added that the intent of the CIL is not to prioritize risks. There is a record of what can be done to remove or reduce the risk. The real issue is to find budget to remove the risk. The current approach is through the Shuttle Life Extension Program (SLEP) with CIL analyses being a major source of information. NASA will start a ranking through the CIL to a funding process. The CIL identifies thousands of components on the integrated vehicle to identify primary drivers for SLEP funding. MGen Barry observed that it is puzzling to him that the high reliability program experts who have spoken to the CAIB all have come down to management of resources to determine where to put available dollars. The CAIB wants to help the program to prioritize the fixes. The shuttle has 1600+ single point failures and that far exceeds the numbers for nuclear weapons or even a fighter plane. The issue is where to put the money. Mr. Harris added that thinking in terms of block upgrades is not in the NASA culture. The question NASA needs answered is how to figure out what to upgrade; how to figure out what to do. MGen Barry concluded the discussion by stating he is struggling with how to recommend some help to NASA on how to fix the shuttle without making things worse or more complicated.
41	There was a question whether this chart contained just JSC data or overall program data. ANS: Just JSC data. It includes such things as flight suits, cameras, crew items, etc. It covers all planned and unplanned open work. There is a significant amount of planned open work when utilizing Spacehab modules because of the integration and subsequent testing that occurs at KSC. Nothing leaves JSC with open work unless both SR&QA and the program or project have approved.
47	The JSC PRACA System has ~7000 records over the past 10 years while the KSC PRACA System has over 250,000. JSC sees only about 3%
50	This chart is new this year and only shows open problems.
51	This chart is taken from open JSC PRACA.
58	Mr. Harris noted that while the data shows the anomalies are coming down the remaining items can be considered the unknown unknowns that are becoming increasingly more difficult to detect. The program can no longer rely on an adaptation of a classical aircraft program. There is a plan to expend a lot of energy to attack this issue. Mr. Erminger added that there is a lot of communication with the upgrades office to provide these analyses to help in determining where to put program money.

62	MGen Barry asked for minutes of the meetings held to review the integrated Shuttle PRA.
64	BGen Deal challenged the last bullet on the chart. He said this was a night flight with no video so the claim that there was no foam shedding could not be verified. ANS: Mr. Erminger agreed and indicated the bullet should say there was no reported orbiter damage from foam strikes.

BGen Deal asked if the Bipod foam losses on STS-50 and STS-52 were ever looked at. ANS: This occurred a very long time ago and this would have to be examined. MGen Barry indicated he believed there had been a large data package delivered addressing this issue.

MGen Barry closed the meeting by stating there is a struggle to come up with something to make the program stronger and any ideas will be helpful.

RFIs Needed:

1. Copies of additional IA reports are needed. BGen Deal (Chart 22).
2. Copies of minutes of Shuttle Program Requirements Control Board (PRCB) meetings concerning integrated Probabilistic Risk Assessment (PRA). MGen Barry (Chart 62).
3. Data package for bipod foam strikes from STS-50 and STS-52. BGen Deal.

This memorandum is hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Memorandum For The Record
May 13, 2003

Attendees are as follows:

NAME	ORG.	PHONE
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Mr. Hartman	Recorder	281-283-7591
Stacey Nakamura	JSC-NS	281-483-4345
David Thelen	JSC-NT	281-483-0675
Mac Himel	JSC-NA	281-483-4086
Scott Johnson	JSC-NC	281-483-4330
David Cases	JSC-SAIC	281-244-1751
Roger Boyer	JSC-SAIC	281-483-6070
Robert Bobola	JSC-SAIC	281-244-1963
Frank Culbertson	JSC-SAIC	281-244-1602
Gordon Ducote	CTF	281-483-8557
EJ Ripma	CTF	281-483-8574
Dennis R Jenkins	CAIB Staff	281-283-7589
Mike Francis	CAIB Staff	281-283-7524
Don White	CAIB Staff	281-283-7570
Dwayne Day	CAIB Staff	281-283-7588
Col Dave Nakayama	CAIB Staff	281-283-7835
David Kral	CAIB Staff	281-283-7571
Col Tim Bair	CAIB Staff	281-283-7521
Bill Harris	NASA/SSPO	281-483-0480
Mark Erminger	JSC – NC	281-483-0044
Yolanda Marshall	JSC - NA	281-483-2422

Johnson Space Center
Safety, Reliability, & Quality Assurance

Columbia Accident Investigation Board

Yolanda Marshall, Director

Agenda

- Organization
- Independent Assessment
- Government Mandatory Inspection Points (GMIPS)
- Surveillance and Metrics
- STS-112 and STS-107 Foam Loss

Office of Safety and Mission Assurance (Code Q)

Associate Administrator
Bryan D. O'Connor
Theresia T. Wijdoogen (Secretary)

Deputy Associate Administrator
James D. Lloyd
Theresia T. Wijdoogen (Secretary)

NASA Administrator

Resources Management
Dale E. Moore (Lead)

Aerospace Safety Advisory Panel
Leonard B. Sirota
Michele D. Dodson (Secretary)

NASA Center SMA Directors

Ames Research Center/L. Doty
Dryden Flight Research Center/L. Davis
Glenn Research Center/V. Wessel
Goddard Space Flight Center/W. Denoon
Jet Propulsion Laboratory/M. Landano
Johnson Space Center/Y. Marshall
Kennedy Space Center/O. Toledo (Acting)
Langley Research Center/A. Phillips
Marshall Space Flight Center/A. Goodson, Ph.D.
Stennis Space Center/M. Smiles

Panels
- Aviation Safety Panel
- Interagency Nuclear Safety Review Panel
- Operations and Engineering Panel
- Space Flight Safety Panel

Enterprise Safety and Mission Assurance Division (QE)
Dr. Peter J. Rutledge
Juanita L. Sandin (Secretary)

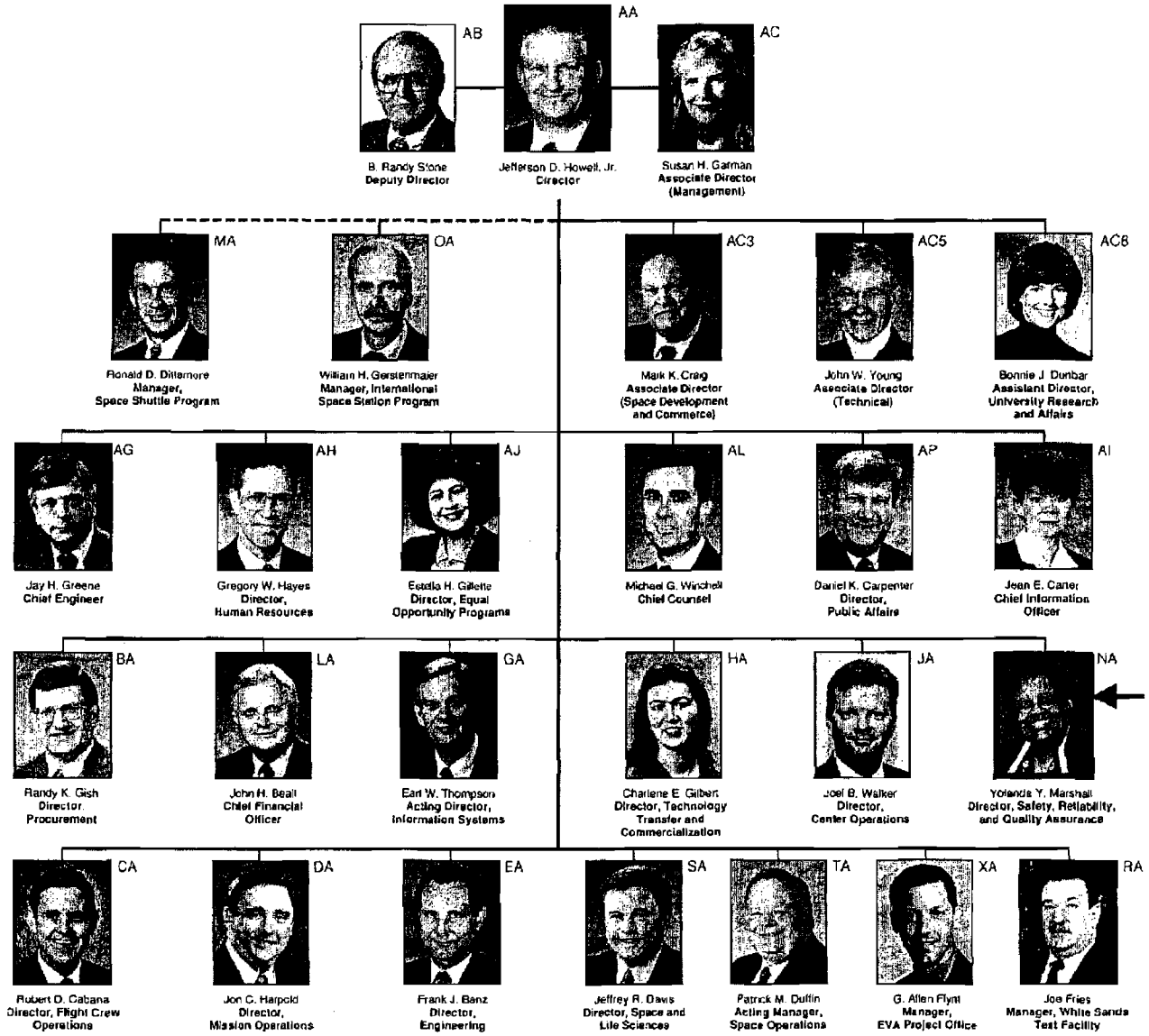
Safety and Assurance Requirements Division (QS)
James D. Lloyd (Acting)
Sylvia E. Brookover (Secretary

Review and Assessment Division (QV)
Dr. Peter J. Rutledge (Acting)
Vacant (Secretary

Rev. 03-26-03

CMM004-0016

Johnson Space Center Organization



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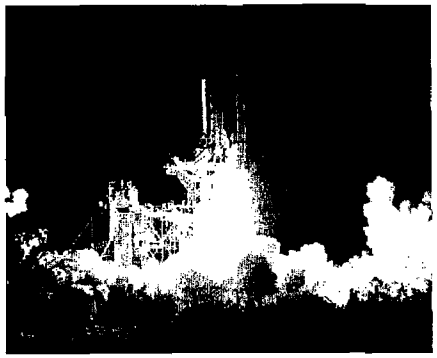
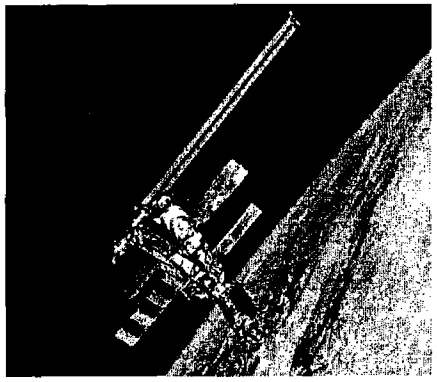
SR&QA Core Competencies





Safety Engineering

Identify and control hazards throughout the life cycle of an activity, function, project, or program.

Reliability, Availability, Maintainability, and Supportability

Establish reliability requirements, measures for design definition and review. Perform analyses, certification, problem resolution, and recurrence control.

SR&QA Core Competencies

Quality Engineering

Evaluate design, manufacture, test and refurbishment of flight hardware and software to ensure delivery of products in accordance with requirements.

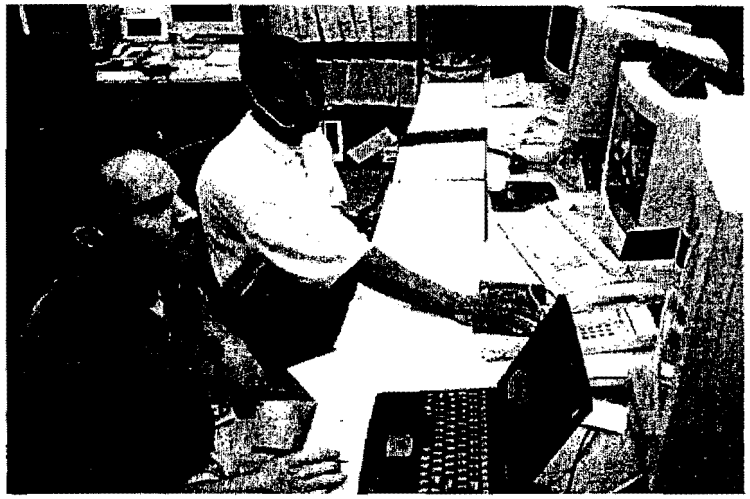
Quality Assurance

Inspect and conduct surveillance to continually monitor and verify status of contracted processes and products to ensure specified are met.

SR&QA Core Competencies

Risk Management

Assess and provide recommendations for disciplined and documented approach to ensure risk is identified, evaluated, managed, and mitigated through the life cycle



Software Assurance

Assess software to determine if it meets reliability, and safety requirements and technical performance requirements

SR&QA Core Competencies

JSC Receiving Inspection and Test Facility (RITF)

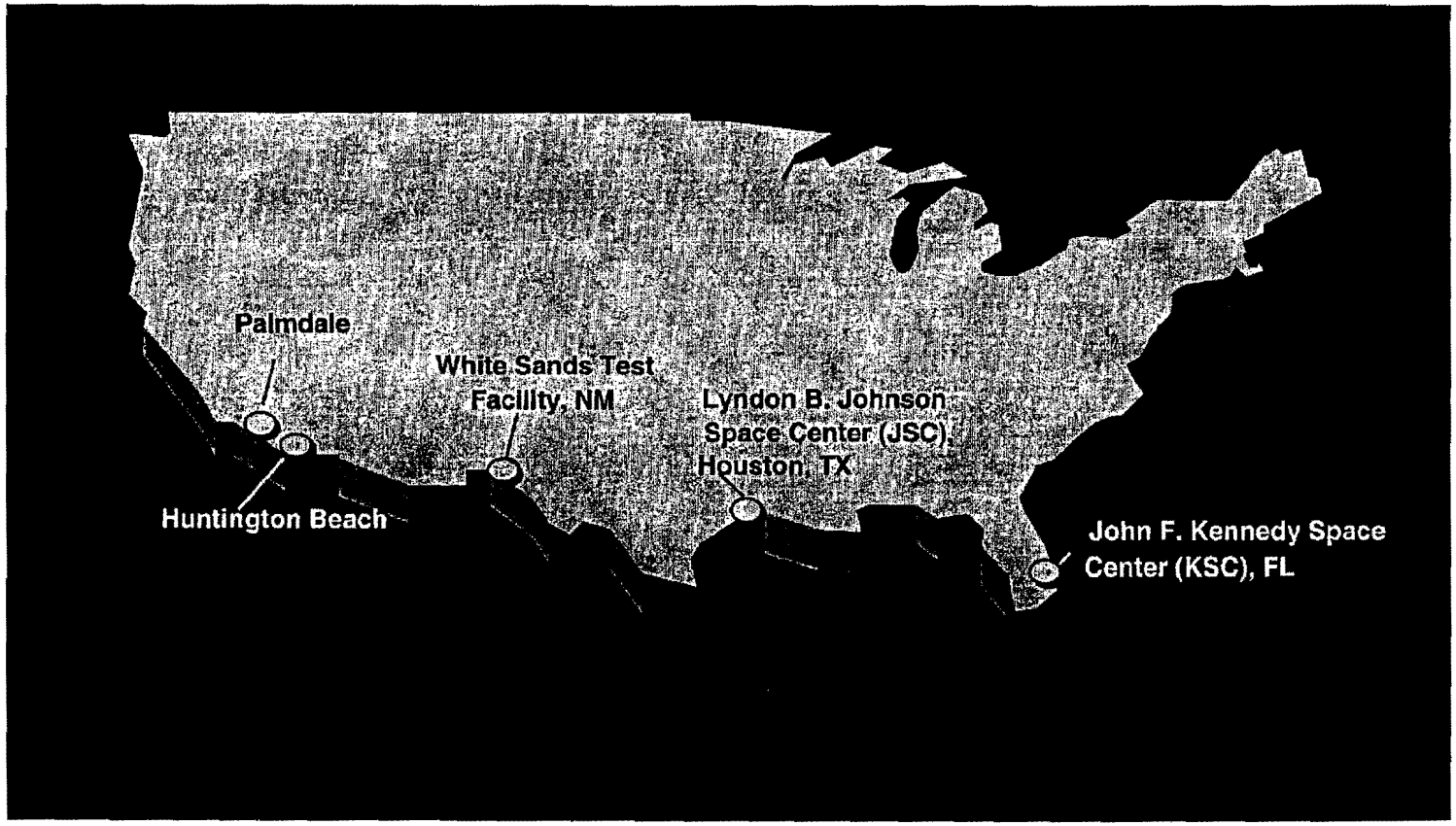
Electrical, mechanical, chemical, and nondestructive evaluation (NDE) testing & inspection. Training in electrostatic discharge, solder, crimping, conformal coating, & fiber optic terminations.

Institutional Safety

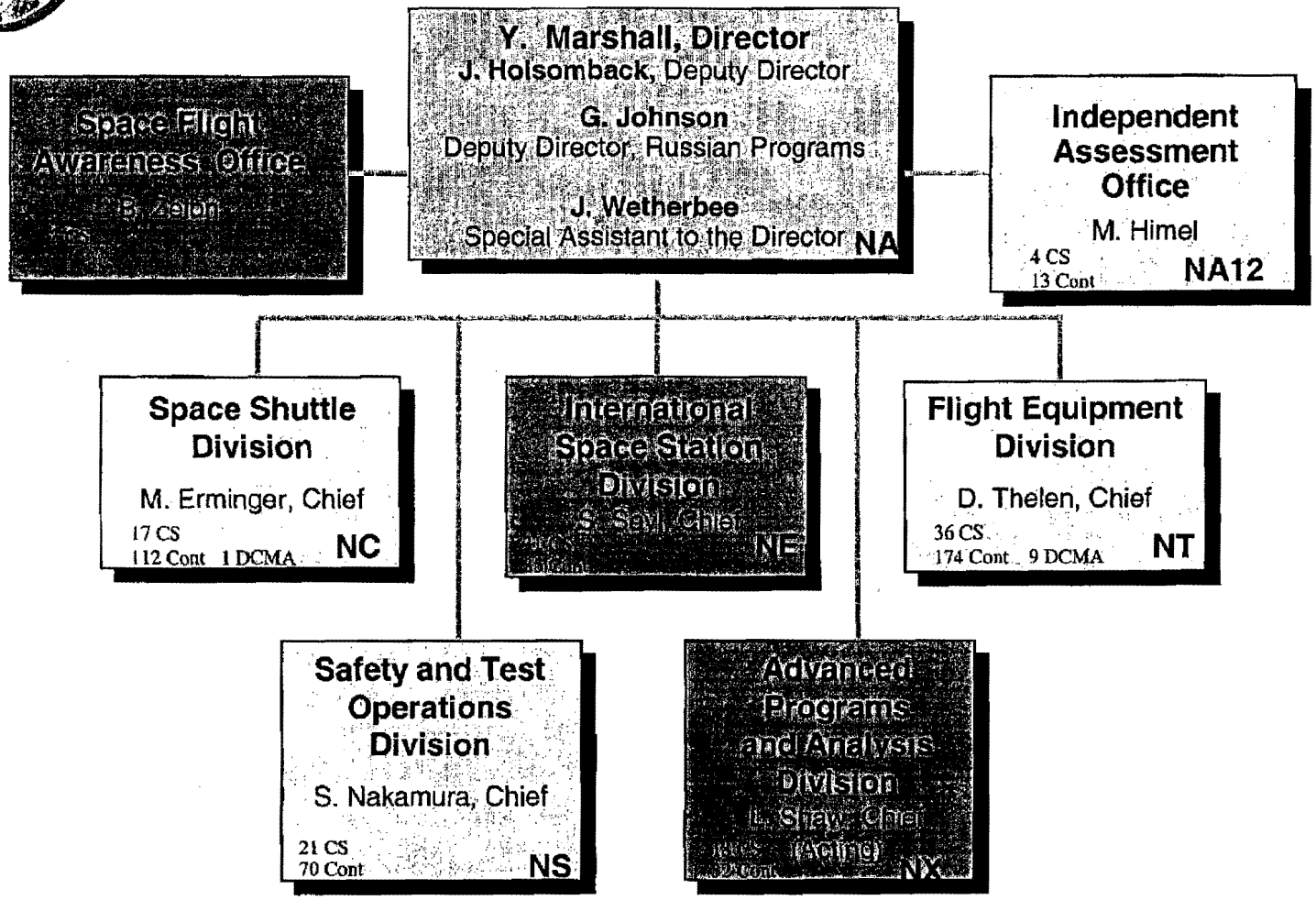
Administer the JSC Occupational Safety Program, Fire Protection Systems Maintenance and Operations, Pressure Systems, and the NASA Safety Reporting System.

CMM004

SR&QA Operations



SR&QA Organization



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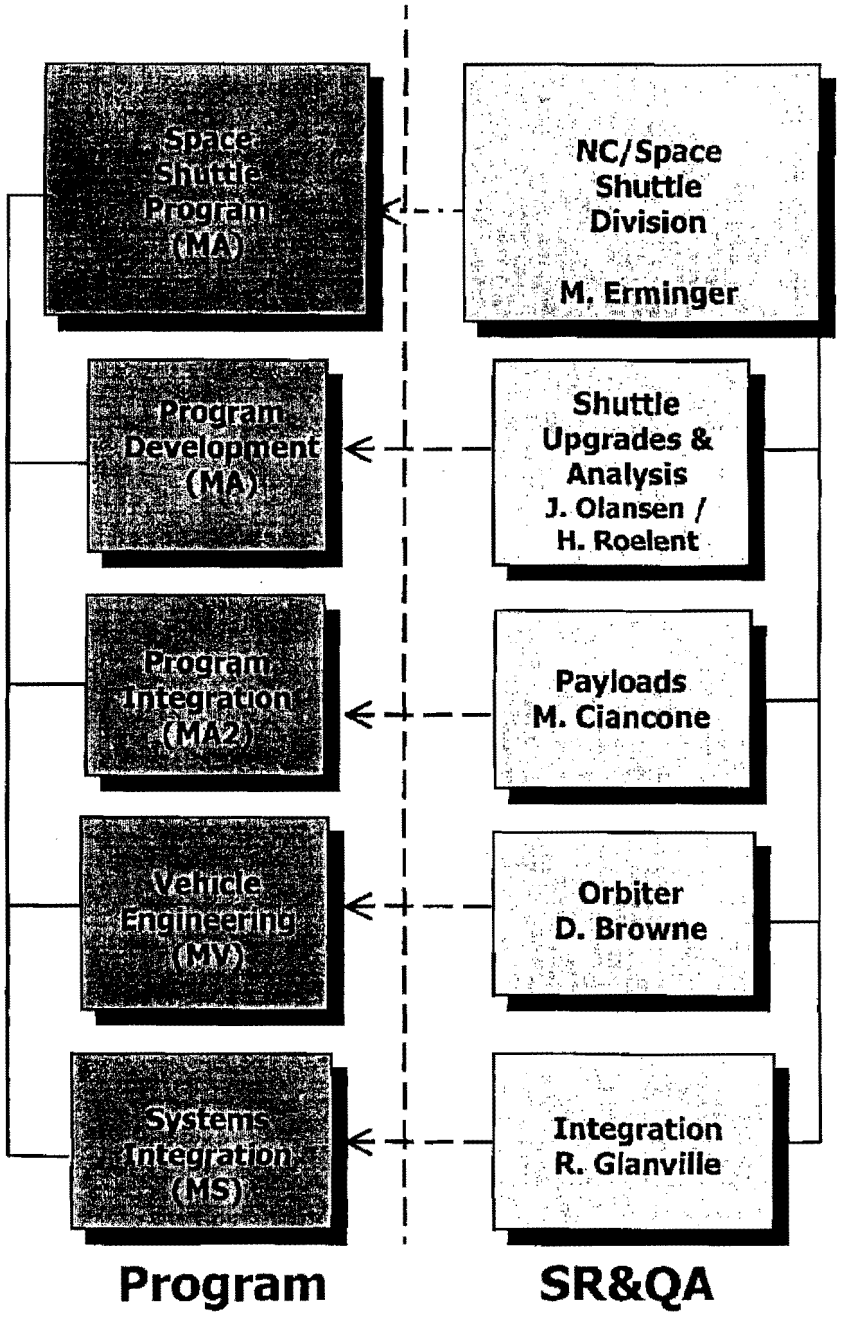


Functions

- Certification of Flight Readiness (COFR)
- Mission Evaluation Room

- Service Life Extension Program
- Probabilistic Risk Assessment
- Trending
- Reliability, Maintenance, & Supportability Analysis

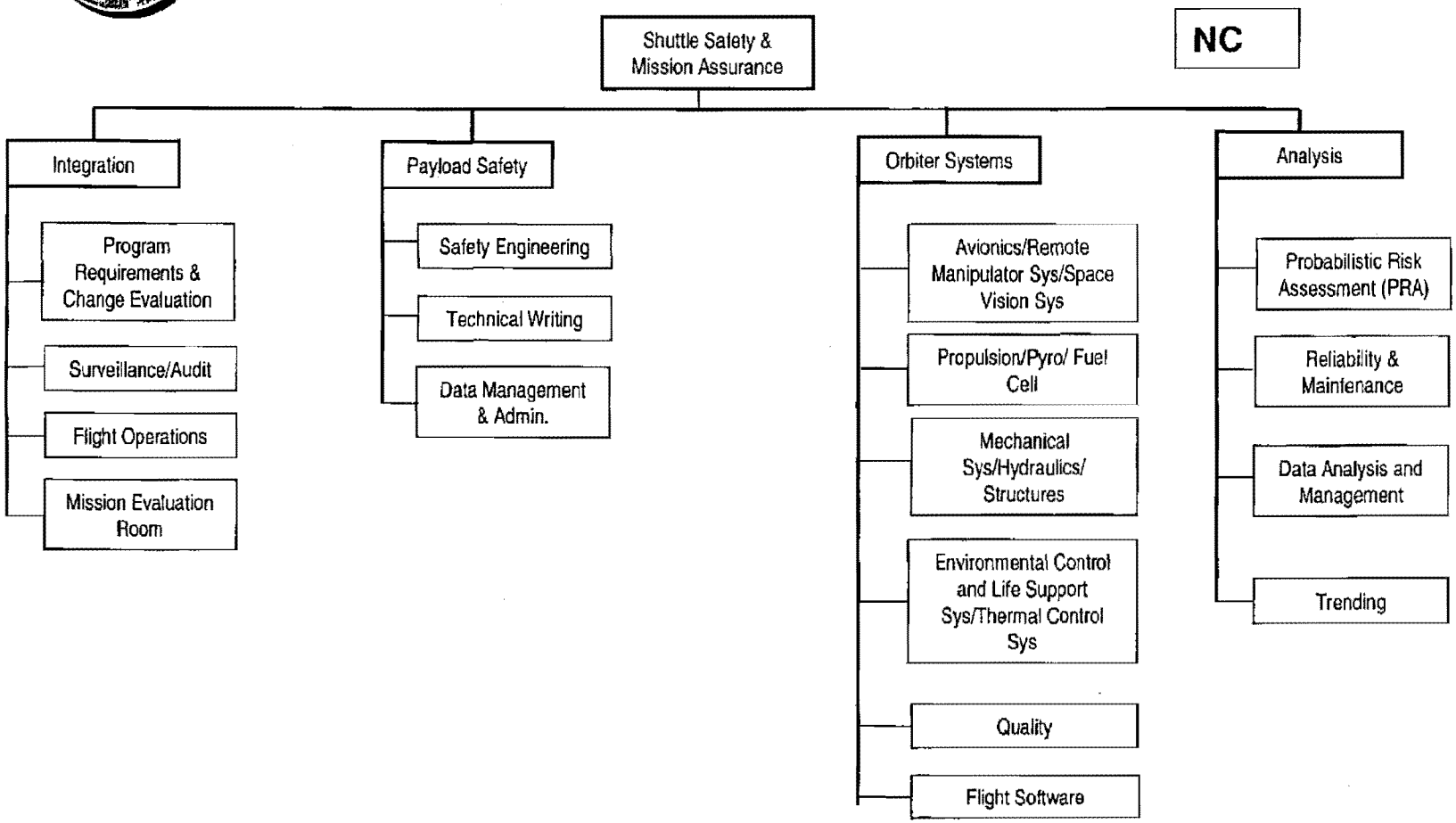
- Payload Safety Review Panel

- MV Boards and Panels
- Orbiter Software Assurance
- Procurement Quality
- Palmdale Surveillance *

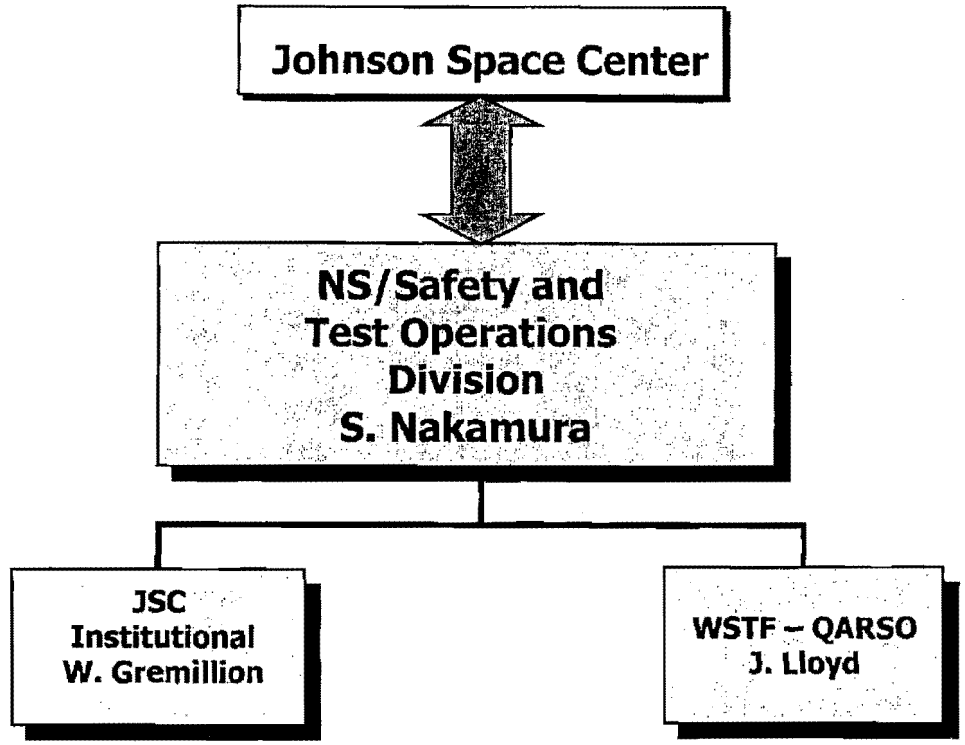
- SFOC Contract Surveillance
- MA/MS Boards and Panels
- Joint Audit Program
- Operations

* Civil Service Only

SR&QA Shuttle Contractor
Functional Areas

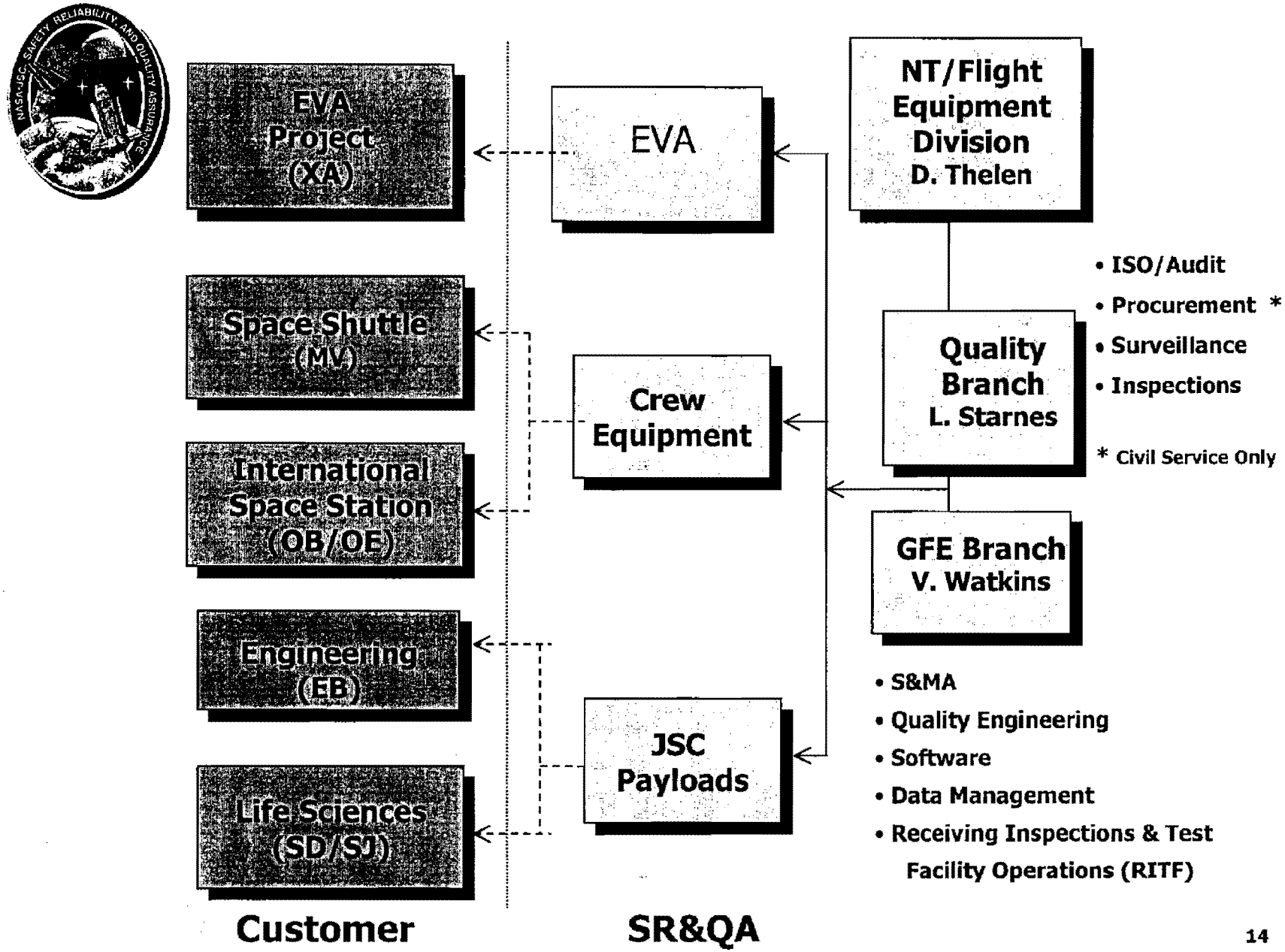


Safety and Test Operations

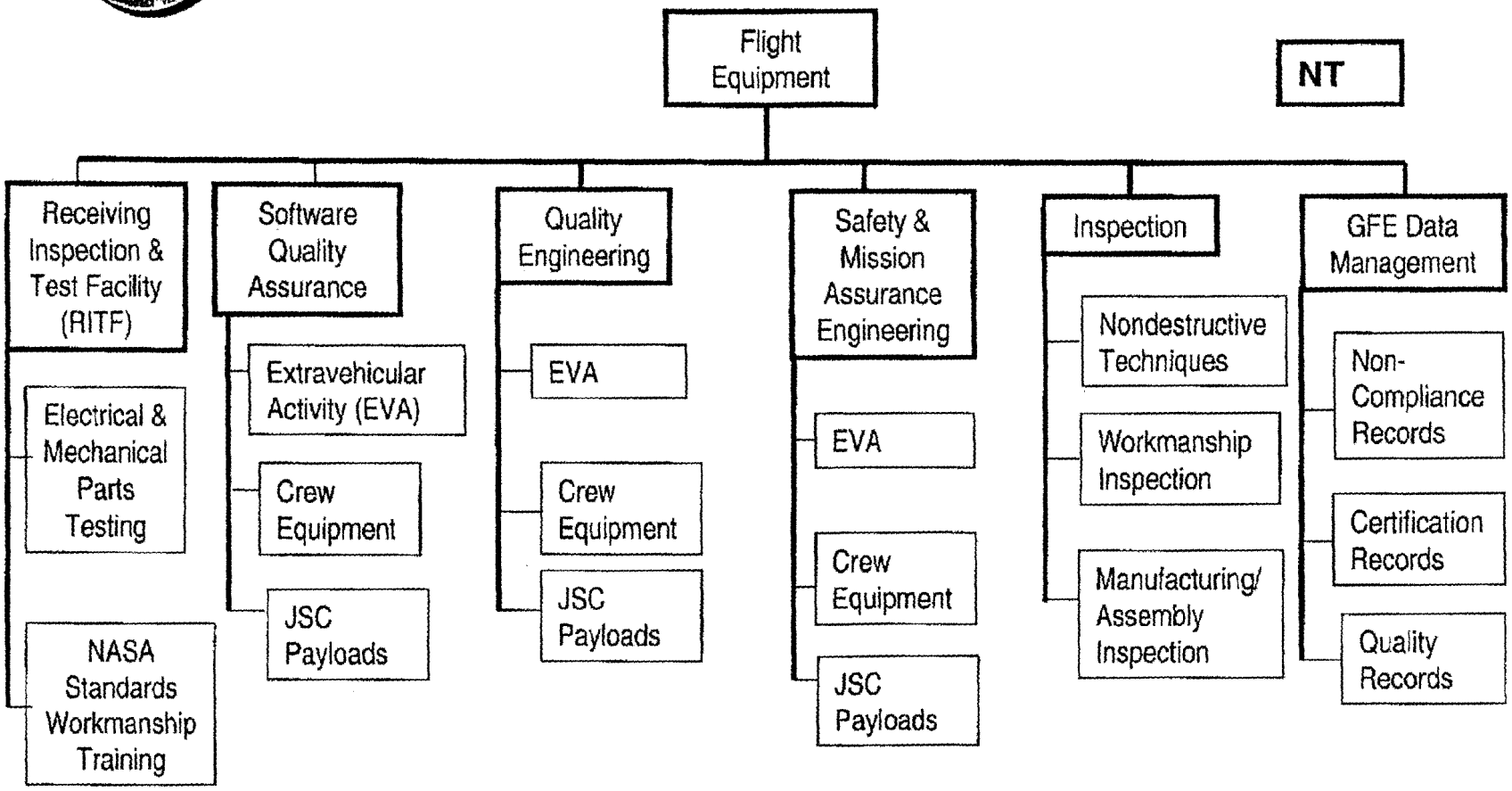


- Institutional Safety
- Fire Protection
- Safety Training
- Pressure Systems
- Safety Program Development

- Institutional Safety
- Fire Protection
- Safety Training
- Pressure Systems
- Safety Program Development
- Quality Assurance/Engineering
- Medical & Security


EVA Project (XA)
Space Shuttle (MV)
International Space Station (OB/OE)
Engineering (EB)
Life Sciences (SD/SJ)
Customer
EVA
Crew Equipment
JSC Payloads
SR&QA
NT/Flight Equipment Division
D. Thelen
Quality Branch
L. Starnes
• ISO/Audit
• Procurement *
• Surveillance
• Inspections
* Civil Service Only
GFE Branch
V. Watkins
• S&MA
• Quality Engineering
• Software
• Data Management
• Receiving Inspections & Test Facility Operations (RITF)

SR&QA Flight Equipment Functional Areas



Independent Assessment at JSC

Presenter: **Mac Himel**

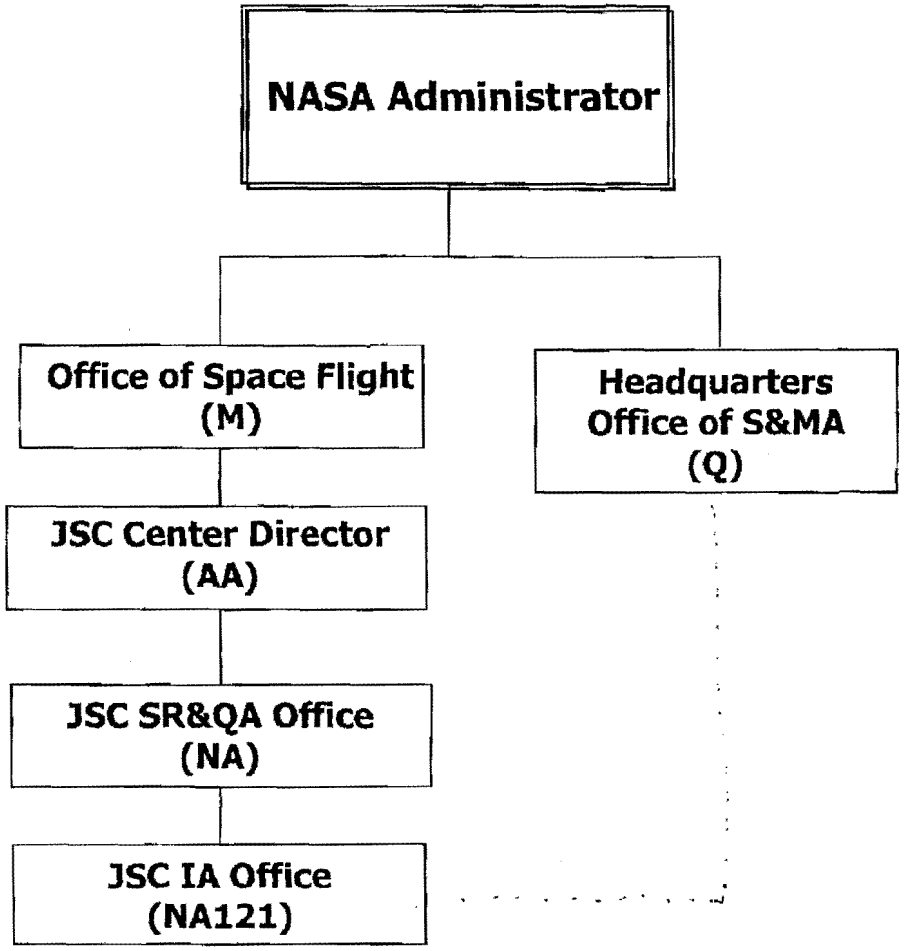
Topics

- Independent Assessment Tasks
- Organizational Structure
- Organizational Relationships
- Contractor Core Competencies
- Significant Independent Assessment Contributions

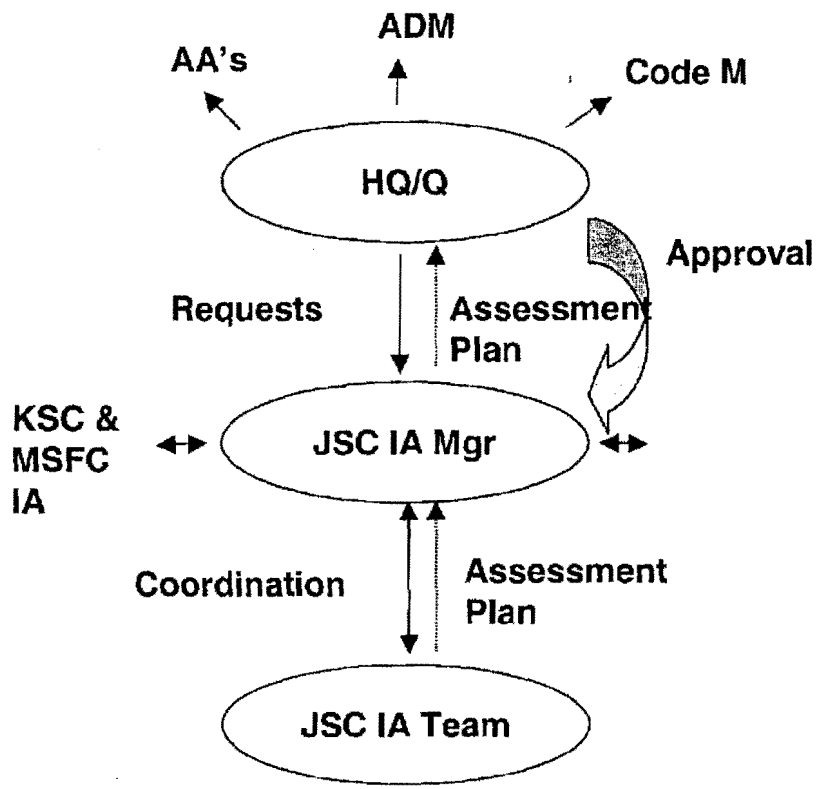
Independent Assessment Tasks

- International Space Station, Space Shuttle and Space Launch Initiative
- (Per NPD 8700.1A and NPG 1000.3)
- Perform Technical and Process Assessments– Program "Customers"
- Review assessments for relevance to mission
- Participate in S&MA Audits

Independent Assessment Organizational Structure



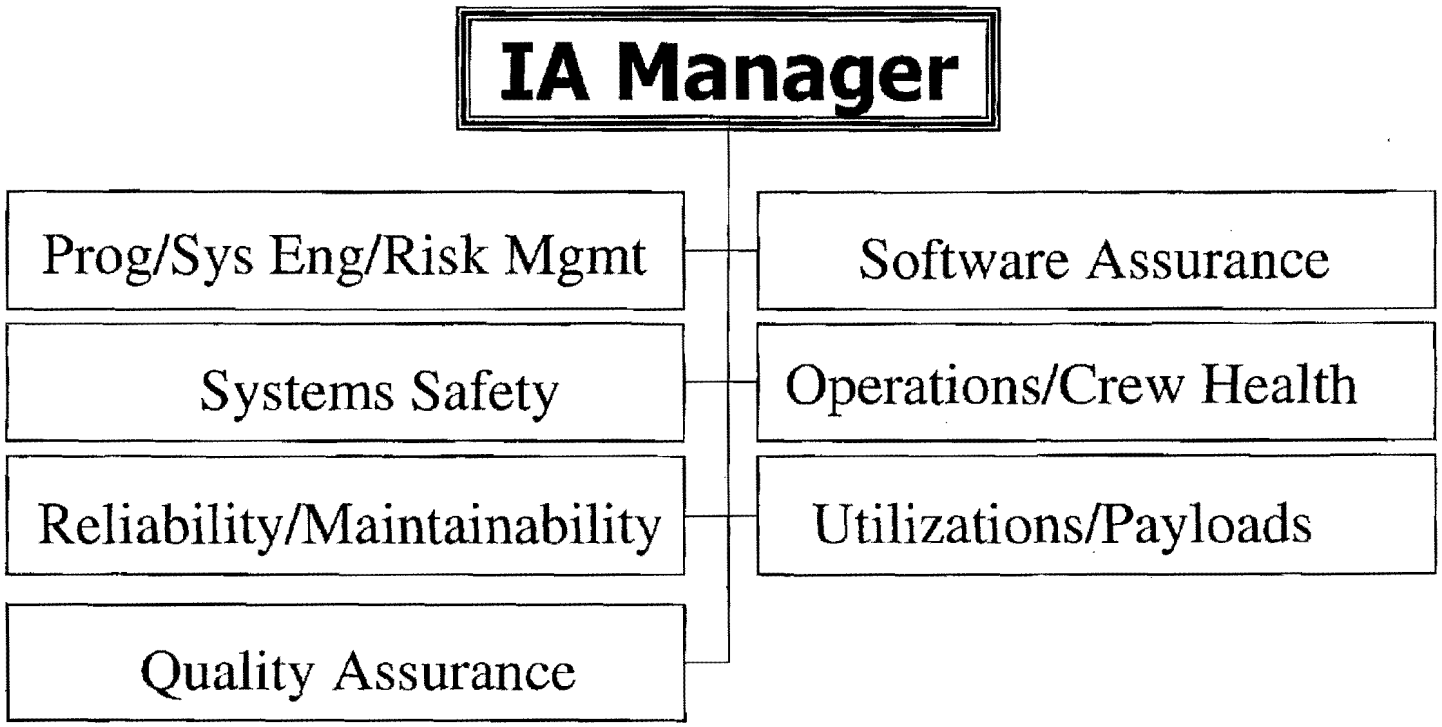
Independent Assessment Organizational Relationships



Requests:

- Program and Project Managers
- JSC SR&QA Director
- JSC Director
- S&MA Managers

Independent Assessment Contractor Core Competencies



Significant Independent Assessment Contributions

JS-2005, Orbiter Contractor Furnished Equipment (CFE) Problem Reporting and Corrective Action (PRACA) Requirements Compliance (8/14/02)

- **Observations**
  - Observations and recommendations (27) grouped into documentation, implementation processes, databases, trending requirements, operations, coding designators, and management.
  - Also identified concerns with Boeing transition of subsystem manager functions and NASA Shuttle Logistics Depot (NSLD) backlog.
- **Response**
  - Space Shuttle Vehicle Engineering Office (SSVEO) agreed with recommendations and took action to review the potential for increased emphasis on the monitoring of the PRACA system.
  - SSVEO also developed a tiger team to develop a risk ranking tool which in turn could assist in addressing the NSLD backlog issue.

JS-0010, Automated Fluid Coupling (AFC) Concept for the Orbiter Propellant Transfer System (OPTS) (1/16/00)

- **Observations**
  - Ten recommendations that affected the design, testing, and operation of the OPTS were provided to the OPTS team. Design recommendations included: designing the crank handle for compatibility with standard EVA tools; ensuring human factors are considered in the design and operation of the crank mechanism; and incorporating positive indication of translation distance and coupler mating into the drive system design.
- **Response**
  - The OPTS team concurred with the IA recommendations and developed changes to the OPTS design to incorporate the recommendations.

Independent Assessment
Shuttle Assessments 1998-2003

Shuttle Assessments

- Adequacy of STS Crew Training Resources to Support the Planned Increase in Shuttle Flight Rate
- Orbiter Major Modification (OMM) Staffing Certification/Training Requirements
- STS Electrical Auxiliary Power Unit (EAPU) Thermal Design Review and Analysis
- HEDS IA Review Reaction Jet Driver PRA
- STS Methodology for Determining Orbiter Kapton Wiring Life
- Space Shuttle Upgrades- Integration
- Orbiter Contractor Furnished Equipment (CFE) Problem Reporting and Corrective Action Requirements Compliance
- Review of the Shuttle Launch Commit Criteria
- Special Assessment: Effectiveness of Proposed Changes to the Shuttle Certification Process for GFE
- Minimum Shuttle Flight Rate to Maintain Safety and Proficiency
- Shuttle Program Annual Risk Management Review Support
- Space Shuttle Program Risk Management/Related Industry
- Evaluation of Orbiter Propellant Transfer Hardware Modifications and Procedures
- Shuttle Post-flight Processing of Critical Care Items
- Evaluation of the Need for Heaters During Columbus Module Launch-Activation Phase
- Space Shuttle Program Orbiter Periodic Maintenance and Inspection Comparison with Older Commercial Aircraft
- System Acceptance Review (SAR) Assessment for Shuttle Wireless Instrumentation System FCA/PCA
- Supportability- Industry Best Practices Survey
- Special Assessment: Identification of Shuttle Program Issues Which Effect Station/Shuttle Readiness for Flights 2A through 7A

Independent Assessment
Shuttle Assessments 1998-2003

Shuttle Assessments - continued

- Overnight Campout of Cargo Element on the Shuttle Remote Manipulator System (SRMS)
- Special Assessment: STS-91Collision Avoidance Flight Rule Interpretation and Application
- Amphenol NZGL Electrical Connector Pinch Point Risk
- Evaluation of the Current (OV-102) Orbiter Major Modification (OMM) Flow
- Long-Term Space Shuttle Logistics Supportability
- Review of Workmanship Cause Codes within the KSC/Shuttle Problem Reporting and Corrective Action System

Joint Shuttle/Station Assessments

- Coverage and Performance of the Space-to-Space Communication Systems (SSCS)
- Automated Fluid Coupling (AFC) Concept for the Orbiter Propellant Transfer System (OPTS)
- Trade Study Selection Criteria for Automated Fluid Coupling (AFC) Concept for the Orbiter Propellant System (OPTS)
- Assessment of H-II Transfer Vehicle (HTV) EEE Parts Management and Implementation Plan
- Adequacy of Intravehicular Detection of Hypergolic Propellant Contamination Following Extravehicular Activity
- International Space Station Program Non-compliance Report (NCR) Process
- Evaluation of Extravehicular Mobility Unit Oxygen System Contamination Mitigation Plans
- Evaluation of On-Orbit Constraints for Nominal Operations During Stage 4A
- Evaluation of On-Orbit Constraints for Contingency Scenarios during Stage 4A

Independent Assessment
Shuttle Assessments 1998-2003

Joint Shuttle/Station Assessments - continued

- Evaluation of Space Shuttle Orbiter Vehicle as a CRV for ISS
- Evaluation of Training Related Factors that Impact the STS Crew Weekly Preflight Workload
- Review of Generic Flight Rules Volume C
- Impact to Tether Hook Induced Pryloads to EVA Handrail Structure Interfaces
- An Evaluation of Flight 2A.1 (STS-96) Plans for Demonstrating Space Vision System Readiness
- STS-93 Through STS-103 General Operations Assessment
- Adequacy of the Certification Process for the SAFER
- Applicability of Spacelab Flight Rules to the ISS
- Phase 1 Program (Shuttle/Mir) to Phase 2 Program (Shuttle/ISS) Hazard Assessment Traceability
- Evaluation of Training Provided by the USA Training Academy for MCC Flight Controllers
- Evaluation of Generic Flight Rule CRs for the JFRCB #6
- Readiness Review of ISS Berthing Operations for Flights 3A-9A
- An Evaluation of Preliminary Space Vision System Test Plans for Flight 2A.2
- H-fixture Stress and Fracture Analysis Review
- Adequacy of the Manifesting and Cargo Integration Processes to Support the ISSP
- The Use of Ethylene Oxide (EtO) for Sterilization of Flight Hardware
- Adequacy of SAFER Training to Support Shuttle and ISS EVA Operations
- Safety and Certification Processes for ISS Russian EVA Hardware and Flight Crew Equipment
- Adequacy of the Wireless Instrumentation System (WIS)
- Quick Look Investigation of Sony Mini-cam (Model #XC-999) Reliability
- Determination of ISS Assembly Activity Failures that would Require Shuttle Contingency Flights

Government Mandatory Inspection Points (GMIPs)

Presenter: **Scott Johnson**

Management of Government Mandatory Inspection Points

- JSC SR&QA is responsible for the assignment and management of Government Mandatory Inspection Points in the following areas:
  - JSC procured Government Furnished Equipment (GFE)
    - Onsite: MIPs Performed by NASA Quality Assurance
    - Offsite: Defense Contract Management Agency (DCMA) MIPs Performed by DCMA by Letter of Delegation (LOD)
  - Orbiter Contractor Furnished Equipment (CFE) procured by Boeing Huntington Beach

Criteria for Government Mandatory Inspections

- **MIP Determination is in accordance with NPG 8735.2, Management of Safety & Mission Assurance Functions for NASA Contracts. Considerations in the selection process include:**
  - Experience with past contractor performance
  - Design, safety, drawing, engineering, configuration, specification, and technical document reviews
  - Reliability, maintainability, and system safety tests and analyses.
  - Failure Mode and Effects Analysis (FMEA) and Critical Items Lists (CIL) and Hazards Analysis.
  - Contractor quality assurance manuals, requirements, and selected quality system documents, e.g., the quality plan or quality policy.
  - The delegated agency or the NASA Safety and Mission Assurance Lead may determine if other actions or characteristics should be identified as mandatory actions or characteristics on a temporary basis.
  - Input from the technical monitor.

DCMA Letters of Delegation

- Letters of Delegation are prepared by SR&QA and issued by the NASA contracting officer to the Defense Contract Management Agency per the guidelines established by NPG 8735.2
  - JSC SR&QA Office approval is required for GFE procurement
  - Shuttle Program S&MA Manager approval is required prior to the release of new delegations for Contractor Furnished Equipment (CFE).

Center MIP Responsibility Summary

- JSC S&MA is only responsible for JSC procured hardware
- Orbiter MIPs performed at KSC are managed by KSC Shuttle S&MA
- MSFC Element MIPs are managed by MSFC S&MA

Contractor Surveillance

Contractor Surveillance

Prime Contractor/USA

Support Contractor/SAIC

Prime Contractor Surveillance

Real-Time Surveillance

- Thoroughness evaluation of contractor risk assessments prepared for Shuttle change boards (i.e. PRCB, VECB, SSRP, FRCB, etc.)
  - Assures impacts to program risk baseline (Hazards and CILs) are identified
  - Evaluations performed by SR&QA Board representatives
- Acceptance of contractor inspection points via MIP process
- Supplier material review board (MRB) approvals

Prime Contractor Surveillance

Audits

- Joint Audits with MSFC, KSC, and JSC
- Contractor compliance audits which validate quality management systems and processes
- SSP Master Audit Schedule is located at
  http://wwwsrqa.jsc.nasa.gov/japc
- DCMA Supplier risk assessments

Reporting

- Quarterly SR&QA surveillance reports for the Space Shuttle Program S&MA Manager

Support Contractor Surveillance

Real-Time Surveillance for Quality and Timeliness:

- Qualitative and Quantitative Analysis
- Risk Evaluations (e.g., PAR presentations, change evaluations)
- S&MA Product Deliverables

Reporting

- Monthly informal, Division-Level Technical Management Reviews (TMR)
- Formal Quarterly SR&QA TMR with NA Directorate

Shuttle Division Support Contractor Quality Rollup
(Requirements Identified in Task Agreements: MA, MV, and MS Tech Base)

PURPOSE: To summarize department performance for quality of selected SS&MA products. Products include quality of change paper evaluations, PAR presentations, one-page summaries & flight readiness packages. Customer scores can range from 1.0 (Poor) to 5.0 (Excellent) and are converted to show the percentage receiving 4.0 or better. Each process is weighted equally.

Excellent= 4.1-5.0 (91-100%)
Very Good= 3.1-4.0 (81-90%) - Preventive Action (PA) initiated below 4.0
Good= 2.1-3.0 (71-80%) - Corrective Action (CA) initiated below 3.0
Satisfactory= 1.1-2.0 (61-70%)
Poor= 0-1.0 (60% and below)

GOAL: Excellence with minimum performance of 4.1 or 91% of scores receiving score of 4.0 or better.

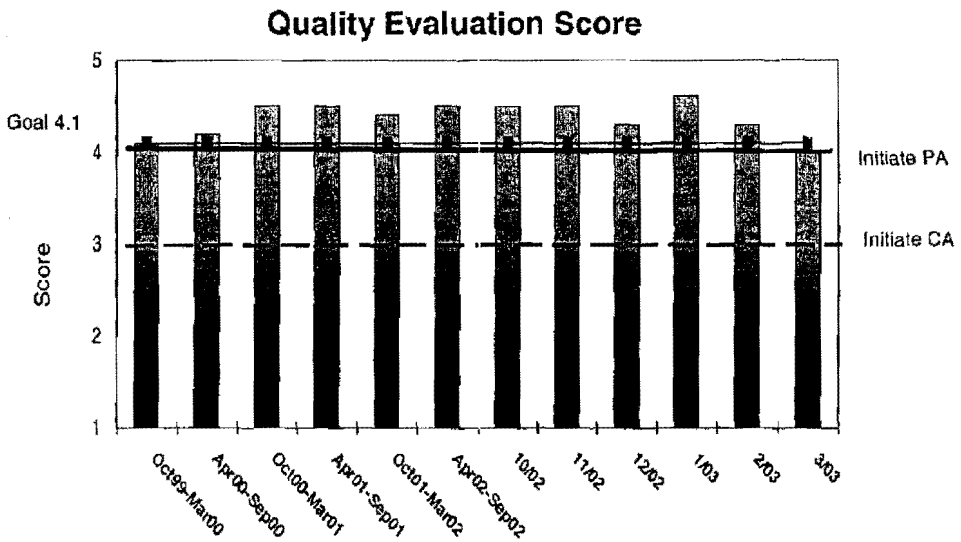
CURRENT ANALYSIS: Performance for **March 2003** exceeded our goal with a score of **93% (40 of 43)** with SSMA products having met or exceeded customer requirements.

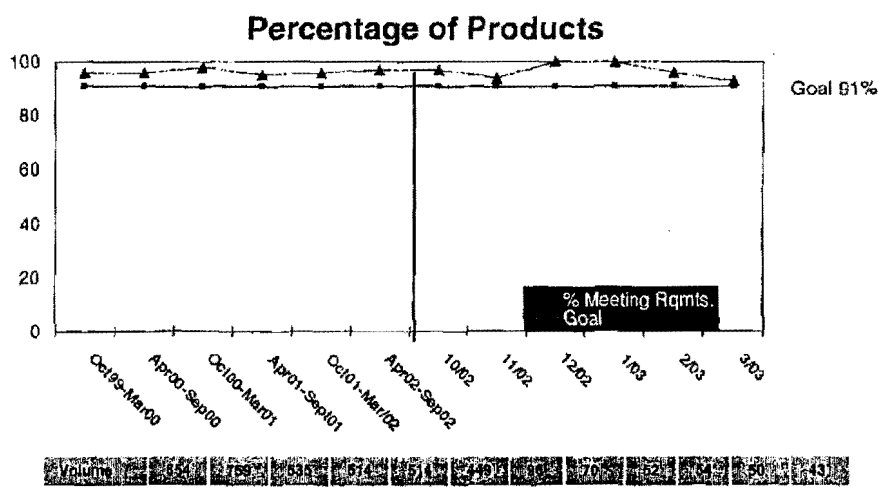
CURRENT PERFORMANCE: Excellent.

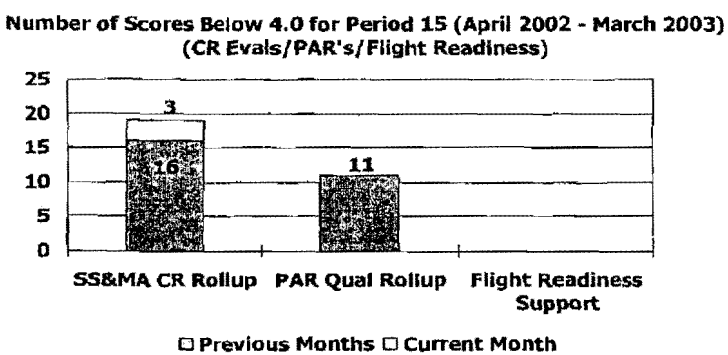
PREVENTIVE ACTION: None required.

CORRECTIVE ACTION: None required.

Customer: M. Erminger







AS OF 3/20/03

Trending

Presenter: **S. Nakamura/R. Boyer**

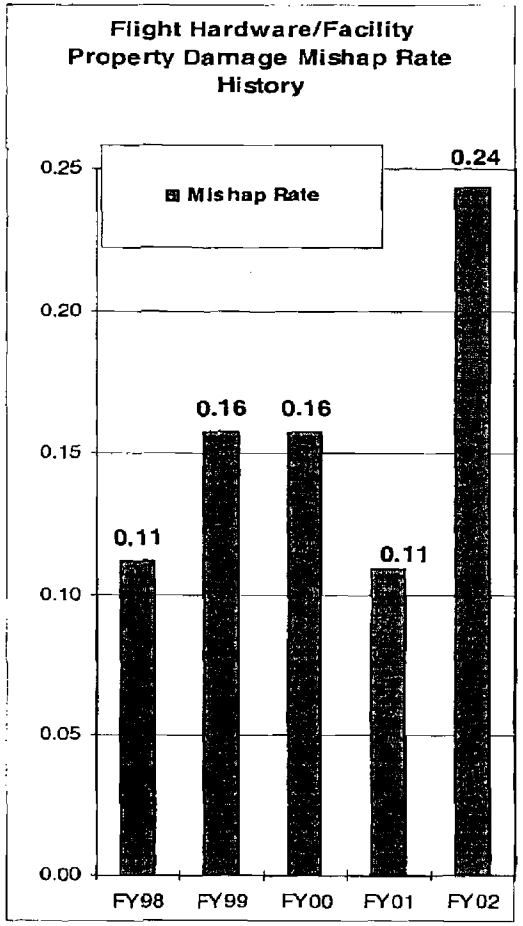
Center Trending

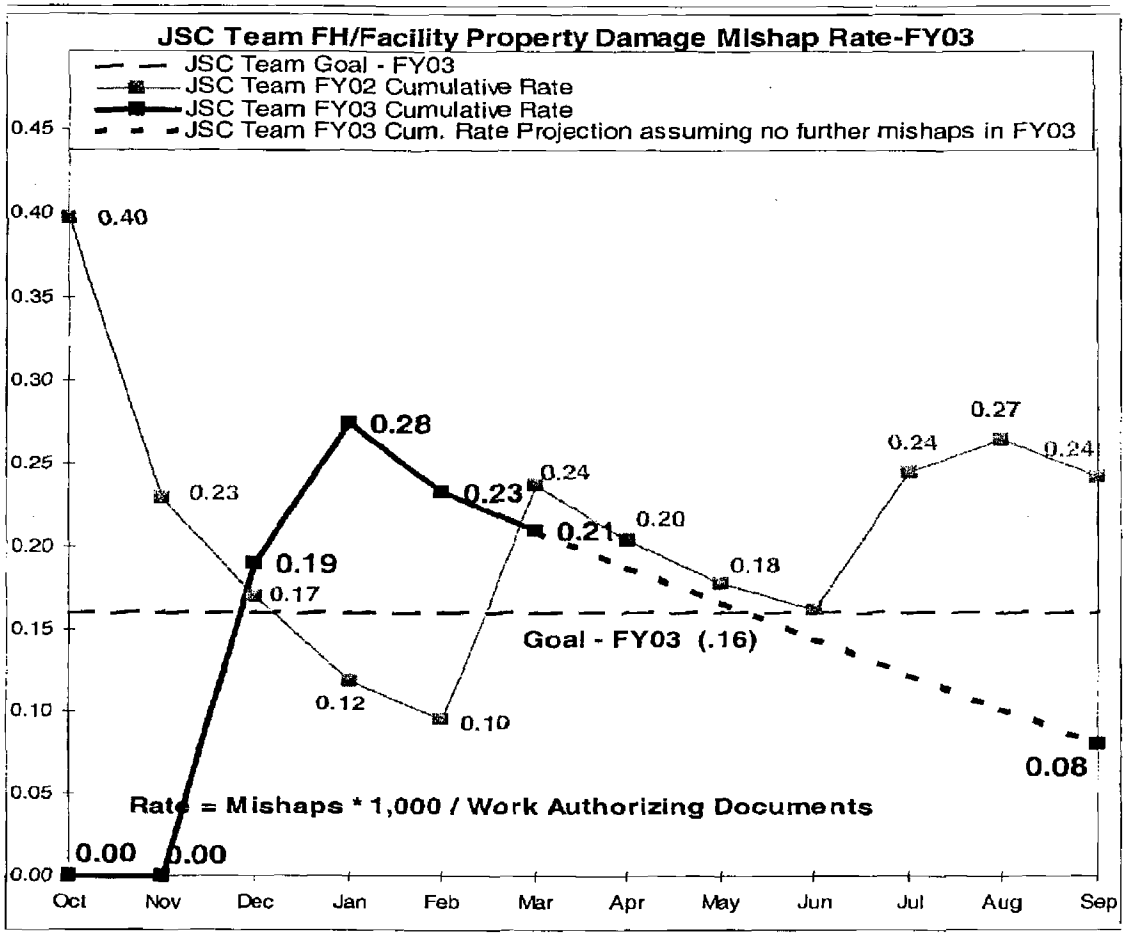
- GFE Processing
- Safety

JSC Team Flight Hardware and Facility Property Damage Mishap Rate FY03 (NA)

Last Update: 3/25/03

Metric Summary: FY03 JSC Team Flight Hardware and Facility Property Damage Mishap Rate through March has been at a rate of 1 mishap per 5000 work authorizing documents. Each mishap has been investigated and corrective action implemented.

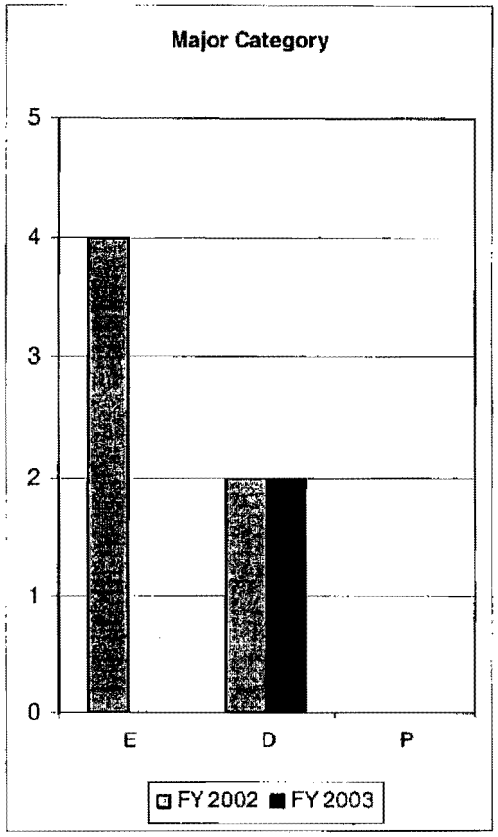


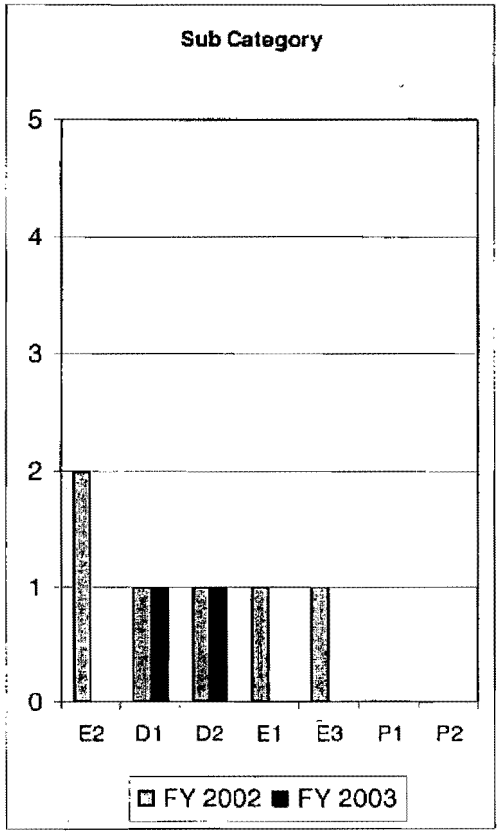


JSC Team Flight Hardware and Facility Property Damage Trend

Flight Hardware/Facility Property Damage Mishap Cause Categories

Metric Summary: To date no specific mishap cause category has been identified warranting additional corrective action





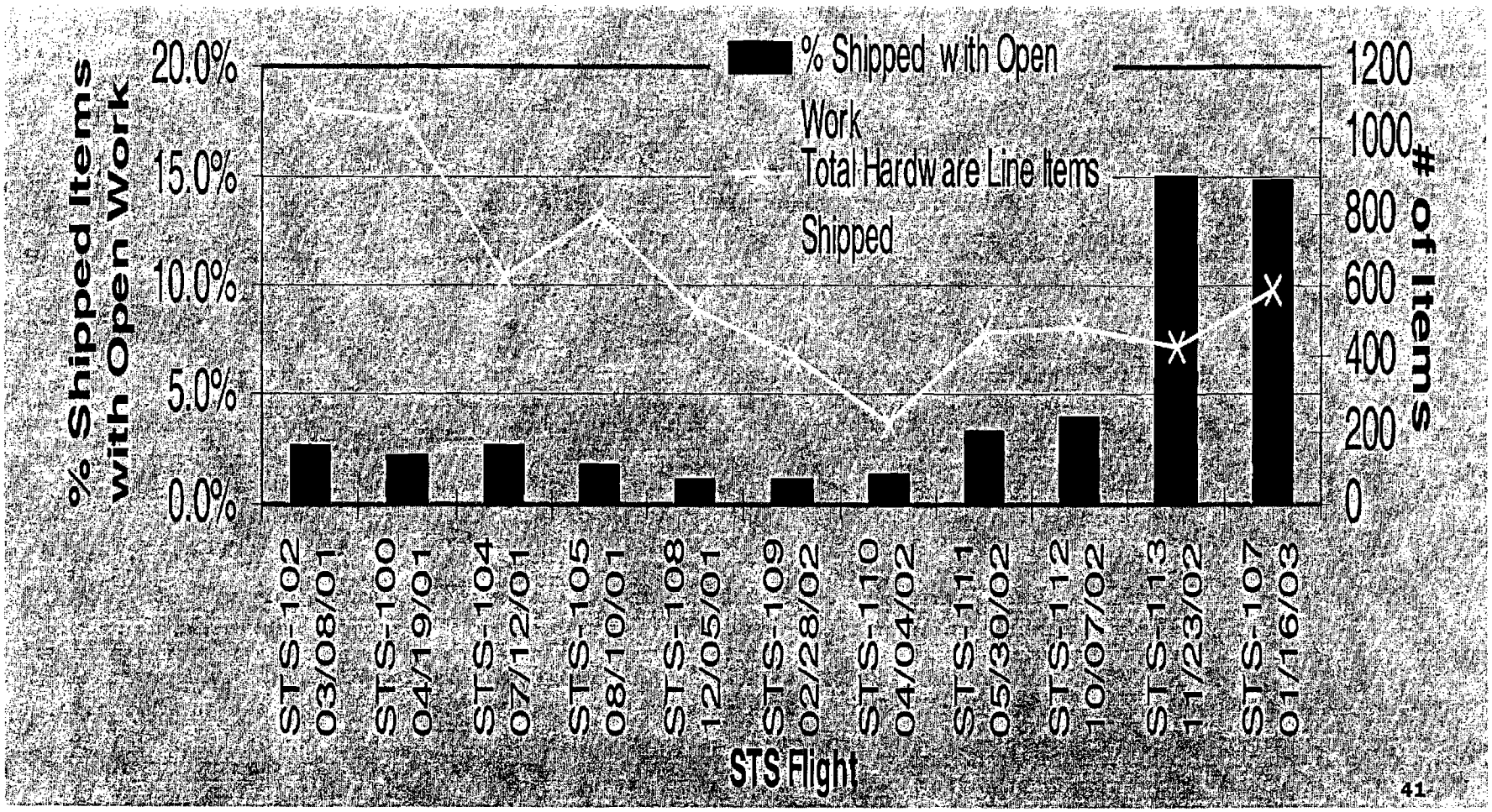
- People
  - P1 – Not properly trained
  - P2 – Not properly equipped
- Documentation
  - D1 – Procedure/instruction not available
  - D2 – Inadequate procedure/instruction
- Equipment
  - E1 - Inadequate design
  - E2 – Not properly fabricated/assembled/installed
  - E3 – Not properly maintained

Last Update: 3/25/03

GFE Flight Equipment Project Completeness at Shipment Metric

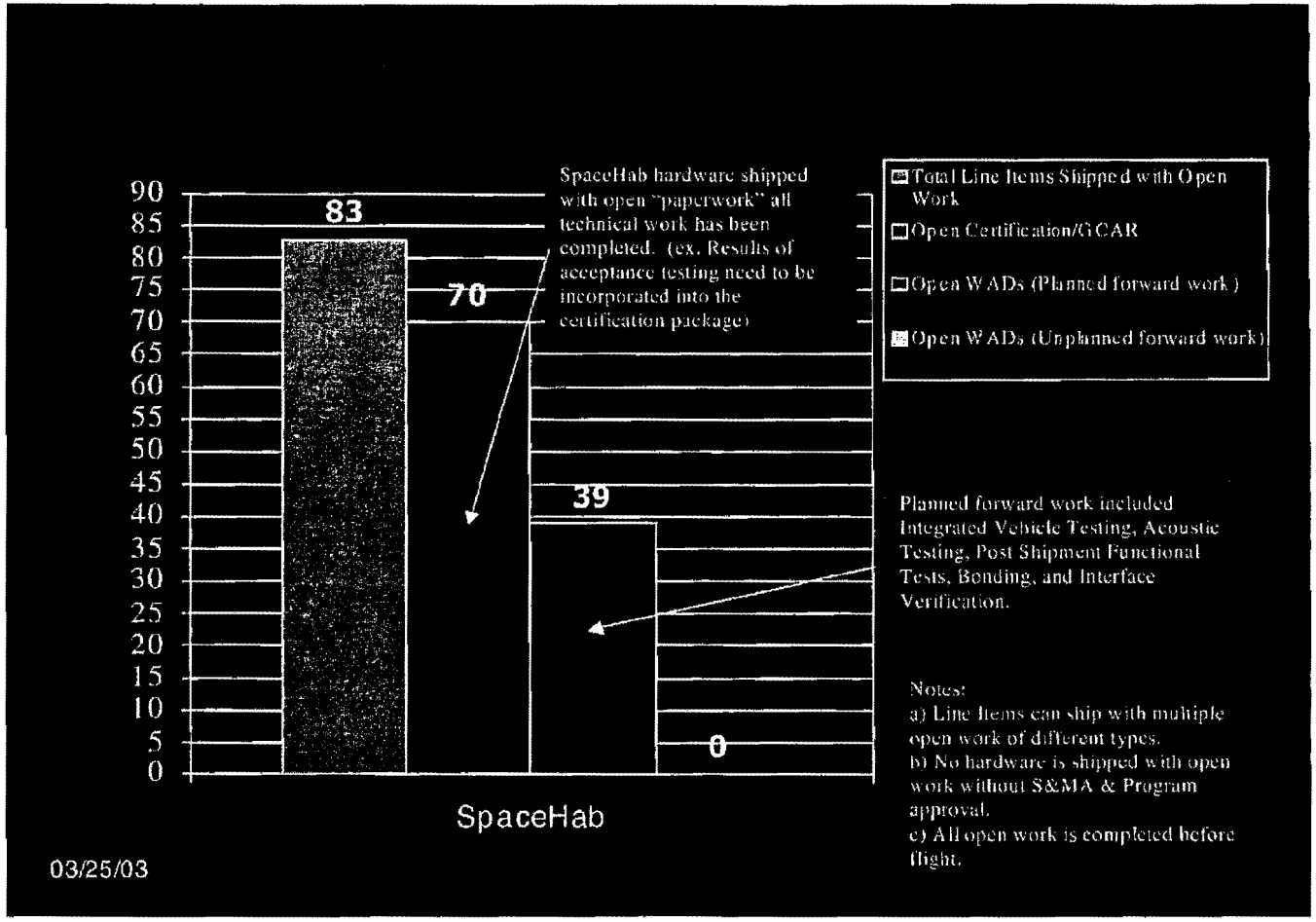
Hardware Shipped for Flight with Open Work

Metric Summary: Typically less than 5% of flight hardware is shipped with open work. However, the past two flights have shown a significant increase due to hardware shipped specifically for the Human Research Facility and SpaceHab. Both projects require early integration at the launch site to complete system verification for flight certification. No corrective action required.



CMM004-0054

STS-107 Breakdown
Items Shipped With Open Work

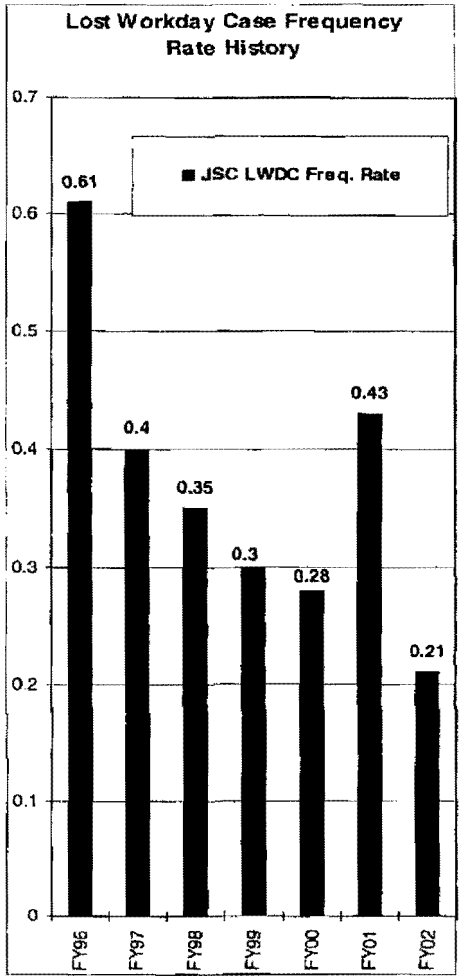


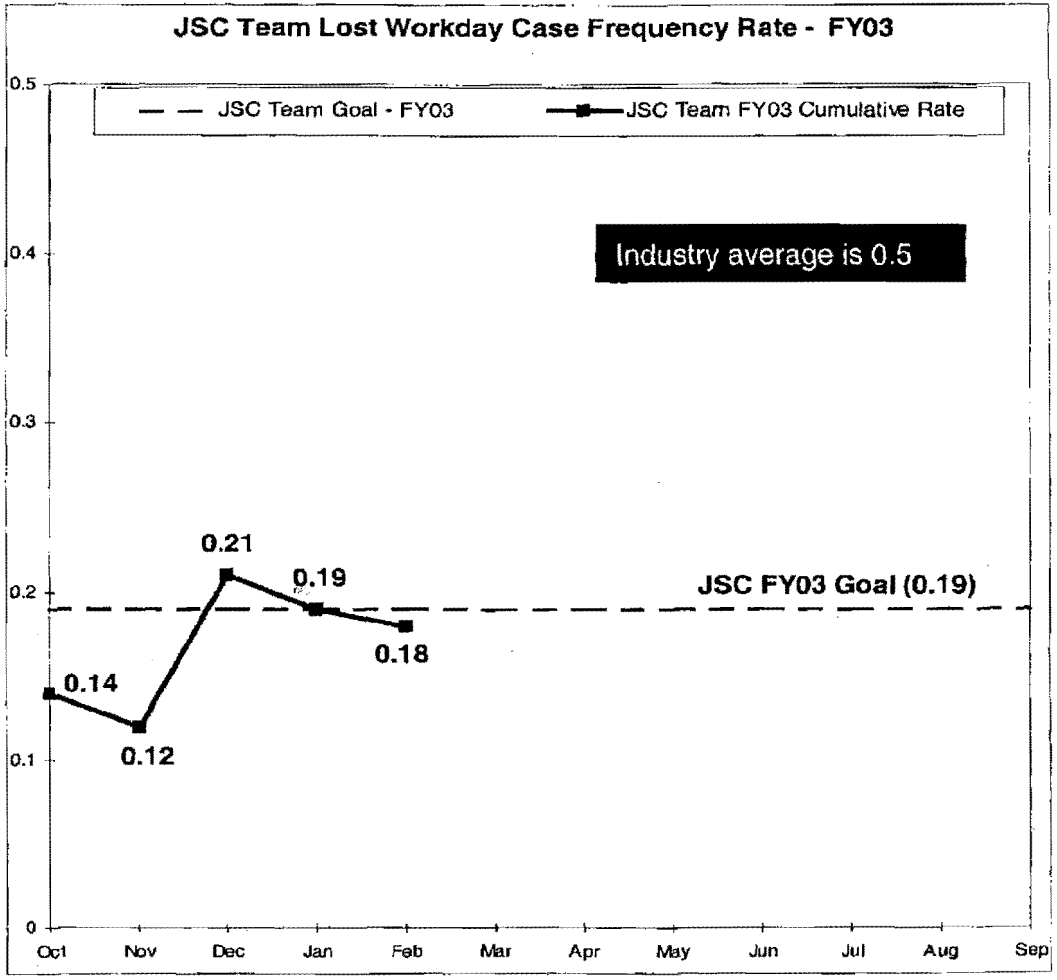
JSC Vision: Hurt No One – Zero OSHA Recordables

JSC Team Lost Workday Case Frequency Rate FY03

Metric Summary: The JSC Team Lost Workday Case Frequency Rate for FY03 was 0.18, equal to the JSC Team Goal (0.19). One LWDC was reported for the month of February.

Last Update: 2/28/03



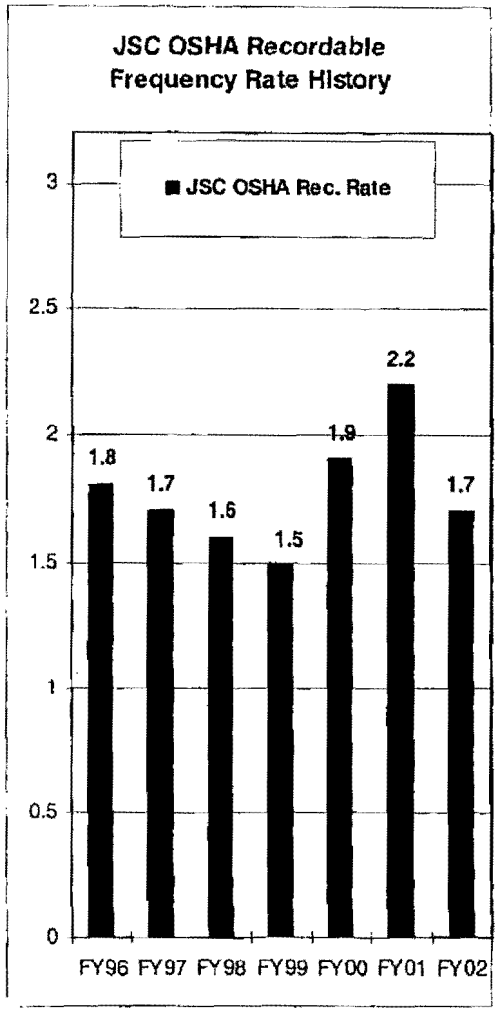


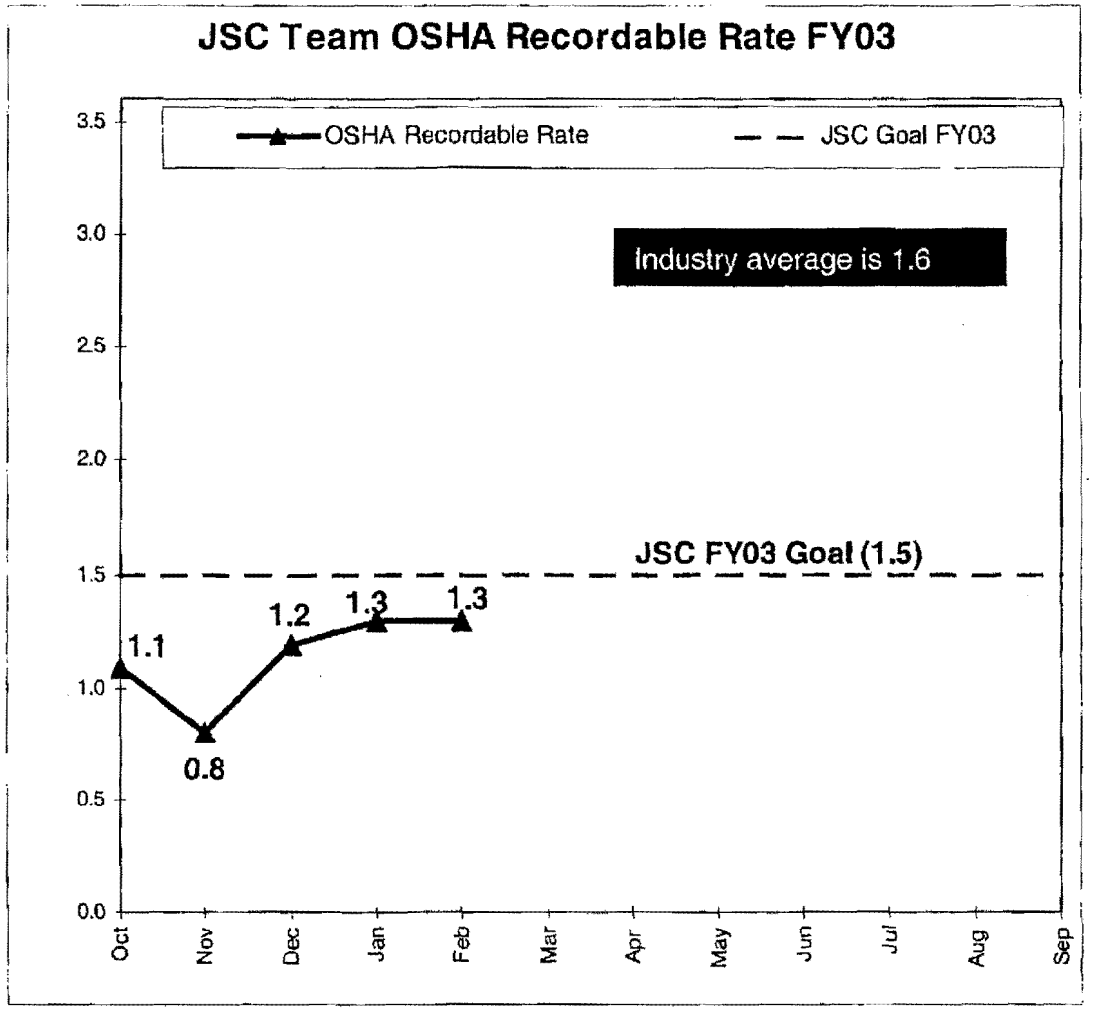
JSC Vision: Hurt No One – Zero OSHA Recordables

JSC Team Occupational Safety and Health Administration (OSHA) Recordable Frequency Rate FY03

Last Update: 2/28/03

Metric Summary: JSC Team OSHA Recordable frequency rate for FY03 was 1.3, below the JSC Team Goal (1.5).



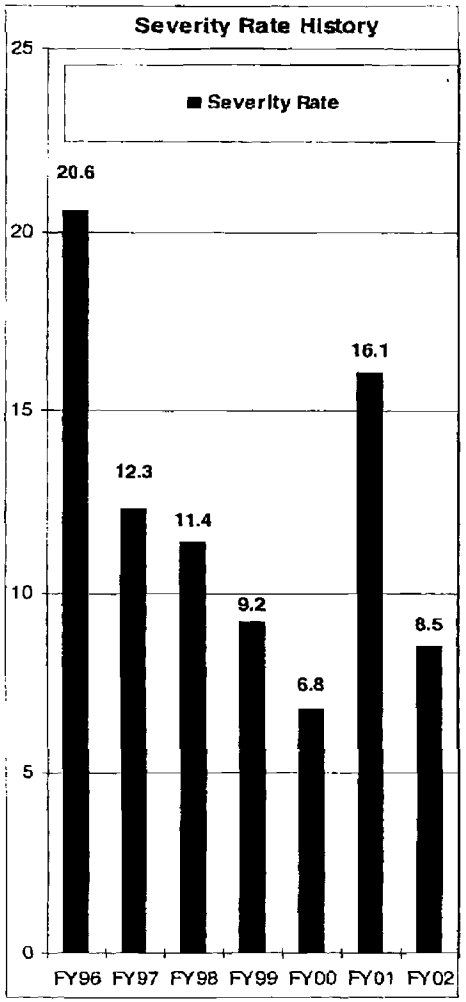


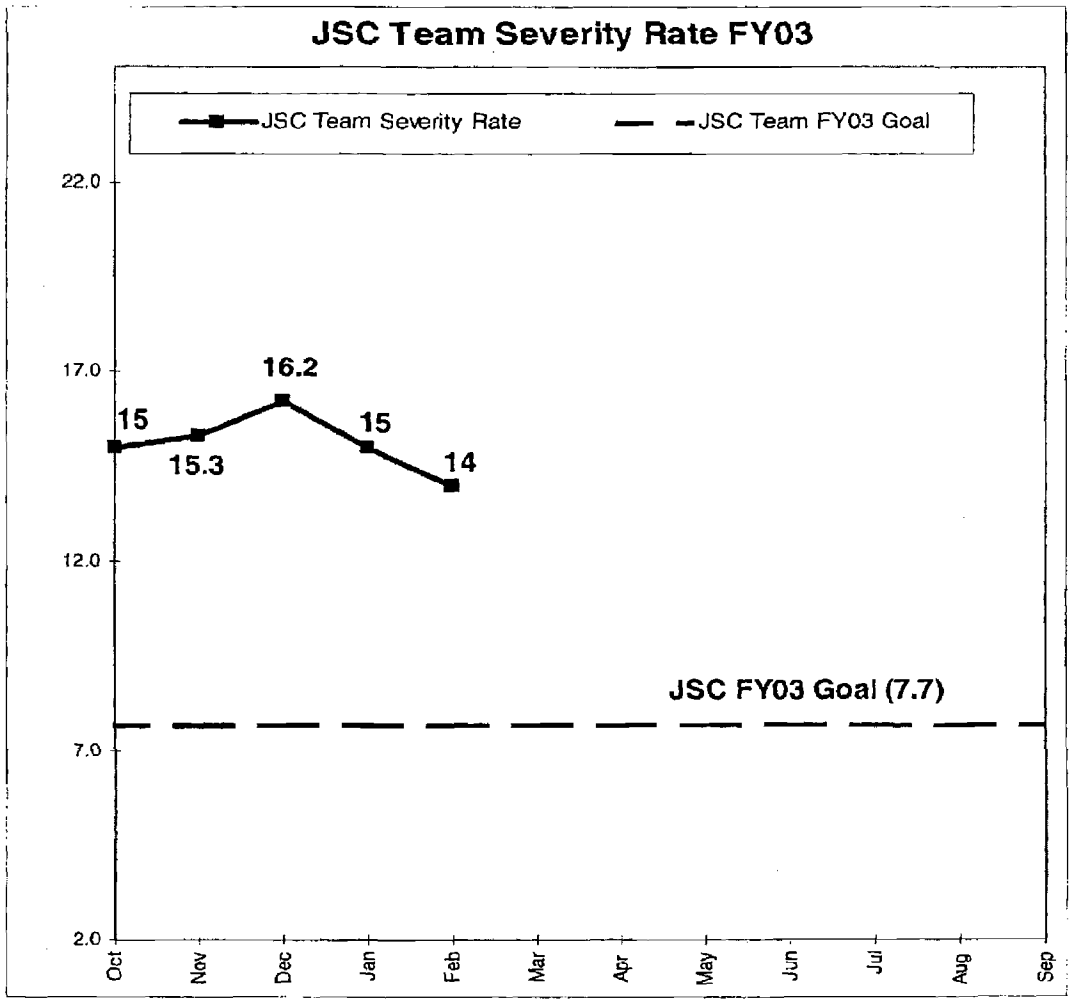
JSC Vision: Hurt No One – Zero OSHA Recordables

Last Update: 2/28/03

JSC Team Severity Rate FY03

Metric Summary: JSC Team Cumulative days away from work for FY03 was 522. Of the 522 days away from work, 468 days (89 %) were from previous fiscal year LWDCs. JSC Team Severity rate for FY03 was 14 which is above the JSC Team Goal of 7.7.





Program/Project Trending

- Trend Report
- Quick Look
- Reliability, Maintenance, & Supportability (RMS) Analysis

Trending

Trend Report

- Assessment of Orbiter vehicle design center problems (excludes KSC non-conformances not required to be reported to the design center)
- Provides "big picture" analysis of trends across all vehicle systems for the recent past (2, 5, & 10 year assessments)
- Utilizes *Risk Index* criteria coupled with age to further assess unresolved problems
- Correlates unresolved problem age with repair location and further assesses high volume/oldest problem vendors

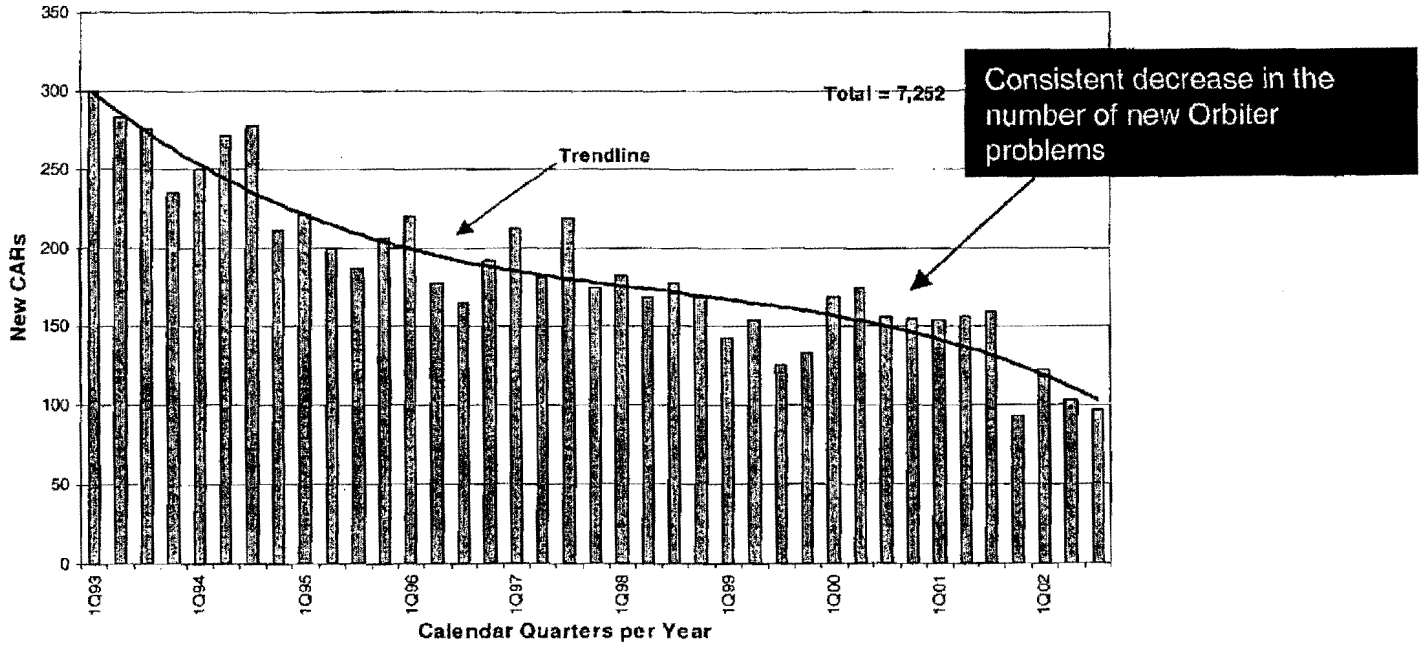
Trending

Trend Report (cont.)

- Analyzes tracking list and multi-occurrence corrective action records (CARs)
- Analyzes problems within major system and part group categories for undesirable trend identification
- Results can be used as indicators to prompt more in-depth assessments
- *Current version does not predict future potential failures within systems or parts due to limited data availability and level of assessment required for entire vehicle*

Orbiter Trend Report

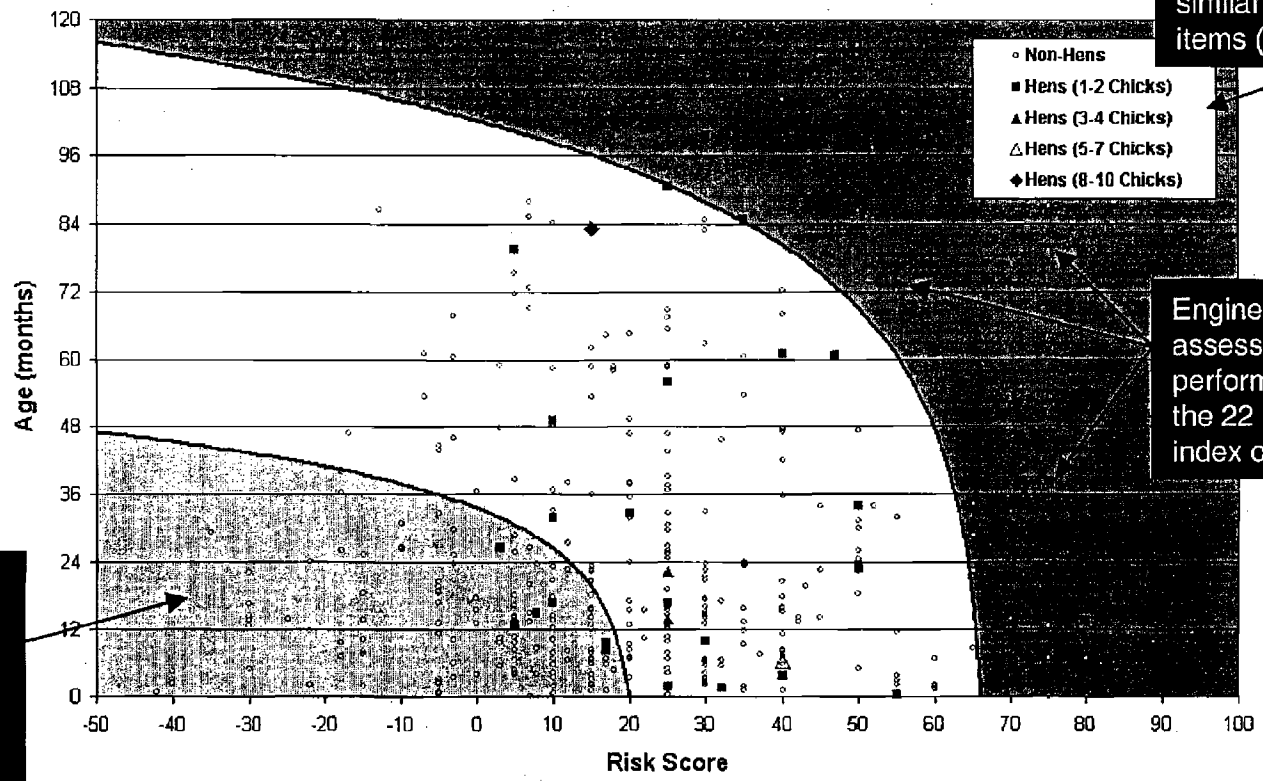
Figure 5.1.1: New Orbiter PRACA CARs Detected by Calendar Quarter
(1/1/93 to 9/30/02)



Orbiter Trend Report

Items (hens) with multiple anomalies of the same type are categorized according to the quantity of similar individual items (chicks)

Figure 2.1.1: Open CAR Risk-Age Index



Engineering assessments are performed for each of the 22 high risk-age index open CARs

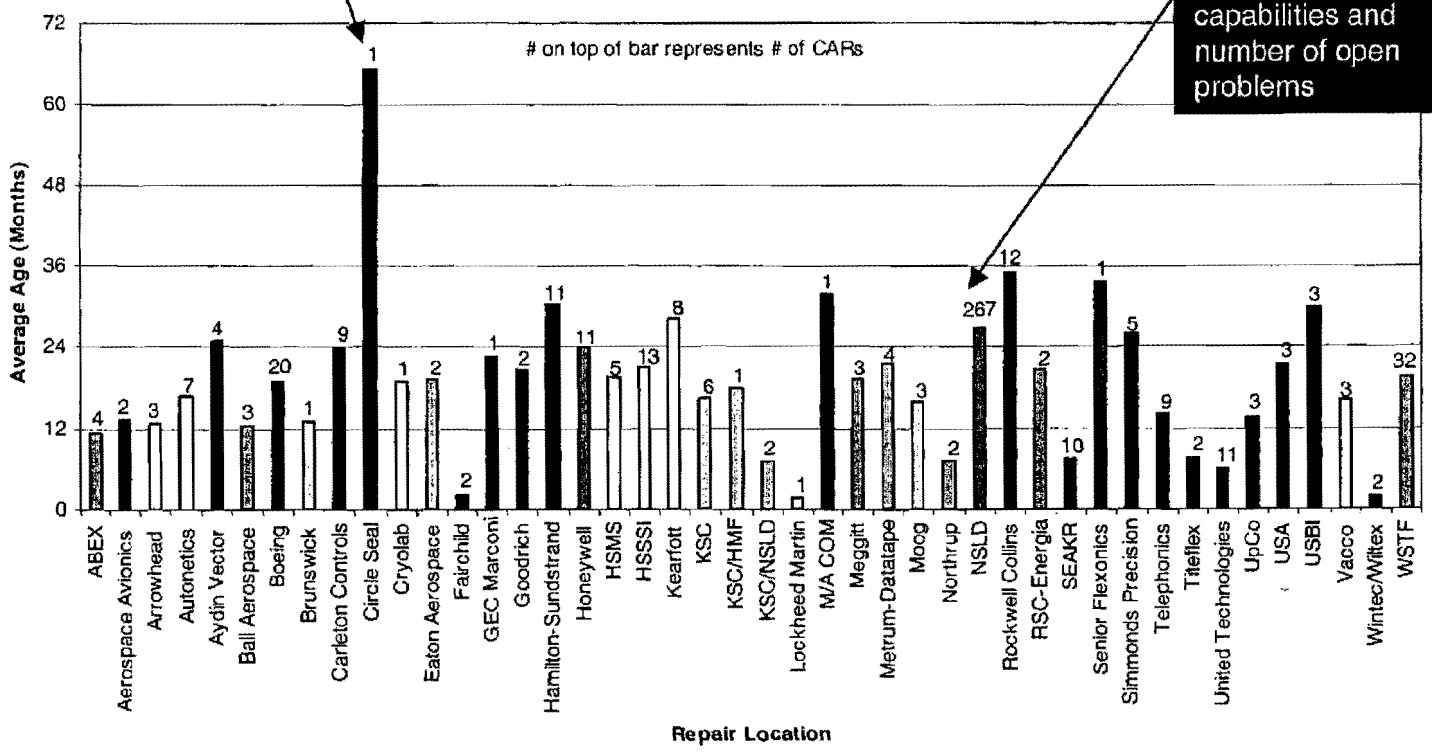
Recommend Problem Resolution Teams reassess items with inherently low risk to the Project

Orbiter Trend Report

Circle Seal manufactures the MPS check valve. Failure investigation is being performed in-house. Vehicle check valve inspections are being performed during OMDP resulting in a protracted closeout of the CAR

NASA Shuttle Logistics Depot (NSLD) maintains the largest concentration of repair capabilities and number of open problems

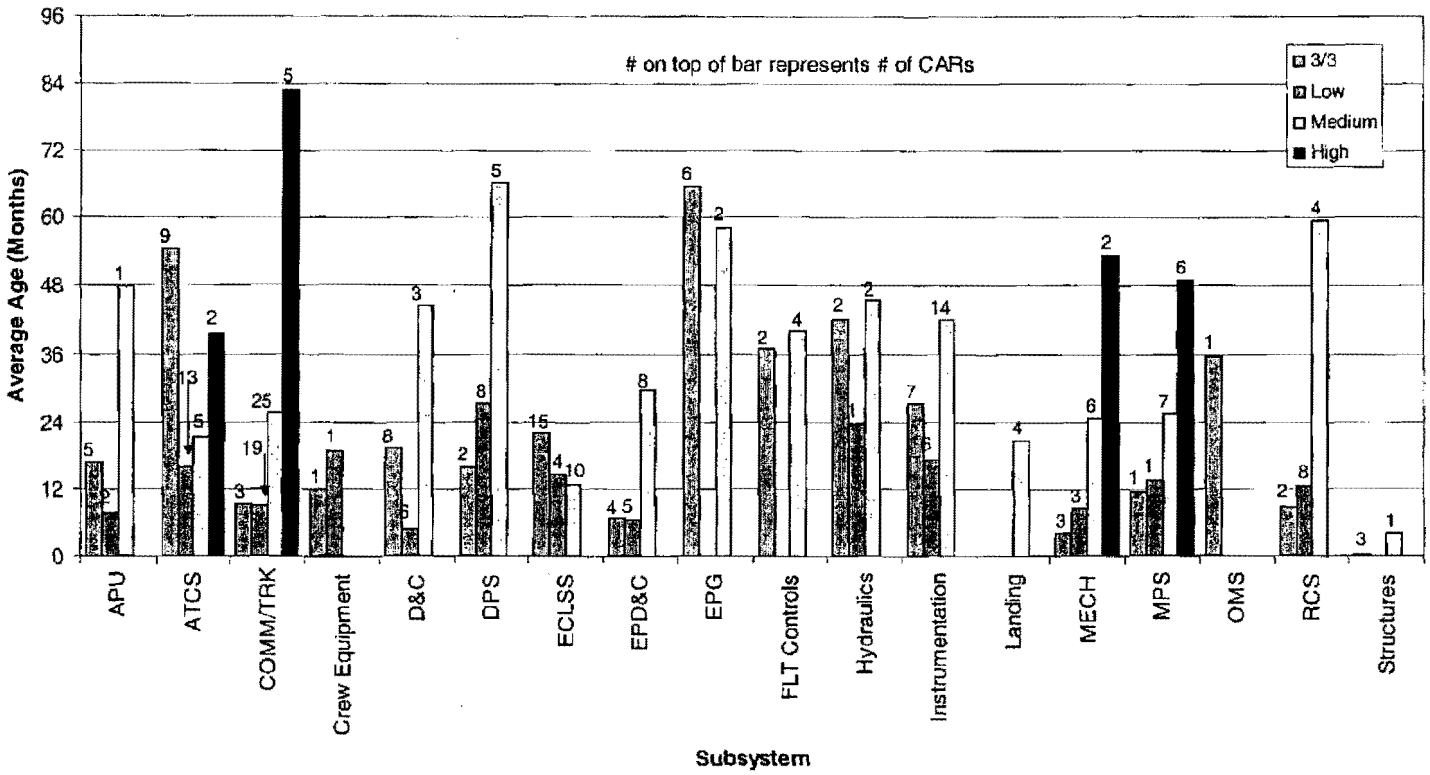
Figure 2.2.1: Repair Location CAR Workload



Orbiter Trend Report

Repair facility with highest open problem volume (NSLD) further expanded by subsystem, age, and risk category

Figure 2.2.3: NSLD Risk by Subsystem



Trending

Quick Look

- Addresses trends at the subsystem level (from Design Center PRACA)
- Analyzes multiple data fields: Part Name, Prevailing Condition, Failure Mode, Material, Defect, Cause, and Recurrence Control
- Focuses subsystem analysis into target areas with most non-conformance volume
- Includes engineering assessments for significant findings
- Serves as a tool to further analyze hardware and identify candidates for more detailed Reliability and Maintenance Analysis

Trending

Dataset groupings to differentiate open (pending), dispositioned, and invalid problems

- **Remote Manipulator System Quick Look**

Group Part Name	Data Set 6: All Problem Records	Data Set 5: Invalid Problems	Data Set 4: Problems Pending Final Disposition	Data Set 3: Problems Resulting In No Corrective Action With or Without Remedial Action	Data Set 2: Problems Resulting In Recommended Corrective Action That Occurred During Non-Critical Periods	Data Set 1: Problems Resulting In Recommended Corrective Action That Occurred During Critical Periods	Data Sets 1-3 Combined Dispositioned Valid Problems	Data S Combined All Valid Problems
Brakes	14		2	4	1	7	a. 12	14
Encoder	6		1	4	1		5	6
End Effector	8		3	3	1	1	5	8
Joint	12			5		7	b. 12	12
Motor Module Assembly	6			2	4		6	6
RMS - Other	8		1	6	1		7	8
Rotational Hand Controller	3			2		1	3	3
Servo Power Amplifier	9			2		7	c. 9	9
Valid Totals	**66**	**0**	**7**	**28**	**8**	**23**	**59**	**66**
Invalid (ZD/ZZ)	27	27					0	0
Blank	0						0	0
Totals	**93**	**27**	**7**	**28**	**8**	**23**	**59**	**66**

Overview of hardware categories associated with RMS PRACA Activity

kes		51140E2323-1			Motor Module Assembly			51140E1214-3
		51140E2323-3						51140E2325-1
		51140E2323-5						51140E2325-3
		51140F688-3						51140E2325-5
		51140F688-5						51140F2325-7
oder		133-9017-201			RMS - Other			51140F39-7
								51140F5-X
Effector		51140F1-5						51140F5-1X
		51140F36-9						M39014/5-2219
								M39014/5-2261
Joint		51140F32-5						
		51140F32-7			Rotational Hand Controller (RMS)			51155E117-1
		51140F32-9						
		51140F38-7			Servo Power Amplifier			51140F1177-3
		51140F39-3						51140F1177-5
		51140F39-7						
		51140F39-9						

Trending

Average problem rates (based on CAR volume) and assessed by time and cycle

- **Remote Manipulator System Quick Look**

Part Name	Part No.	Data Sets 1 - 3 Combined (OMRSD/Flight failures) *	Quantity Vehicle	No. of Missions	Average Problem Rate per Year (see note below)	Average Problem Rate per Mission (see note below)
Brakes	51140E2323-1 51140E2323-3 51140E2323-5 51140F688-3 51140F688-5	0	6	38	0.0E+00	0.0E+00
Encoder	133-9017-201	1	6	38	1.7E-02	4.4E-03
End Effector	51140F1-5 51140F36-9	1	1	38	1.0E-01	2.6E-02
Joint	51140F32-5 51140F32-7 51140F32-9 51140F38-7 51140F39-3 51140F39-7 51140F39-9	1	6	38	1.7E-02	4.4E-03
ule	51140E1214-3 51140E2325-1 51140E2325-3 51140E2325-5 51140E2325-7	1	6	38	1.7E-02	4.4E-03
RMS - Other	51140F39-7 51140F5-X 51140F5-1X M39014/5-2219 M39014/5-2261	2	N/A	38	N/A	N/A
Rotational Hand Controller (RMS)	51155E117-1	1	1	38	1.0E-01	2.6E-02
Servo Power Amplifier	51140F1177-3 51140F1177-5	1	6	38	1.7E-02	4.4E-03

* Count for Data Sets 1-3 Combined only includes Test Operation codes associated with OMRSD testing and Flight (Codes LF, PF, and F).
Note: Average Problem Rate per Year = (# of "Data Sets 1 - 3" Combined (OMRSD/Flight failures)*) / [(Quantity per Vehicle)(# of Years)] (# of Years = 10)
Note: Average Problem Rate per Mission = (# of "Data Sets 1 - 3" Combined (OMRSD/Flight failures)*) / [(Quantity per Vehicle)(# of Missions)]

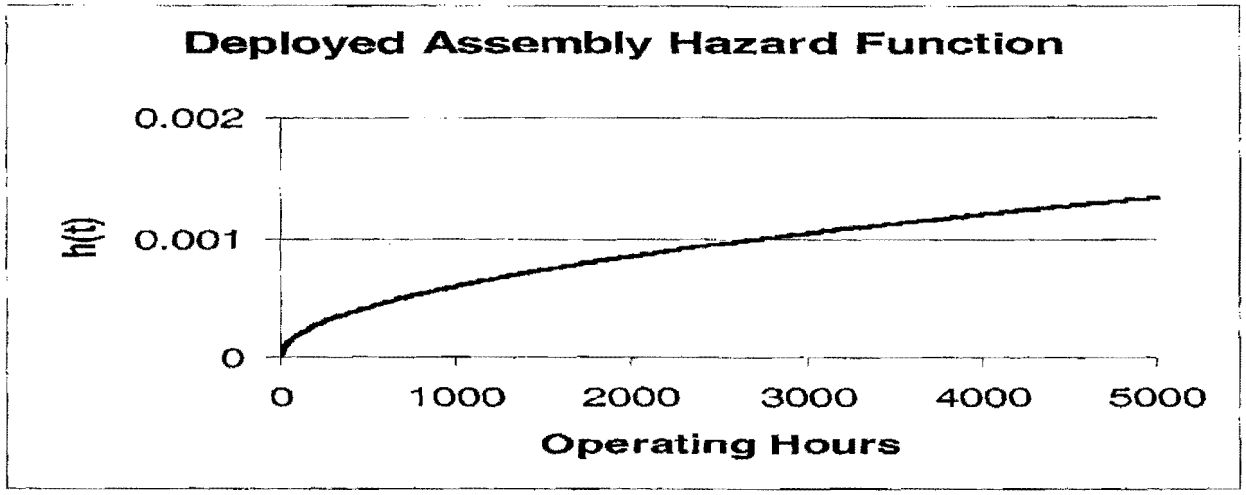
RMS hardware associated with reportable problems

Trending

- Reliability, Maintenance, & Supportability (RMS) Analysis
  - Derive quantitative metrics to be used to understand and forecast operational capacity of the Orbiter
  - Produce Reliability, Maintenance and Supportability (RMS) Assessments
    - Use repairable systems model
    - Employ Markov Methodology to assess supportability
    - Perform maintenance analysis to forecast unscheduled maintenance actions (UMAs) and unscheduled removals (URs)

Trending

- **Reliability, Maintenance, & Supportability (RMS) Analysis (cont.)**
  - **Reliability Indicator**

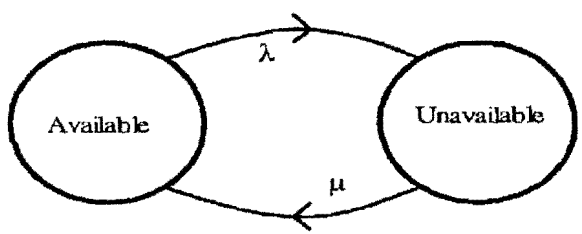


Trending

- **Reliability, Maintenance, & Supportability (RMS) Analysis (cont.)**

Supportability Evaluation – KU-Band LRUs

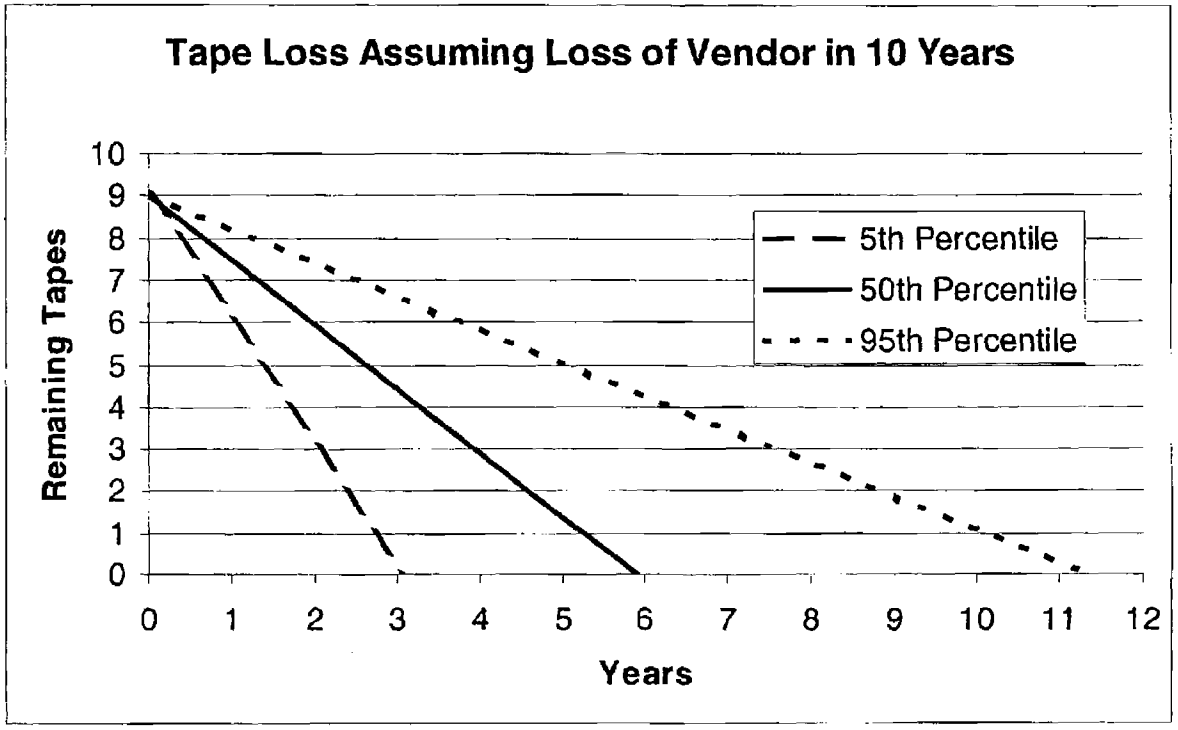
Inputs				Outputs		
LRU	Number in Inventory	RTAT (Days), μ	Removals per Year, λ	Expected Number in Repair	Probability of at Least 3 Ship-Sets	Probability of at Least 4 Ship-Sets
DA	5	245	0.93	0.67	0.95	0.85
DA	6	245	0.93	0.67	0.99	0.95
EA1	6	461	0.3	0.39	0.99	0.98
EA2	6	461	0.3	0.23	0.99	0.99
SPA	6	293	0.15	0.18	0.99	0.99



Trending

- **Reliability, Maintenance, & Supportability (RMS) Analysis (cont.)**

Supportability Evaluation – Discreet Event Simulation / Orbiter Experiments Recorder Tape Availability



Trending

- Future Plans
  - Further engineering analysis of Orbiter Design Center trending tool
  - Trending of Orbiter Operations Center (KSC) PRACA data for comparison with Design Center PRACA trends
  - Extensive use of the integrated Shuttle PRA to influence future analytical assessments
  - Effect changes in hardware processing and data collection to enhance future analytical assessments and improve predictive capability

STS-112 and STS-107 Foam Loss

Presenter: **Mark Erminger**

Foam Loss Investigation

STS-112 Failure:

- On Flight Day 7, the Consolidated Film/Video Report stated debris had hit the External Tank Attach Ring
  - MSFC S&MA started working the issue
  - Space Shuttle Division Chief, Assistant Division Chief, and SR&QA Thermal Protection System (TPS) Subsystem Engineer reviewed this report
    - The Debris Assessment Team, of which the TPS Subsystem Engineer is a member, determined that the Orbiter was not affected

Foam Loss Investigation

STS-112 Failure (cont.):

- Post landing, an External Tank film review identified loss of foam in the ET bipod area.
- The External Tank Project reported at the Shuttle Standup "in-family" Orbiter tile hits during post landing inspections
  - There is no JSC Problem Resolution Team involvement for "in-family" tile damage
- Space Shuttle Division Chief added Foam Loss as an issue for the STS-113 Prelaunch Assessment Review (PAR)

***In-Family.** A reportable problem that was previously experienced, analyzed, and understood is an in-family problem. Manufacturing, processing, and operations within the experience base as program-accepted performance are defined as in-family. In-family problems are in compliance with established requirements and processes for the end item or system. Activities to return to the design requirement or performance specification by removal and replacement or rework using a standard repair or maintenance procedure approved by the design project are in-family. Out of limits performance or discrepancies which have been previously experienced may be considered as in-family when specifically approved by the SSP or design project.

NOTE: Established program requirements include engineering drawings and specifications, engineering requirements, acceptance test requirements, NSTS 08171, LCC, NSTS 08151, Intermediate and Depot Maintenance Requirements Document (IDMRD), certification basis, and flight constraints and limits as modified by approved waivers and exceptions.

Foam Loss Investigation

STS-113:

- Pre-flight
  - MSFC S&MA presented the STS-112 Foam Loss at the STS-113 PAR, provided flight rationale, and recommended no constraint to STS-113/ET-116 and subsequent flights
  - S&MA community accepted rationale
- Post-flight, there was no bipod foam loss

Foam Loss Investigation

STS-107 SR&QA Timeline:

- Launch screening report 1 day after launch reported debris from the ET bipod area striking the left wing leading edge.
- JSC SR&QA Thermal Protection System, Subsystem Engineer, as a member of the Debris Assessment Team, started working this issue after it was reported and kept the MER Console and MMT representative advised of his activity.
  - SR&QA's role on this team is to use safety engineering judgment to ensure risks are being addressed

Foam Loss Investigation

STS-107 SR&QA Timeline (cont.):

- The Debris Assessment Team determined the STS-107 foam loss was not a safety of flight issue. SR&QA was a member of that team and agreed
- Mission Management Team (MMT) Representative, Space Shuttle Assistant Division Chief, participated in foam loss discussions at several MMT meetings
  - The MMT concurred that the foam loss was not an STS-107 Safety of Flight Issue

Questions?

Les Reingold, Lead Editor
Chris Kirchhoff, Editor

Draft CAIB Report Outline, Rev. 4 (Pre-Decisional)

5/14/03

[Note: This outline is set up with prospective chapter and subchapter headings, as they would appear in the published document. Explanatory comments appear in italics.]

In Memoriam *(with photo of crew)*
Board Statement *(A preface describing CAIB's purpose and the inquiry's significance, including a mention of the Board's use of the social science literature on risk, and a brief mention of the victims of the helicopter accident. Identification of the various causal elements – "probable," "contributing," and "underlying." Also included, a statement of the CAIB's independence.)*
Letter of Presentation *(signed by each CAIB Board Member)*
Executive Summary *(will not contain separate findings and recommendations)*
Table of Contents

CHAPTER 1: EVOLUTION OF THE SPACE SHUTTLE PROGRAM

A brief description of the Space Shuttle Program, charting how it emerged from the post-Apollo spaceflight program, its design tradeoffs resulting from political and budgetary decisions made in the early 1970s, its development, testing and initial flights, the Challenger accident, and the Shuttle's current role primarily servicing the ISS.

1.1 Genesis of the Space Transportation System *(including a brief mention of the events that led to President Nixon's decision, e.g George Mueller, Space Task Group, 1969; further discussion in chapter 6)*

1.2 The Original Program Concept *(as a logistics vehicle for the space station and as part of a larger post-Apollo plan to go to Mars)*
- Planned Mission Types *(including DoD role)*
- Operating Cost Expectations *(including flight schedule and cost assumptions)*

1.3 Design Tradeoffs
- Political Constraints *(DoD support, joint Air Force-NASA committee, Congress and White House approval)*
- Budget Restrictions *(OMB, liquid vs. solid rocket boosters)*
- Technical Challenges *(including discussion of ejection seats/crew escape)*
  - Thermal Protection System
  - Main Engines
- Operational Requirements *(DoD requirements, cross-range, payload weight, etc.)*

1.4 Final Space Shuttle Design
- Orbiter *(including SSME)*
- External Tank

Solid-Rocket Booster *(Including RSRM)*
Component Systems and Sub-Systems *(e.g., flight control system and especially TPS, etc.)*

1.5 Shuttle Testing and Qualification *(pre-flight testing, STS 1-4, and post-STS-4)*

1.6 Treating the Shuttle as Operational *(effects of declaration of "routine access to space" on schedule, budget, engineering expertise, etc., with a mention of examples of mission types and U.S. vs. ESA competition for commercial launches)*

1.7 The Challenger Accident
Resulting Shuttle System Modifications *(crew escape pole, pressure suits, etc.)*
Management Changes and New Regulations

1.8 The Shuttle Program in the Post-Challenger Era
Science Missions
International Space Station *(Columbia and its capabilities vis-à-vis the ISS)*
The Idea of Privatization/Commercialization

CHAPTER 2: COLUMBIA'S FINAL FLIGHT

Chronology of pre-launch and launch events, including selection of mission and crew, as well as the FRR process. (Primarily a factual account, with little analysis.)

2.1 Mission Objectives and Their Rationale
Pressure for a Science Mission
Manifest *(including: an orbiter heavier than usual)*
The Members of the Crew
Crew Training
Payload Preparation

2.2 Preparations for Launch *(turnaround issues)*
Flight Readiness Review
Certification of Flight Readiness
Launch Readiness Review
Other Pre-Launch Activities (*e.g., tanking meeting)*

2.3 Notable Pre-Launch Conditions
Schedule Slippage *(moved behind Hubble repair mission, flow liner cracks, problem with ball strut tie rod assembly, demating of orbiter from external tank stack, potential crushing of foam, etc.)*
Exposure on Launch Pad *(including icing and heavy rain, potential loss of foam, zinc paint concerns, etc.)*

Security Measures *(covers both post-9/11 changes and procedures adopted because of presence of Israeli crew member; discussion will be general, avoiding details that would compromise security)*

2.4 Launch Sequence
- Crew Activities
- Weather on Morning of Launch
- Predicted and Actual I-Loads
- Wind Shear *(key loads vs. design parameters and experience)*
- Nozzle Deflections
- Debris Strike

2.5 On-Orbit Events
- Crew Activities *(including payload activities and on-orbit anomalies, such as SPACEHAB module control issues)*
- On-Orbit Debris Shedding

2.6 Mission Support *(Mission Control/Mission Management Team/Mission Evaluation Room, including meeting times, frequencies, and attendees)*
- Initial Debris Strike Analysis
- E-mail Communications
- Department of Defense Imagery Request

2.7 Re-Entry Sequence
- Re-Entry Configuration *(including de-orbit prep, Mission Control consideration of entry trajectory)*
  - Weight
  - Speed
  - Total Heat and Maximum Heat
- Loss of Signal
- Vehicle Disintegration

2.8 Events Immediately Following the Accident
- NASA Emergency Response
- Establishment of the Columbia Accident Investigation Board
- Debris Collection

CHAPTER 3: PROXIMATE CAUSES OF THE ACCIDENT SEQUENCE

The proximate cause or causes of the Columbia accident. For each causal element, documentation is given of the means by which it was identified and agreed upon, including explanation of investigation methodologies.

3.1 Statement of Proximate Cause

3.2 Analysis of Impact
- Photographic Evidence *(establishing foam trajectory)*
- MADS Data
- Foam Strike Tests

3.3 External Tank Foam
- Foam Purpose and Composition
- Bonding the Foam to the Tank
  - New EPA Regulations
  - Super-Lightweight Tank
- Cryo-Pumping
- Design of the External Tank's Bipod Assembly
- Earlier Instances of Foam Shedding and responses to those incidents

3.4 Wing Leading Edge Systems
- Description of Wing Leading Edge System
- Structural Analysis
  - NDE of RCC Flight Articles

3.5 On-Orbit Debris Separation *(during days 2-4, including discussion of RCS and mass/ratio data from ground-based space radar)*

3.6 Re-Entry Sequence
- Telemetry/On-Board Recorder Data *(including MADS)*
  - Aerodynamic Anomalies
  - Thermodynamic Anomalies
- Computational Fluid Dynamics Testing
- Arc Jet Testing
- Wind Tunnel Testing
- Radar Data
- Photographic Data
- Debris Analysis
  - Patterns in Debris Location
  - Examination and Testing Methodologies

3.7 Other Factors Considered *(including discussion identifying those factors that could be affirmatively eliminated, as well as those that could not, but were deemed by the Board unlikely to be involved in the accident sequence)*
- The Fault Tree Analysis Method *(including all potential system failures and internal hazards in SSME, Orbiter, SRB, etc.)*
- Material Issues
  - SRB Bolt Catcher
  - Kapton Wiring
  - Launch Pad Runoff *(zinc-based paint)*
  - Palmdale Water and Hydrazine Contamination

Unique Wiring Configuration
Willful Damage
Training and On-Orbit Performance of Flight Crew
Payload
Space Weather
Abnormal Re-Entry Characteristics
Rough Wing
Early Transition
Micrometeorites and Space Debris

CHAPTER 4: FACTORS THAT CONTRIBUTED TO THE LOSS

Beyond the direct causal chain, a discussion of the factors that combined to destroy Columbia.

4.1 The Machine Was Talking, but NASA Failed to Separate Signals from Noise
Challenger: A Precursor of Columbia?
Redefining Risk to Accept Anomalies
Normalization of Deviance *(Vaughan, etc.)*
Cutting into Design Margins
Original Design Margins vs. NASA's Operational Rules
On-Orbit Repair Disregarded as Mitigation Strategy
Space Shuttle Program Decision-Making
Identification and Disposition of In-Flight Anomalies (*both MMT and FRR)*
Audit of Foam Anomalies
Inadequate Computer Tracking of Anomalies
Program Requirements Control Board

4.2 Space Shuttle Processing
Space Shuttle Program Management of Materials
Material Review Board
Flight Readiness Review and Certification Processes
Waiver Process
Workforce Qualification and Management Structure
Maintenance
Upgrades of Equipment and Processes
Non-Destructive Evaluation
The Certification Process
Adherence to the Rules
Adequacy of the Rules
Aging
Lack of Metrics
Non-Destructive Evaluation *(interim recommendation, etc.)*

4.3 Mission Management Team and Mission Evaluation Room Decision-Making

Debris Strike Analysis in the Mission Evaluation Room
- The CRATER Program Analysis
- Concerns about Foam Strike Revealed in Internal Communications
- On-Orbit Photography Decision *(including discussion of relevant e-mails; interim recommendation)*

Mission Management Team Performance
- Qualifications of Team Members
- Culture within the Team
- Schedule of Meetings *(failure to meet at required frequency)*
- Information Flow *(typo on foam size in briefing, etc.)*
- Chain of Command
  - Presence and availability of key leaders
- Mission Evaluation Room
- Formal Requirements, Standards and Precedents
  - Adherence
  - Sufficiency

Possibility of Crew Survival *(the "Apollo 13" question)*
- On-Orbit Repair
- Re-Entry Profile

Minimizing Injury/Damage from Potential Re-entry Debris *(Did public safety concerns dictate that the Shuttle land at Edwards?)*

CHAPTER 5: THE SHUTTLE PROGRAM IN CONTEXT

The ability of the space shuttle team (NASA, USA, and other contractors) to manage the Shuttle program to meet the objectives of flying safely, meeting the manifest, improving mission supportability, and improving the system has been threatened over the past decade or more by a complex combination of factors. This chapter will discuss those factors and how they might have influenced shuttle operations overall, and potentially have contributed to the events leading to the STS-107 accident.

5.1 The Early Years of the Shuttle Program: Tensions between Design Compromises and Expectations of Performance
- The Space Shuttle decision *(including designing to a development budget ceiling, the emphasis of cost reduction and thus reusability, economic studies, and gaining DOD support for the Shuttle).*
- Original Requirements and Design Compromises
  - Shuttle Design Issues – SSME, TPS
  - On-Orbit Inspection and Repair
  - Protection from Launch Debris, Space Debris, Micrometeorites
  - Crew Escape Systems
- Budget and Cost Battles during the 1970s *(including debates over the number of orbiters to build and the possibility of program cancellation during the Carter administration)*
- Early Image of the Shuttle as an Operational Vehicle

1982 Decision to Declare the Shuttle Operational (*and subsequent pressure to use the Shuttle in an operational capacity, competing with Europe for commercial launch contracts, not addressing problems with system, pressure to increase launch rate to 24 flights/year)*

The *Challenger* Accident: Shattering the Operational Myth

Policy Changes – No Commercial Payloads

DoD Switches to ELVs

Shuttle Modifications and Upgrades

Management and Safety Process Changes

Were the Lessons of the Challenger Accident Learned?

5.2 The Shuttle Program in the 1990s

National Priorities for Space and the Shuttle Program

NASA Budget and Shuttle Budget Patterns

National Space Policy and the Shuttle

The Role of the Shuttle in the Human Spaceflight Program

Link between Shuttle and International Space Station

Image of the Shuttle as a mature design capable of regular "operational" use

Shuttle as a "going out of business" Program

The "Reinvention" of NASA

Impact of Dan Goldin's Ten Years

Emphasis on Returning NASA to R&D and Getting It Out of Operations

Downsizing the Workforce

Program Management Delegated to Lead Centers – JSC Becomes Lead Center for Shuttle Program

Uncertainty Over When Shuttle Would Be Replaced and Impacts of Shuttle Upgrade Investments

1994 Decision to Freeze the Shuttle Design and Decide on Shuttle Replacement before 2000

1996 Decision to Begin Upgrade Program

1999 Decision That Shuttle Would Fly Beyond 2010; Intensified Upgrade Efforts

SFOC: Shuttle Privatization and Possible Commercialization

NASA-Contractor Relations on Shuttle Program until 1995

Kraft Report

Creation of United Space Alliance

1997 USA Privatization Plan Rejected by NASA

Contract Provisions

Responsibility and Authority Sharing *(NASA decides not to transition ET and SSME contracts to USA)*

Oversight Mechanisms

Contract Incentives (*Cost reductions vs. safety?)*

Approach to Safety and Mission Assurance

Workforce Skills (*including "brain drain," layoffs by USA, aging/retirement and training issues)*

Workforce Dislocation

2001 Proposals for Privatization/Commercialization

Other Shuttle Contracts
Evolution of NASA Safety and Mission Assurance Function
Budget, Personnel, Independence
Role of Aerospace Safety Advisory Panel
Risk Management Practices (*including probabilistic risk assessment)*
Documentation of Minority Engineering Views
Authority of Engineers vs. Program Managers
Organizational Variations among Centers

5.3 Recent Developments Affecting the Shuttle Program
Return of program management to NASA Headquarters
Role of the Shuttle in the Integrated Space Transportation Plan (*more money for upgrades, 2010 decision on how long to fly the shuttle, SLEP)*

CHAPTER 6: MITIGATING RISK IN THE SPACE SHUTTLE PROGRAM (or: MANAGING RISKY TECHNOLOGY)

NASA's organizational culture and performance, with reference to both the theoretical literature on high-reliability organizations and accident investigation findings.

6.1 Space Shuttle Program Operations vs. "Best Business" Practices
The Management of High-Risk Technologies: Theory and Practice *(attributes of High Reliability Organizations, including offshore oil rigs, aircraft carrier flight decks, nuclear subs and nuclear reactors, etc.)*
Challenges of Managing Aging Technology: the Concorde Comparison *(like the Shuttles, a small fleet of old aircraft that are emblematic of national pride)*
Risk and Safety Scholarship on NASA
Occupational Safety vs. Mission Assurance *(preventing "trips and falls" isn't good enough; systems safety is also important)*

6.2 Evolution of NASA Safety and Mission Assurance
Budget, Size, Independence
Risk Management Practices *(probabilistic risk assessment, etc.)*
Documentation of Minority Engineering Views
Divisions of Authority *(engineers vs. program managers vs. safety officials; questions of what backs up that authority)*
Organizational Variation Among Centers
Advent and Influence of Aerospace Safety Advisory Panel

6.3 Vertical Communication in Space Shuttle Program
Is technical information being communicated to the top?
Are management decisions being communicated down the line?
Is Headquarters increasingly disengaged from the Shuttle Program's technical management?

6.4 NASA as a Learning Organization?
Previous NASA Reports and Independent Assessments *(Rogers, SIAT, NASA-U.S. Navy Benchmarking Exchange, Vaughan, ASAP, etc.)*
Has NASA Adequately Learned From Those Who Have Studied It?

CHAPTER 7: A LOOK AHEAD

The implications of the accident for the future of the Shuttle program and U.S. space policy in general.

7.1 Conditions Necessary for Return to Flight
Re-Certification Requirements
Return to Flight
Long Term
Management Reforms

7.2 Toward a More Realistic Accounting of the Shuttle Safety Performance: Past, Present and Future

7.3 Future Expectations of the Shuttle Program *(consideration of whether the Shuttle could be made to fly through 2020, including increases in operational costs, necessary upgrades, changes in inspection, re-qualification, parts and vendor support, etc.)*

CHAPTER 8: OTHER SIGNIFICANT BOARD OBSERVATIONS

The CAIB's other significant observations, made during the investigation, but unrelated to the direct cause of the accident.

8.1 Flight Controller Certification Paperwork Lapses
8.2 Workforce Morale in Visited Contractor Facilities
8.3 Shuttle Engineering Drawings
8.4 Software *(CLCS issues)*
8.5 Pad Cameras
8.6 Fault-Tree Analysis

[Additional observations to be determined by Board.]

CHAPTER 9: FINDINGS/RECOMMENDATIONS

Recapitulation of findings and recommendations, which will also be included at relevant junctures in the text.

9.1 Launch and On-Orbit Photography Capability
9.2 Non-Destructive Evaluation Testing

9.3 Independent Follow-up on NASA's Implementation of CAIB Recommendations

[Rest to be determined by Board]

CHAPTER 10: THE CAIB INVESTIGATION

10.1 History of CAIB *(including steps taken to ensure independence; change in Board charter)*
10.2 Organization of CAIB and CAIB Sub-Groups
10.3 CAIB Policies and Procedures
10.4 Methodologies Used in the Investigation
10.5 CAIB/NASA Interface
10.6 CAIB Documentation System

APPENDIX A

A.1 CAIB Board Member Biographies
A.2 Acknowledgement of Board Staff and Board Consultants/Experts Consulted
A.3 List of Non-Privileged Witnesses

OTHER TECHNICAL APPENDICES

Note: Selection of documents in the final appendices will depend upon investigation outcomes and direction from the Board. The following is a preliminary list of topics these documents might address.

Debris Recovery
Debris Testing and Analysis
Orbiter Design and Modifications
External Tank Design, Testing and Modifications
Solid Rocket Booster Design and Modifications
Fault Tree Closeouts
Aero-Thermal and Structure Testing Methodology and Results
Maintenance and Quality Assurance
Human Factors Analysis
Flight Readiness Review
Review of Previous High-Level Space Shuttle Reviews
Materials (including transcripts) from CAIB Public Hearings

CD-ROM

Complete copy of report, appendices, as well as relevant multimedia; to be distributed with full report, stand alone executive summary or simply by itself.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 16, 2003
These Minutes Contain No Sensitive Data

Purpose: Spacewalk Capability Briefing & Daily Investigation Meeting

Date: 16 May 2003 **Time:** 1230 - 1400

The list of attendees is appended to the end of this report.

Spacewalk Capability Discussion with Dr. Story Musgrave

Admiral Gehman began by stating that the Board does not plan on including any analysis of what NASA should have or could have done in the report, however, they would like Dr. Musgrave's views on what is technically possible. If they become convinced that there were missed opportunities then that would be reflected in the tone of the report.

Dr. Musgrave made the following opening remarks:

> The relevancy of what I have to bring to you is somewhat dependent upon the urgency to go and get the information. If the system perceived absolutely no urgency to take any steps beyond a video then this presentation is not relevant, because it is dealing with the possibilities and the decision process. So, if you assume no action is required then what is about to be presented is not that relevant. If there is any urgency to do anything then this presentation is incredibly relevant because if you are convergent on the video and the commitment to light the engines for a deorbit burn, everything from the foam to the deorbit burn could be viewed upon as "do I take a walk or don't I take a walk".
>
> Dr. Musgrave stated that he was compelled to come here because in the early days there were words like "we did not take a walk because we could not, we did not have equipment, we did not have a Manned Maneuvering Unit, it is dangerous; we are going to ding the tiles". All of those statements are not true.
>
> He stated that he has developed over 100 spacewalks—and the key word is development. You have a task that you want to do, and the task is to get human eyes and hands, and a camera on the problem so that the people on the ground can make a good decision. It is the only decision that could have changed history. You have seen the foam, are you going to take a walk or not take a walk?

Dr. Musgrave then gave examples of spacewalks performed in the past to make repairs, and stated that it is important to note that two of the STS-107 crew were trained to do spacewalks, including the contingency EVA to translate under the belly to manually close the External Tank (ET) doors if required. Closing the ET doors is a challenging task because there is not much to hang on to for restraint or leverage purposes. On the other hand, of the 100 plus spacewalks he has developed, a spacewalk to assess the condition of the area around RCC panel 8 would be the easiest he has ever approached. This is because the payload bay door bulkhead and centerline latches form a secure translation path leading to a spot 5 ft above RCC panel 8. A single spacewalker could perform a quick assessment in only 15 minutes. A second spacewalker (the "end-effecter spacewalker"), securely held by the boots upside down by the first spacewalker (the "manipulator spacewalker"), could put his eyes or a camera directly on the wing leading edge or even 3-4 ft. below the wing where he would have good visibility of the main landing gear door area.

Admiral Gehman asked if a digital camera was on board. Dr. Musgrave replied that they have a digital still camera, but it is not certified for the space environment. That said, there is a very high probability that they could make it work if they take steps to protect it thermally. The vacuum of space should not be a problem. They also have a hand-held camcorder stowed on board. As a last resort, the crew could build a cable to interface with the payload bay camera, which they would remove from the aft bulkhead and use to survey the damage.

Mr. Buzzard asked if there was test data showing those cameras could work in a vacuum, or is it just supposition. Dr. Musgrave said it was extrapolation from all the other data they have. Vacuum was not an issue for all the other cameras they have used in the past. Thermal is an issue. He went on to say that there should be an action to get the digital still cameras certified so they will have that capability in the future.

Col. Bloomfield pointed out that they do have the helmet mounted WBS wireless 3-camera system in the inventory. This could have easily done the job.

Admiral Gehman asked about vehicle inspections performed in the past. Dr. Musgrave replied that he could not think of a single spacewalk where the sole purpose was to go out and assess something. They had other reasons to go, and while they were out they looked at things. The bottom line is if there was any reason to get this data (STS-107) it converges on the decision whether or not to take a walk.

Col. Bloomfield asked Dr. Musgrave if it was possible to get all the way to the wheel well area, which was originally speculated to be the trouble area. Dr. Musgrave replied that he believed they could have surveyed the entire wheel well area using a scaffold-like structure fashioned with orbiter hardware from the middeck area.

Admiral Gehman asked what could have been done if they had determined that there was damage to the leading edge. Dr. Musgrave replied that he could not comment on whether or not they could have fixed the problem. But experience shows that NASA always comes through.

Admiral Gehman asked if an astronaut working below the leading edge would have enough leverage to work effectively. Dr. Musgrave replied that they could have built an 'erector-set' structure with enough rigidity to apply the necessary force. That said, his own intuition tells him that they could not make repairs to the leading edge because it is too high tech and they do not have the materials. And since heat rejection is so critical they would instead have to focus on a rescue mission, which begs the question "can Columbia stay up long enough?"

Dr. Musgrave went on to say that NASA developed an incredibly dangerous vehicle in which the engineering had to be perfect every time. The heat rejection system is state of the art. Everything is custom fit. The shuttle program slipped two and a half years just due to difficulties with the Thermal Protection System (TPS). In fact, it was so difficult that they considered doing a Return-to-Launch-Site (RTLS) on STS-1 to verify tile integrity without subjecting the vehicle to the heating effects of re-entry.

Admiral Gehman asked about the STS-107 EVA capabilities. Dr. Musgrave replied that the baseline is two spacewalks of eight hours each, though they have done 11-hour walks. They may be able to do more but the availability of consumables becomes an issue.

Admiral Gehman asked if it is possible to do three 3-hour spacewalks or three 4-hour spacewalks instead of two 8-hour spacewalks. Dr. Musgrave replied that it becomes a different issue—consumables in a backpack versus consumables used cycling the airlock.

Admiral Gehman asked about the requirement to carry two EVA suits on a science mission like this. Dr. Musgrave responded that it is for orbiter contingency purposes. Procedures have already been developed to bring in the S-band antenna, close the radiators, close the payload bay doors, or close the ET doors etc. The checklists are already on board and the crew is trained to execute these procedures. There is a trained EVA crew on every shuttle mission.

Dr. Musgrave was asked to comment on what to do with the remaining shuttle crew if you had a rescue mission. He responded that extra EVA suits could be brought up on the rescue vehicle, so getting the crew off would not be a big problem. The big problem would be to put the damaged orbiter into hibernation at some safe altitude.

Mr. Buzzard asked if there was anything on board that could be stuffed into the hole in the leading edge that would allow any hope of a safe return. Dr. Musgrave replied that his intuition tells him that because of the complex physics involved in heat rejection there is no hope for repair, but NASA will provide the real answer.

Mr. Howard Goldstein, who was recognized for his TPS experience, stated his belief that it is possible to find something on the orbiter to stuff into the hole and create a boundary layer to prevent plasma from flowing into the wing. He pointed out that plywood has been used as a heat shield in the past, and the heat fluxes on the shuttle are not excessive—so even something as simple as a phonebook could possibly be used. Smart people at NASA working night and day could come up with something. There is literally tons of material available. You could conceivably fill up the leading edge—though that may impact the c.g.

Admiral Gehman noted that this is why he asked about the number of spacewalks (to get a sense of what could or could not be done). Mr. Cooke added that EVA consumables could be used up just getting rid of the Spacehab.

With that, Admiral Gehman thanked Dr. Musgrave for sharing his knowledge with the Board.

Roundtable Discussion

RAdm. Turcotte reported that he had learned firsthand that a large number of the lower-level workforce members at KSC feel they are part of the Shuttle family--no matter what company they were employed by.

Admiral Gehman asked for Board feedback on two possible implications of what Admiral Turcotte just stated. The first implication is that the delineation between who is a government employee and who is a contractor is not all that big a deal. That said, several people have expressed concern that the government has certain oversight and fiduciary responsibilities that cannot be delegated to a contractor.

Col. Bloomfield and Mr. Hubbard both responded that it depends on where you sit. It may be true out on the floor, but the delineation diverges once you get to the first management line where bonuses, incentives, promotions, and budgets are at stake. In the end it all comes back to the government has a

fiduciary responsibility that it cannot delegate.
Admiral Gehman stated that the second implication is that if the majority of front line techs are unconcerned about whom they work for because their loyalties are to the shuttle, then there should be no issue with recompeting the contract.

Mr. Cooke cautioned that changes in benefits could be a significant factor in an employee's decision to stay with the incumbent or change badges.

Admiral Gehman noted that people who have knowledge of these types of things have told him that USA has the lowest benefits of any major contractor in the United States in terms of percentage of health care supported, contributions, etc.—worse than anything they had ever heard of.

RAdm. Turcotte reported that while he was at KSC he went to get a better understanding of the reduction in GMIPs and the effects on the Orbiter. His initial assessment is that a significant amount of government QA is still required in critical areas such as RCC processing, and that GMIPs were eliminated only in noncritical areas

RAdm. Turcotte also reported that they investigated the amount of time it takes to change out RCC panels, which has implications on on-orbit repair. He found that it takes about 1.5 hours to take off a carrier panel and a RCC panel. Reinstalling is the hard part. It takes six hours per panel, without even considering if you need to shim it to set the right step and gap. So he has a better understanding of why it takes so long to process and why it does not get inspected more often. It is very process sensitive. USA is ready to remove RCC for non-destructive evaluation (NDE), but NASA hasn't issued the order yet.

Dr. Hallock reported that the reviews of the fault trees for the SRB (minus the bolt catcher) and the ET (minus foam shedding) will be conducted in the near future. He has concerns about the ET fault tree closeout because on the web version of the tree, the closure rationale for three quarters of the items consists of a one-pager that says "we looked at this and it is not a problem" and nothing else.

Mr. Hubbard reported that some of the impact testing activity is slipping a bit to prevent people from burning out. The Test Readiness Review is now on May 22. Fiberglass impacts are May 28 to the 31st. Consequently, RCC panel 6L test has been pushed to June 7.

The impact test team has been oscillating between two test philosophies. One philosophy is to test to failure. The other approach is to duplicate as close as possible the observed environment and see what the results tell us. Currently he is leaning towards the latter.

The team also spent a lot of time trying to determine the size and velocity of the foam log, and they have come to the conclusion that there are two types of foam debris that NASA needs to worry about. One is the high angle small pieces coming off from the mid tank area and causing the popcorning and divots. The other is the foam log that comes off higher up the tank and hits the RCC at a higher velocity.
The latest issue they are working is the rotation factor for the foam test. Analyses performed independently by Southwest Research, Sandia Labs, and JSC all conclude that the rotation of the foam as it hits adds a significant amount of energy. Since they cannot increase the velocity of the foam projectile to compensate for the rotation (too big a challenge for the gun), they have to increase the angle of impact.

RAdm. Turcotte cautioned that if NASA plans on updating the CRATER model based on tile testing they should not use pristine tile as they did during the acreage tests, because most of the tiles on the Orbiters

are patched and plugged and therefore denser than the pristine tiles. Mr. Hubbard replied that NASA recognizes that and will factor tile damage/repair into any testing performed after the primary test objectives are complete.

The four fiberglass shots were originally thought of as a "tune-up", but they have since concluded that these shots are necessary to establish the sensitivity and accuracy of the responses. Simply stated, does moving the aim by an inch invalidate the results? They want to get that right because the latest structural analysis from Mr. Glen Miller (still very preliminary) indicates that the face of the RCC panel did not fracture on impact. Instead, the force of impact was intensified and transferred to the positioning brackets on the backside.

MGen. Barry showed the latest animation of STS-107 ascent and entry, which incorporates OEX data. The animation reflects the telemetry, behavior of the OEX sensors, and the timeline of events as they occur. Mr. Hubbard suggested that they use the results of the physics-based Computational Fluid Dynamics (CFD) analysis to realistically depict the flipping and turning of the Bipod foam as it falls off the ET and strikes the Orbiter.

MGen. Barry stated that he received the report on the T-seal that was flexed 400 times in 1991 and then reinstalled on Columbia. As a sanity check, Group 1 is looking to see if this is something that the Navy or Air Force would do. Admiral Gehman replied that he thought it should have been classified as non-flight hardware.

MGen. Barry then reported that they are expecting Ames Research Center to provide a firm estimate of the weight increase that would result from going with Tuffy Tiles. He added that Group 1 is also working to determine what it would take to recertify the vehicle and working with NASA on closeout of actions and issues.

This meeting was adjourned at 1400.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees were as follows

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Dr. Hallock	CAIB	281-283-7518
Dr. Hubbard	CAIB	281-283-7594
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Ride	CAIB	281-283-7503
Dr. Bluford	CAIB	281-283-7813
Colonel Bloomfield	CAIB	281-283-7809
Doug Cooke	CAIB Staff	281-283-7576
Mike Boulavsky	Recorder	281-280-8062
Dave Lengyel	CAIB Staff	281-283-7581
Steve Schmidt	CAIB Staff	281-283-7577
Dennis Jenkins	CAIB Grp 4	281-283-7589
Don White	CAIB Grp 2	281-283-7570
Lisa Reed	CAIB Grp 2	281-283-7815
Tracy Dillinger	CAIB Grp 2	281-283-7845
Rick Burgess	CAIB Grp 2	281-283-7566
Dave Kral	CAIB Grp 2	281-283-7571
Dr. Story Musgrave	EVA Expert	
Howard Goldstein	TPS	

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 19, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting

Date: 19 May 2003 **Time:** 1230 to 1530

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting are attached to this report.

There were no action items or requests for information generated from this meeting.

Admiral Gehman convened the meeting by introducing Mr. Doug Cooke who gave a presentation titled "Beyond Low Earth Orbit: The Future of Space Exploration: The Integrated Space Plan". Admiral Gehman explained he wanted to hear this briefing in order to understand what NASA envisions. Specifically, he believes it is important for the board to understand whether this future affects the urgency of returning the Shuttle to flight. The future plans could affect how urgently the Shuttle replacement needs to be addressed by NASA.

Mr. Cooke then gave his presentation. Explanatory material, questions, and comments from each chart are noted below. His briefing described on-going work within the agency related to the Integrated Space Plan that will be rolled out this summer. Much of the plan is aimed at technology and getting more focused on what NASA has to do in the future.

Chart 2 – NASA has now adopted the "Space Architect" approach. Over the past few years the agency has exhibited narrowly focused, "stove-piped" approaches. Admiral Gehman observed that for the past 15 years iterations of these types of plans have not stuck to the wall. ANS: They haven't. NASA is always getting directed to complete current projects before trying to start new programs. The latest efforts are to try to get the agency focused first. There was a question as to the budget for this effort. ANS: Mr. Cooke was not sure but it is in the neighborhood of $10M.

Chart 3 – The approach is to have a top down approach beginning with answering the question of why NASA is here. There has been some success over the past few years.

Chart 5 – NASA has a stepping-stone approach beginning with where we are today and developing the technologies for the next steps. There was an educational discussion describing environments of Mars and Venus for the board. Looking for biomarkers and understanding climatology of other planets are long-term scientific interests. There are also items of interest on the Moon: cratering, history of the sun as reflected in Lunar soil, water, and using Lunar operations as a stepping-stone for operations on other planetary bodies.

Chart 8 – Having to use chemical engines would preclude humans from going to Mars.

Chart 10 – This chart represents a set of technologies in sending a single crew to Mars with today's capabilities representing 100%. Even if all the technology advancements were made the mass involved is equivalent to that of the fully built-up Space Station.

Chart 17 – We are basically bound by the laws of physics in getting from Earth to Mars. There is a 15 year cycle between Earth and Mars orbits.

Chart 19 – There is a heavy use of inflatable modules in an attempt to reduce mass.

Chart 21 – There was a question on commanding robotic missions at Mars. ANS: Mars pathfinder science could have been accomplished in 3 hours had a person been close by the planet to operate the vehicle versus a timeline of several months caused by the 20 minute communicating/commanding time between Earth and Mars.

Chart 26 – This chart addresses the issue of getting off the face of the Earth which is the hardest thing to do. The EELV-H solution is a Delta IV class vehicle that lifts 23 metric tons. The probability of success numbers reflects launch failures with hardware for which there is no back-up.

Chart 30 – Approach would be for a wingless vehicle due to higher return velocities from beyond low Earth orbit. Wings would add extra mass and tear off during reentry.

There was a tutorial type discussion relating to the various types of nuclear and other engines addressing such topics as plutonium based, uranium based, nuclear thermal, nuclear electric, ion engines, plasma engines, etc.

Admiral Gehman stated that a manned trip to Mars is a long way away, 25 years or more. Mr. Cooke agreed that while the technologies are feasible and within reach, there are a lot of them to be mastered. Dr. Osheroff observed that before embarking on such a project NASA has to establish a better track record at delivering products closer to promised budgets and schedules.

Admiral Gehman expressed a concern that by building a series of interrelated pieces one could get into the same situation as today where the Shuttle is the justification for Space Station and the Space Station is the justification for Shuttle.

Admiral Gehman expressed a concern that taking on such a large project with a budget determined on an annual basis. Mr. Cooke indicated that changing budgets caused many delays in Space Station. Admiral Gehman indicated that flat budgets also cause similar problems especially when you operate with small budgets as NASA must do. While DoD faces the same issue as NASA they are able to minimize the impacts of flat budgets because of the large size of the DoD budget and their ability to reprogram funds among different programs when necessary thus allowing more optimal funding profiles.

Following a discussion of the rationale and justification for the Shuttle, Admiral Gehman observed the board would have to assume the Shuttle is the only space transportation system for the next number of years. Getting a safer more reliable way to transport humans to and from space must be accomplished quickly.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 19, 2003
These Minutes Contain No Sensitive Data

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 19, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Osheroff Via Telecon	CAIB	281-283-7511
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mr. Lengyel	CAIB Ex. Secretary	281-283-7581
Mr. Hartman	Recorder	281-283-7591
Mr. Choban	Audio	281-483-4890
Mr. Buzzard	CTF	281-483-8412
Col. Bloomfield	CAIB Staff	281-283-7809
Doug Cooke	CTF	202-329-8844
Dr. Bluford	CAIB Staff	281-283-7813
Mr. Cobb	NASA	Via Telecon
Bill Sikora	CAIB Counsel	281-283-7564
Les Reingold	CAIB Staff	281-283-7539
Chris Kirchhoff	CAIB Staff	281-283-7821
Ari Simon	CAIB Staff	281-283-7539
Robert Hammond	CAIB Staff	281-283-7533
Steven Schmidt	CAIB Staff	281-283-7577

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 21, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting – Group 4 Status Report

Date: 21 May 2003 **Time:** 1230 to 1745

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the DOJ CDS database.

There were no action items or requests for information generated from this meeting.

Admiral Gehman convened the meeting at 1230 hrs. He asked the board members to comment on the outline of the Group 4 section of the final report that was displayed on each member's laptop using the GroupSystems software. CAIB members comments made during the meeting are attached to this report.

Dr. Logsdon then introduced the members of his team who were present for the meeting. The data contained in the briefing was taken primarily from documents and the personal experience of senior members of Group 4. The group has tried to identify a whole set of factors that may have contributed to the unsettled environment in which the program is operating. Thus far the group has been devoting most of its attention to the context of the Shuttle Program and its operation in the 1990's and has not paid much attention to the period since Mr. O'Keefe took over as NASA Administrator. Clearly the group will have to address to the O'Keefe era.

Dr. Logsdon then began the briefing. Comments over and above what appears on the charts, questions, and responses are listed below and referenced to each chart.

Charts 3 through 9 provide the "laundry list" of factors that have been identified by group 4 and are being addressed. Dr. Logsdon asked each board member to indicate any factor they felt the group had missed.

Chart 5

Large Shuttle budget reductions occurred between 1991 and 1995 with additional pressure to further reduce costs in order to free-up money in a flat budget environment to support other NASA initiatives and the International Space Station (ISS).

Chart 6

Mr. Wallace said he had a reporter ask him what he thought about the fact that the space program doesn't seem to have the ability to rivet the nation as it had in the past. ANS: The space program cannot go on as public entertainment. If the space program has to depend on its ability to capture the public's imagination, the program is not sustainable.

Until the late 1990's, when the Congress mandated two science missions, NASA was giving serious consideration to giving Columbia to a contractor to operate because it was surplus to the needs of the Shuttle Program that was concentrating exclusively on supporting ISS.

Chart 9

MGen Hess asked if Group 4 intended to take a macro look at managerial constructs. He wanted to know if NASA was optimally organized to complete the mission or did NASA add to the complexity of the program by spreading responsibility all over the United States. ANS: Group 4 will look at ways the program has been organized over the years. However, it is not part of the group's mandate to look below the center director level. Mr. Hubbard then observed that such an analysis would also be affected by the full cost accounting process which effectively limits the ability of center directors to direct the application of resources since everything is organized and paid for by programs.

Chart 10

Only 5 of the 17 factors were discussed at the briefing.

Chart 11 Dr. Lambright presenting.

The group has made liberal use of the quotations of Mr. Dan Goldin who, as the longest serving NASA Administrator, had great influence on the agency. This part of the briefing was devoted entirely to a discussion of Mr. Goldin who saw himself as an "agent of change".

Chart 13

It is extraordinary that Mr. Goldin served as long as he did. He was deliberately appointed after the previous administrator was forced out and was perceived as someone who would be an agent of change. It was thought that Mr. Goldin would implement at NASA the "faster, better, cheaper" philosophy then prevalent in the Department of Defense (DoD) Strategic Defense Initiative (SDI) Program.

Chart 15

Major managerial changes bring the Shuttle Program and the ISS under the same Associate Administrator. Mr. Buzzard added an historical footnote by observing that the Shuttle always had based its design on serving a space station.

The International Space Station (ISS) also became a foreign policy tool when the Russians were brought into the program and inserted into the critical path. This meant that NASA could not back out of the ISS Program even had it wanted to do so.

Chart 17

Dr. Lambright believes that in 25 years people will look back on the period between the end of the Cold War and the terrorists' attack of 9/11 as the inter-war era.

Chart 18

Mr. Goldin was heavily praised within the Washington D.C. structure for his actions at decentralizing NASA such as moving both the Shuttle Program and ISS to Johnson Space Center (JSC).

Chart 19

Mr. Goldin had so much stature in Washington that he was heavily praised by both Vice President Gore (a Democrat) and Speaker of the House Gingrich (a Republican). It is believed that Mr. Goldin was a zealot whose heart and soul was devoted to interplanetary exploration.

Chart 23

Dr. Logsdon said he believed Mr. Goldin saved the agency from irrelevance and that he loved his job but stayed around too long.

The post-Apollo planning that occurred in the 1960's called for building both a Shuttle and space station within 10 years to serve as infrastructure so the agency could be about its real business of exploration and settlement. Instead we have spent over 30 years building this infrastructure and the public has lost interest.

Dr. Logsdon then asked the board if his group had gotten it right. Dr. Ride responded that Mr. Goldin only became a proponent of the space station when the Clinton Administration embraced it. The ISS was the principal carrot that the administration gave to Russia in return for Russian signing of the Nuclear Non-Proliferation Treaty. Mr. Goldin found a way to link the station to foreign policy that caused the station to be designed in such a way so as to bring in heavy Russian involvement. Mr. Hubbard agreed Group 4 had gotten it right.

Chart 24 Dr. Logsdon presenting NASA and Space Shuttle Program Budget History

Chart 26

Historically, NASA has suffered from being a low federal budgetary priority. Dr. Logsdon believes that Mr. Goldin feared for his job and therefore did not fight very hard for NASA's fair share of the federal budget.

Dr. Logsdon then observed that he believes the board has to make a judgment as to whether NASA can run a healthy Shuttle Program with available resources.

Chart 27

NASA has operated under a shrinking budget for most of the past decade.

Chart 28

Since the Shuttle Program budget has not grown, the program has not fared very well.

Dr. Bluford observed it would be interesting to see a breakout of the Safety, Reliability & Quality Assurance (SR&QA) budgets over this period. ANS: That would be very difficult to do since the budget for Code Q at NASA Headquarters only gives a partial answer as each center also funds SR&QA activities out of their operating budgets.

Chart 29

Mr. Wallace asked where the flight rate fit in. ANS: The flight rate was at 7 to 8 per year.

Chart 32

The data on this chart reflects the situation before the recent changes in the Shuttle budget.

Dr. Logsdon observed that one could argue the Shuttle was on a "going out of business" budget. Additionally, within this budget one could also question whether the dollars were spent wisely; witness the Electric Auxiliary Power Unit (EAPU).

Chart 33

Mr. Wallace asked what were the objectives of the Advanced Solid Rocket Motor (ASRM) Program. ANS: Cynically, it was to put business into the correct Congressional district in Mississippi. Technically, it was supposed to be safer because the single piece construction eliminated the joints and it offered a performance increase of 15%.

MGen Barry then observed that his group had heard that the Congress required the Shuttle upgrades to be "program-centric"; that is "big things" that cost a lot of money even though the technology was not available such as was the case with the EAPU.

Charts 34 and 35

There is no single organization that has taken money from the Shuttle Program budget. NASA, the Office of Management and Budget (OMB), and the Congress all have used the Shuttle budget as a source of funds to be used for other purposes such as $54 million for Mars initiatives. There were 2 Congressionally mandated science missions and STS-107 was one of them.

MGen Barry then asked whether Group 4 discusses the fact that the Shuttle budget has not been increased due to inflation as has the ISS budget. ANS: The group has not contrasted the budget fates of the 2 programs in much detail. Since 1995 OMB has mandated that Human Spaceflight (HSF) problems had to be settled within the HSF Enterprise without "robbing" the science or aeronautic budgets so ISS has been getting the priority.

Admiral Gehman then observed that the board has to draw the relevance of these 2 charts. He also said it was up to Groups 1 and 2 to relate the effect of a $135 Million mark down as low as the shop floor. This will be difficult to accomplish but the board will have to demonstrate relevance of these kind of budgetary moves.

Mr. Hubbard then asked if Group 4 had the budget requests that went forward from the Shuttle Program. ANS: No but we can get it.

Mr. Hubbard then observed that it appears money has been "skimmed" from the Shuttle Program to pay for technologies that have nothing to do with the Shuttle Program but was spent on "fun technology things to do". ANS: We haven't got that detail but will get it.

MGen Barry then asked whether Congress should shoulder the blame for funding Shuttle modifications but not funding sustainment. ANS: There is plenty of blame to go around but Congress is not the problem, the White House is.

Chart 36 Mr. Launius presenting When Will Shuttle Be Replaced.

Chart 37

Almost from the day the program was launched, and for sure over the past decade and a half, a key tenet of space policy has been Shuttle replacement. Recognizing that the Shuttle is a costly and risky system, every study report for the past decade and a half has recommended replacing the Shuttle.

Mr. Wallace asked whether the idea of separating cargo and crew spacelift had been around for a very long time. ANS: Yet, it has been the theme of many reports.

Dr. Bluford then asked why the National Aerospace Plane (NASP) was terminated. ANS: Materials, propulsion, and weight problems caused the demise of the NASP.

Admiral Gehman then observed that we do not have the technology for single stage to orbit (SSTO) nor will we have it any time soon.

Chart 43

Dr. Logsdon indicated that the Clinton Administration wrote a technical design, SSTO, into space policy and he thought this was not a very good idea.

Chart 44

The X-33 Program is a long, sad, troubling, but interesting story. Admiral Gehman then observed that the board had heard many such stories about programs that have cost billions of dollars for which nothing had been received.

Mr. Hubbard then indicated there had been multiple proposals in response to the NASA Research Announcement (NAR) and the most technologically challenging was picked. Admiral Gehman then said he could explain the rationale behind that choice. One cannot get anything through the Congress that is an incremental upgrade. They want "big-bangs" for the buck.

In 1957, prior to Sputnik, President Eisenhower asked about the cost of developing missile launch vehicles. He was told that since 1953 a total of $11.8 Billion had been spent and an additional $25 Billion would be spent through 1963. The results of this investment are still flying today and are known as the Delta, Atlas, Titan, and Polaris programs. The point of the chart is that NASA intended to make an enormous technological leap with an investment of only $1.5 Billion.

Chart 49

Mr. Buzzard observed that the error in the risk numbers presented in the chart was probably 100%. Mr. Wallace asked if the risk numbers were as a result of a probabilistic risk assessment. ANS: Yes. Mr. Buzzard then observed that the useful data to be gleaned from the chart is not the risk numbers themselves but the differences in the numbers that portray relative improvements in the risk posture.

MGen Barry then indicated he was concerned because there is no differentiation between sustainment upgrades and major modifications. Mr. Buzzard indicated he had been working these issues for years and when safety upgrades and sustainability/operability upgrades compete for the same pot of money the safety work is inevitably funded. The key has become to be able to craft sustainability and operability upgrades in terms of safety.

Mr. O'Keefe came to the agency at the end of 2001 and found that future space transportation plans were in sad shape. Although the Orbital Space Plane (OSP) Program is a band-aid it will still take 8 years to implement. The agency still does not have either the fiscal or technology bases to proceed to the next generation vehicle.

Chart 52

Dr. Bluford asked whether Boeing and Lockheed/Martin were supporting or opposing NASA. ANS: Clearly there are camps in both companies on each side of the discussion. There is not a lot of effort at the corporate level of either company to go one way or the other. OSP is seen as a more real program.

MGen Barry then asked how supportive the DoD was to the Space Launch initiative (SLI). ANS: DoD was not very supportive in the early days under the Clinton administration but since Mr. O'Keefe took over as NASA Administrator relations are better. They are working closely at the technical level via Joint Partnership Council to coordinate investments.

Dr. Logsdon then observed that Shuttle replacement is a tricky business for the board to address. Admiral Gehman indicated that he believed the topic of Shuttle replacement would have to be addressed by the CAIB in their report, at least tangentially.

Chart 54 Dr. Logsdon presenting Contract Consolidation, Privatization, Commercialization.

This presentation did not address the nuts and bolts of the Spaceflight operations Contract (SFOC) but concentrated on why SFOC happened and why it has not lived up to expectations.

Chart 55

There has been an idea around the Shuttle Program for a long time that efficiencies could be gained by consolidating contracts.

Charts 56 & 57

The Kraft Committee report reinforced the predilections of NASA management at Headquarter by recommending reducing and consolidating Shuttle contracts. Mr. Hubbard asked if the report said how to cut back SR&QA without compromising safety. ANS: The idea was that there were far too many people watching other people work without enhancing safety. Admiral Gehman then observed that the ugly history about how SFOC came about is not relevant to the board. What is relevant is that SFOC exists.

Chart 59

The transfer of operations responsibility to the United Space Alliance (USA) was supposed to be the first step in a process leading to eventual total privatization of the Shuttle Program including transfer of assets. The 1997 USA plan was put into a file and has not been seen since. The board has issued an RFI to obtain a copy of it. Mr. Hubbard observed that Mr. Goldin felt that privatizing the Shuttle Program was a step in a process to get NASA back to its core mission and would free up resources that would allow NASA to concentrate on Mars and other exploration. Admiral Gehman said what was more interesting to him was that there occurred functional shifts in the levels of government oversight where contractors replaced the government as sub-system managers.

Chart 62

Admiral Gehman stated that his recollection of the main point of the Ron Dittemore Privatization Plan was to move away from the current splitting of responsibilities and merge total program responsibility into a single entity.

Chart 63

Any NASA discussion of the Rand Corp. report is on hold for now but a private, for-profit operator of the Shuttle Program is a non-starter. Admiral Gehman added that the CAIB perception is that the Space Shuttle Program does not provide an operational, reliable space transportation capability but in reality is using a research and development (R&D) vehicle to perform operational missions.

Chart 64 Dr. McCurdy presenting Shuttle Image in National Policy.

The board should wonder why setting and then not achieving all these unobtainable goals have not raised red flags. The image of the Shuttle in Washington DC policy making circles is essentially unchanged over the past 30 years. One would think this image would have changed after Challenger but it did not. Therefore, the treatment of the Shuttle Program at the policy level is at odds with its true nature as a risky technology.

Chart 68

Admiral Gehman wondered whether responsible people really believed the Shuttle would really be so cheap to operate that it would make money for NASA. ANS: Mr. Buzzard said yes; that in

the 1980's responsible people did believe this. Many assumptions about the amount of tender, loving care that would be required by the Shuttle fleet proved to be wrong. For example, engines could not be flown 4 to 6 times between maintenance periods and the Thermal Protection System required much more maintenance than had been projected and these are just 2 of many assumptions that were incorrect. These assumptions were proven wrong by flying the vehicle, not by being naïve.

Dr. McCurdy then observed that there is a perception in Washington, DC, which has been prevalent since the 1970's, that NASA should not be allowed to move on to the next step in human exploration until the current system is declared operational. This meant no space station without an operational Shuttle and no beyond Low Earth Orbit (LEO) without a fully operational space station. Hence, there is a tremendous drive within policy making circles in Washington, DC to declare current systems as operational.

Dr. Logsdon then asked Dr. Bluford and Dr. Ride how risky they considered flying the Shuttle to be. Dr. Ride replied that most astronauts had a good idea of the risks involved in flying shuttles. The astronaut corps was not "sucked into" believing that the Shuttle was operational. The yearly flight rate began increasing and by 1985 it was at 12 per year and headed for 24. Resources were stretched incredibly thin. The system was at the brink of not being able to handle the load. Dr. Bluford agreed. Training facilities were stretched to the breaking point and the pressure exerted by the press for missing a launch date was so great that NASA changed the numbering system for its flights. Dr. Logsdon added that his group was sensing some schedule pressure being exerted on the Shuttle Program by space station operations. Dr. McCurdy offered the opinion that had NASA went to Congress in 1985/1986 and declared the Shuttle not operational the Congress would have cancelled the space station. Dr. Logsdon said it is almost impossible for people not heavily steeped in Shuttle history to imagine the amount of self-deception with which the program was managed although it may have been politically necessary self-deception.

Chart 73

Many decisions are heavily influenced by this old cultural vision of the Shuttle. It will be valuable to get rid of old perceptions and change the way people talk about space transportation.

Chart 74

For a long time the Shuttle has been viewed as something to be gotten rid of, at least from a Washington, DC perspective. But, we haven't invested in the necessary technologies nor made the commitment to pay for them. There is no national commitment towards a robust space program. The Integrated Space Transportation Plan (ISTP) is a product of necessity and is viewed as a way to get out of the current dilemma.

A question was asked about what Mr. O'Keefe was talking about. ANS: A number of things such as reshaping of priorities, enhanced security, education, what NASA does will be shaped by science and not destinations, emphasis on good management, emphasis on nuclear propulsion, and putting agency on sound financial footing.

At this point the formal briefing concluded and a post-briefing discussion ensued.

Admiral Gehman pointed out that the task at hand is for the board to give Group 4 guidance for writing their sections of the final report. They need ideas about the message to be delivered.

Dr. Logsdon pointed out that although Group 4 listed 17 factors, only 5 were discussed, so the Group still has more work to do.

Admiral Gehman cautioned against overstating the characteristics of a single individual.

Dr. Ride agreed that the board should not get too far into a single personality or the effects of one person on the Shuttle Program.

Admiral Gehman indicated he would like Group 4 to introduce relevant contributing factors which are then discussed and recommendations made by other groups in succeeding chapters of the report.

Dr. Logsdon indicated he thought only Mr. Goldin's influence on the Shuttle Program should be brought out in the report.

Dr. Ride said the element still missing from the discussion is a description of the changing Shuttle role in becoming critical to the ISS. Beginning 3/1/2003 there was an accelerated flight schedule of 7 flights in one year leading up to Node 2 complete. This was more flights than had been flown in some time and is a heavy burden for what the current Shuttle Program is sized to accommodate.

Dr. Logsdon agreed and indicated the topic needs to be more explicitly reflected in the outline.

Admiral Gehman indicated this issue was the nearest thing to schedule pressure that the board can demonstrate for STS-107.

Mr. Hubbard indicated the presentation brought out that the Shuttle is a vehicle born in compromise that continues to this day.

Admiral Gehman said two themes keep coming up in various ways and from different perspectives: the design compromises that were made and the low investment and research and development capping at the beginning of the Shuttle Program. We are still paying for these mistakes 30 years later.

Dr. Logsdon indicated it could be shown that schedule pressure as early as STS-1 led to not fixing obvious problems even then.

Mr. Wallace stated that there appeared to be a lot of pressure to get the science mission done so that the ISS work could continue.

Dr. Logsdon then asked the board about the discussion of the Safety & Mission Assurance role because he did not believe that discussion was a Group 4 responsibility. ANS: Admiral Gehman responded that S&MA is discussed in Section 6.2 of the final report that Group 2 is writing and Group 4 should not pursue that topic.

A discussion of the budget section of the briefing followed:

- Admiral Gehman said the CAIB task is to relate budget numbers to impacts. Some jump out at you like the 1994 decision to suspend upgrades. Others like failure to keep drawings current and PRACA issues are also important.
- Dr. Logsdon indicated his group had requested the Shuttle Program Office budget requests but there has been no response. He indicated the request for information (RFI) had been submitted some time ago.
- Mr. Wallace reminded the board that Senator McCain had asked Admiral Gehman to look into the effects on the program of non-Shuttle related "pork" such as aquariums and petting zoos.
- Dr. Logsdon indicated the board has to differentiate between pork and politics. He said Senator McCain is talking about budget earmarks. He warned the board that the senator is considered by many on Capitol Hill to be a maverick on this issue and that an attack on pork in general risked alienating many important lawmakers. The board must show how allocating money for other programs has hurt the Shuttle Program.
- Dr. Logsdon said it is fair to say that the Shuttle Program met its development budget within reasonable bounds but did it with a design that caused enormous operating costs.
- Mr. Hubbard then observed that when assessing ISTP it would be useful to recall the mistakes made on Shuttle, X-33, and X-34 of dictating the technology while capping the budget and schedule.

Next came a discussion of Shuttle replacement and the Shuttle Life Extension Program (SLEP).

- Admiral Gehman challenged the board to determine what role in the final report a discussion of a Shuttle replacement would have. He asked if there should be a characterization of the urgency of replacing the Shuttle. He said the CAIB could construe that commenting on the next generation launch vehicle was outside the charter of the board.
- Mr. Tetrault said the CAIB does not have sufficient expertise to say what the next launch vehicle should look like but can say what it will take to fly the Shuttle for another 30 years.
- Mr. Hubbard offered the opinion that if the board looks at themes that led to the accident they should also discuss not making the same mistakes as were made at the beginning of the Shuttle Program: design compromises that led to enormous operational costs, capping development budget, schedule pressures, etc.
- Dr. Logsdon said the board should offer its opinion on whether the Shuttle should fly for another 20 years and then offer opinions for how to accomplish that.
- Mr. Hubbard indicated he had heard the ISTP briefing many times but has never heard anything about drawing lessons learned from Shuttle or ISS.
- Admiral Gehman said that it is his opinion that if we want to operate the Shuttle for the next 20 years the program first has to do what is necessary and prudent to return to flight. Next they need to start with a clean sheet of paper and institute major project management structural changes because the past 20 years is a testament to failure. He then asked the board that if these things are done what is the probability of losing another vehicle in the next 20 years. The board agreed one would be lost.
- Admiral Gehman then asked about the urgency of building a safer human rated vehicle. Dr. Ride cautioned that this was easier said than done. One should look at the experience of other vehicles. Rockets blow up and the Shuttle has done better than any of the others.

Dr. Ride went on to say she doesn't like saying the Shuttle is not safe. There are many problems with the current safety organizations that can be fixed and there are many safety improvements that would enhance safety of the vehicle. One cannot say that a new vehicle would be safer than the Shuttle until after a new vehicle has flown.

- Col Bloomfield said the feeling in the Astronaut Office is the Shuttle is there for the station but that the agency needs to think about building a new vehicle that is safer.
- Admiral Gehman said one thing you could do with requirements for a new vehicle would be to decouple loss of vehicle from loss of crew.
- Dr. Ride said the board should not be so cavalier as to say the Shuttle is no good, it should be retired, and to get on about developing the next vehicle.
- Mr. Hubbard said the Space Shuttle Program does not have a true operational organization but are really doing development.
- Mr. Tetrault then asked the boards position on ascent debris hits. While the call has not been made as yet but if we are going to fly for 20 more years then an external tank redesign is feasible.

Next the board discussed privatization and commercialization.

- Admiral Gehman indicated his opinion that a Shuttle sub-system manager should not be a contractor position. He wondered how a contractor could do things that were inherently a government job.
- Dr. Logsdon said that his group needed to get up to date on the current thinking about commercialization at NASA HQ since new management has taken over.

Admiral Gehman made the only comment about the presentation on the image of the Shuttle in national policy. He indicated he thought it was a very compelling presentation because it brought home several things: national egos sometimes get in the way of doing the right thing when running a program and public perception of the Shuttle is at odds with reality. The Admiral also finds the cataloging of previous studies from 1986 through 1996 compelling. All essentially say the same thing that leads the board to two findings: You have been told this before and you are not paying any attention.

The meeting was adjourned at 1745 hrs.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees were as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Logsdon	CAIB	281-283-7594
Dr. Osheroff Via Telecon	CAIB	281-283-7511
Dr. Ride	CAIB	281-283-7503
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Mr. Lengyel	CAIB Staff	281-283-7581
Mr. Hartman	Recorder	281-283-7591
Mr. Boulavsky	Audio	281-283-7591
Mr. Buzzard	CTF	281-483-8412
Col. Bloomfield	CAIB Staff	281-283-7809
Dr. Bluford	CAIB Staff	281-283-7813
G. Ducote	CTF	281-483-8557
Dave Pye	CAIB Staff	281-283-7549
Jack Lehman	CAIB Staff	281-283-7842
Chris Kirchoff	CAIB Staff	281-283-7821
Robert Hammond	CAIB Staff	281-283-7533
Tracy Dillinger	CAIB Staff	281-283-7845
Bill Sikora	CAIB Staff	281-283-7564
Dwayne Day	CAIB Staff	281-283-7588
Dennis R. Jenkins	CAIB Staff	281-283-7589
Jim Mosquera	CAIB Staff	281-283-7546
Woody Woodyard	CAIB Staff	281-283-7565
Pat Brach	CAIB Staff	281-283-7849
Howard McCurdy	CAIB Staff	202-885-6236
Roger Lounius	CAIB Staff	202-633-2428
Les Reingold	CAIB Staff	281-283-7539
Ari Simon	CAIB Staff	281-283-7539
Richard Buenneke	CAIB Staff	703-812-0639

CAIB Feedback on Group 4 Briefing--Management/Policy Issues

Managerial issues/reinventing NASA

- Discuss options for better management schemes
- How much does the reduction in IFAs reflect redefinition and how much was a real reduction
- Note that a consequence of full cost management and planning from programs alone is to eliminate Center flexibility to solve problems or provide alternate analyses
- Not convinced we should emphasize the role of one person (goldin)
- NASA has been forced to be too program centric in getting funding from Congress--also, NASA has sold some programs to Congress without valid analysis if the enabling technologies were within reach: electric APU, X-38, etc.
- Shuttle and ISS are joined at the hip.....any findings/recs which might lead to replacing Shuttle before 2015 will impact the science return of ISS.....ISS has been sold as a world-class laboratory (that just happens to be in space).
- Intl relations aspect of ISS is important
- Recurring themes...same story with different characters...show that a shortcut at beginning causes issues over and over again
- All opera have the same plot
- Trying to implement non-applicable programs such as ISO 9000 into an R&D manned spaceflight program.

NASA and SSP budget history

- John, what can we do to respond to Sen. McCain pork tasking requirement?
- We must relate budget trends to program issues or we don't have an argument
- Look into congressional earmarks
- Insight: since complex systems fail in complex ways, need to trace back accountability to Congress and the White House (OMB). As we move into an era of aging spacecraft in an R&D environment, we need to focus criticism of NASA budgets that have been centered on programs and ignoring sustainment--better tiles, better foam, better wiring, NDE for RCC and tiles, etc.
- How do we treat congressional direction to fly a science mission?
- Can u provide any basis for sharing budget woes with congress and OMB and NASA?
- Look into focusing on space vehicles while facility infrastructure crumbles.

Interaction between anticipated date for Shuttle replacement and approach to upgrades

- Mention continuous push of shuttle replacement in 10 yrs increments out is not worthwhile management
- Need to argue for a robust capability to get to space so we don't have to rely on the Russian Soyuz--in other words NASA needs to develop a capsule system in accessing space that can be the prelude for going beyond LEO as a secondary objective.
- At the same time, the Russians have it right--heavy lift (modules for Salyut/Almaz/Mir/ISS space stations) is on the Proton K, cargo is on the Progress M/M1 (Soyuz-U booster) and people are on the Soyuz-TM/A (Soyuz U booster)....
- Discuss we must settle for incremental improvements in capabilities and not go for "unobtainium"
- We must comment on risk associated with flying shuttle another twenty years. We lose a shuttle every ten years...therefore twenty years from now we will have/lose how many?
- Note that to date no in-house (inside NASA) studies of next generation space vehicle have been allowed. This reflects the (pre-Columbia) view that only the contractor community has the "real" expertise.
- The set of major Shuttle upgrades (HeAPU TVC, EAPU, CAU, and AHMS) was developed in a timeframe where the Shuttle was "going out of business" in 2012.
- The ground rules were such the upgrades had to be tested and in place NLT 2007 to assure some "payback". If the planning horizon were extended beyond 2012 NASA may have had a different set of upgrades.....
- Shuttle replacement has been driven by the status quo...Congress would have not been receptive to a shuttle replacement because there was no real mission for the shuttle
- Shuttle exist for the ISS (except for Hubble)...after the completion of the ISS there would be limited use to no need to the shuttle
- Some upgrades have been delayed/cancelled based on the life expectancy of the shuttle (e.g., a mod that would take 2.5 years for a shuttle life of 3.0 years)
- Describe what it would take, or can we even fly this for another twenty years
- Describe the process of developing the next system, not to design the next system
- Any replacement should draw on the lessons from the flaws and compromises inherent in the shuttle program

- Completely redesign ssp management for the twenty year haul

Proposals for Shuttle privatization and commercialization

- The transfer of a basket of contracts to one bucket called SFOC seems to me not very interesting because the same people are doing the work. However, more interesting is shifts of functions and responsibility for safety, sub system management etc.
- Award procedures extremely important must be discussed somewhere
- Comment on what to do at recompete time two years from now.
- The SPC was a time/material contract without motivations on cost and schedule. When the SFOC came about it was a cost plus award fee contract with incorrect motivations to work cost and schedule that is anti-thetical to a flight test vehicle in an R&D environment!!!!!!!!!!!!
- Also, we need to work a recommendation that adjusts the SFOC by pulling out segments of the contract that incorrectly focuses on cost and schedule and make these segments time/material or fixed price cost contracts.
- May want to discuss this topic with Otto Goetz who led the ASAP assessment of the RAND report on comp sourcing
- There is no incentive to a private company to take on a risky venture...currently, USA, LM, and others can make profits without risk
- The shuttle is not a profitable commercial venture...the vehicles are not operational
- Privatization and commercialization of the Shuttle will only occur if market forces make it profitability for industry to operate the Shuttle. This effort will not succeed without a reasonable return on investment for industry

Image of Shuttle in national policy

- Need to recommend that NASA get the Vision, Strategic Plan and a Concept of Operations outlined before listing requirements -- then and only then should they begin to discuss what programs they need to propose for the future!!!!!!!!!!!!!!
- It is important that we not delude ourselves as to the cost and effort required to achieve the next space capability as we did in both the shuttle and the ISS
- In order to reach agreement on next space program, leadership is required to maintain focus on the true purpose of program rather than trivializing the issues, as our political process absolutely will do.

- Goldin's "safety hierarchy" was much more than Shuttle.....the priorities, from the top down, were protecting: the public, the astronauts/pilots, the workforce, and finally NASA's high-value assets.....he would ask people in the hallway, "what are the components of NASA's safety hierarchy?"
- Public perception of shuttle is at odds with reality, makes policy decisions very difficult. Congress and Administration have tough time making sound decisions if they are swimming in a sea of mistaken impressions.

Discussion topics/observations during session (added by facilitator/observers)

- Working hypothesis: a series of factors have contributed to a 'high degree of uncertainty' of the program
- What impact does the inability of the space program to 'rivet the nation' and capture the imagination have on the overall program/operations?
- Organizational alternatives: understanding the implications of dispersed geographic leadership/engineering
- Weighing the implications (longer term) of Goldin's term (the positives and the negatives)
- Space station redesign was based on larger administration issues...linking to national policy, etc
- Should we document greatest pork projects over NASA history up to the present?
- Just how far did NASA get in funding high priority safety upgrades? Were all the improvements really related to safety?
- Lack of national commitment to the $$ investment required to build a new generation vehicle...always 8-10 years out
    - We need to concentrate equally on sustainment vs. upgrades
- Debate issue: if conclusion that shuttle not operational orientation, then that directly impacts feasability/desirabilty of handing over to private concern
- With regard to future space vehicles, is technology advancement (SSTO) a higher priority than crew safety?

Observations and Learnings: Implications to CAIB (Board discussions after session--What's the 'so what?')

- The theme of the compromised program was there at the beginning and has continued to the present
- Question the transitioning of safety responsibility and authority to the contractor (at KSC)
- Redefined role of Shuttle in supporting node 2 completion of Space Station (we need to capture more of this, it implies buildup and schedule pressure)
- Implications of Shuttle as a 'vehicle born in compromise' (recurring theme...)
- Implications of paying for 30 years for the lack of appropriate R/D budget at the start
- Implications of 'days of margin' as tracking mechanism--does it begin to influence tradeoffs
- Ability to relate budget numbers/impact (safety, upgrades, etc)
- Implications of building a space exploration system on a 'fixed budget' (we need to make a clear leadership point/issue: it's a self fulfilling prophecy, unrealistic constraint and expectations). Unless you are willing to break this mode, you will likely repeat the same mistakes...
- Key question: do we want to have part of this report deal with the urgency/issue of shuttle replacement? (Base conclusion needs to be whether we feel Shuttle can be flown another 20 years...)
- We may need to communicate that even with major changes for ongoing shuttle flights, we still have risk of losing another shuttle. How might this impact the issue of developing a replacement vehicle? Would an initial flight of a replacement vehicle be safer that current shuttle flights?
- Increased safety may be realized by crew escape capability in replacement (safer) vehicle. Key message: we may be able to make something safer, that doesn't mean we can make something entirely safe.
- What are the implications of the loss of another orbiter (regardless of the cause)
- And...If you do conclude that you can fly the shuttle for another 20 years, it gives you significant latitude about

investment decisions and processes (it also may influence the kinds of recommendations we may relative to this accident cause and how to address it...)

- Key issue: there are certain aspects of the program that simply cannot be privatized...there are government responsibilities
- Compelling that many previous studies/conclusions say the same thing: a) it's been said before and b) you're not paying attention. We need to catalogue these.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 22, 2003
These Minutes Contain No Sensitive Data

Purpose: STS-107 Inflight Options Assessment Briefing and Daily Investigation Meeting

Date: 22 May 2003 **Time:** 1230 to 1345

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the DOJ CDS database.

There was 1action item from this meeting that is listed at the end of this report.

Admiral Gehman convened the meeting and spoke for a few minutes about the relations of the board with the press. He pointed out that he has a policy of not trying to control the statements that individual board members release to the press nor was he trying to tell board members what to say to the press. He suggested that the topic of "what could have been done" was a tricky subject and informed the board that he has a telephone press conference established for 5/23/2003 and requested the board defer to him to interface with the press corps on this subject. Admiral Gehman continued by enumerating the main points relating to this study:

1. The study was only completed because a formal request for information (RFI) was issued to NASA by the board on 2 May 2003.
2. The board requested the study be completed in order to assure the completeness of the final report; no other reason.
3. It was not done to imply any second-guessing of NASA decisions. It has been implied that the board is becoming less satisfied with the NASA decision making process as the investigation progresses. This is absolutely not true.

Dr. Osheroff then offered the observation that NASA did say there was nothing that could have been done. Admiral Gehman responded by saying the those statements were made by someone under the glare of press lights only two days after the mishap and we now have 20/20 hindsight.

Mr. Shannon then presented the STS-107 Inflight Options Briefing. He began by offering a disclaimer that this was not to be considered the "Shannon Report" as many highly qualified people contributed to its development. He indicated there would be a written report made available to the board as well as this presentation. Mr. Shannon then introduced Capt. Brent Jett (USN) and Mr. Joe Tanner from the Astronaut Office who had worked on the study and were present to answer questions on the topics of rendezvous/proximity operations and extravehicular activity (EVA) respectively.

Comments, questions and responses, and explanatory material offered for each page of the presentation is presented below and is referenced to the title of each page of the presentation.

<u>Rescue Mission - Assumptions:</u>

NASA has not been working on this since 1 February. It has been a 2-week activity, the brevity of which has added some realism to the exercise.

The team did not go so far as to prepare the actual flight products but rather looked for "show stoppers".

The team approached the aero/thermal team and requested them to provide a representative damage scenario. The aero/thermal group responded that we could assume a 6 inch hole in the lower half of a Reinforced Carbon-Carbon (RCC) Panel or a missing T-Seal.

Rescue Mission - Consumables:

Admiral Gehman asked what the carbon dioxide limit is for submarines. ANS: Mr. Shannon did not know what the Naval carbon dioxide limit was but indicated that the Apollo 13 mission readings for carbon dioxide reached as high as 15mm of Mercury. Mr. Shannon indicated he has copies of all the technical medical discussions on the subject if anyone on the board was interested.

Rescue Mission - Inspection EVA:

Mr. Tanner was invited to offer any comments to this chart. He indicated that while translating down the payload bay door had not been previously accomplished it depended on the use of a human as a translation aid and that process had been successfully performed previously. Mr. Tanner noted that the maneuvers required for translating down the payload bay door were practiced in the virtual reality laboratory as well as in the training pool and he felt the maneuvers were "very doable".

Mr. Shannon indicated that Kennedy Space Center would have been immediately turned on in a 24 hour/7 day operations mode to prepare Atlantis for the rescue mission while planning and training was going on for the inspection EVA and other mission procedures.

Rescue Mission – Launch Vehicle (LV) Processing:

Hardware problems were the greatest hazard to a successful processing flow and therefore the greatest threat to achieving a timely launch. Orbiter processing for a rescue mission would not have been a crash effort that would cut corners as has been portrayed in the media. All checks would have been performed and the mission was achievable if nothing broke during the checks leading up to launch. A flight crew escape demonstration test could have been eliminated because the chosen ground crew would have been composed of veterans who had already demonstrated their capability to perform this procedure. Ground crew rehearsals could have been eliminated because the same ground crew that had just launched Columbia would have been employed. Hardware problems could have contributed slightly more than 30% of potential delays while weather problems could have contributed a little less than 30%.

Capt. Jett added that the most important factor in crew selection would have been lack of susceptibility to Space Adaptation Syndrome because the mission could not have been successful if an important crew member could not perform all duties in a timely manner due to illness. There was a large debate within the team on crew size with three being considered but a crew of 4 was settled upon primarily for safety reasons. Although the team did not actually name a crew

they probably would have selected a flight crew composed of a Commander/Pilot pair and an EVA pair. These personnel either would have been currently training together or recently flown together.

Rescue Mission – Proximity Operations (PROX OPS)

Mr. Shannon invited Capt. Jett to comment on the PROX OPS chart. Necessary rendezvous maneuvers were practiced in the simulator using the only large structure models available, Hubble Space Telescope and the Space Station structure because the simulator is not equipped with a Shuttle model with which to rendezvous.

Rescue Mission – EVA

There would have been a short period of time when no "safe haven" was available to EVA astronauts. The plan was to bring the Columbia crew aboard Atlantis in 4 groups: 2 + 2 + 1 + 2 with the last group needing to be the two crew members who would have prepared Columbia for its deorbit burn. MGen Hess asked how long there would have been no safe haven. ANS: Ten to fifteen minutes per transfer.

Rescue Mission – Columbia Deorbit

The team looked into the possibility of boosting Columbia into a higher, safer orbit for the purpose of mounting a repair mission later on. That idea was discarded when it was realized all the cryogenic consumables would have been depleted resulting in loss of power. The power system cannot be serviced on-orbit.

There were no comments or questions on the repair mission charts.

At the conclusion of the briefing, Admiral Gehman complimented Mr. Shannon and the team for what must have been a most difficult and emotional task. He then asked how a flight readiness review (FRR) for Atlantis would have been accomplished. ANS: Mr. Stone responded. The biggest challenge in the Certification of Flight Readiness (CoFR) process would have been deciding to launch Atlantis without understanding why Columbia was lost. As much of the normal LRR process would have been accomplished as possible. Because of the stage of Atlantis preparation for its planned launch to the Space Station 41 days after the Columbia launch there would have been very high confidence in the software and day of launch initialization loads with only a patch and several days testing required for the changed mission. The training intensity would have been diminished but that could have been largely mitigated through selection of trained flight and ground crews.

Mr. Tetrault asked why Atlantis would have had to be launched at night. ANS: That is when the Columbia would have been over Kennedy Space Center.

Admiral Gehman declared the RFI closed and adjourned the meeting at 1345 hrs.

The action item generated from this meeting are listed below:

1. The CAIB staff to close the RFI.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 22, 2003
These Minutes Contain No Sensitive Data

Attendees were as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Logsdon	CAIB	281-283-7594
Dr. Osheroff	CAIB	281-283-7511
Dr. Ride	CAIB	281-283-7503
Mr. Tetrault	CAIB	281-283-7509
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Lengyel	CAIB Ex. Secretary	281-283-7581
Mr. Hartman	Recorder	281-283-7591
Mr. Buzzard	CTF	281-483-8412
Col. Bloomfield	CAIB Staff	281-283-7809
John Shannon	CTF	281-483-0716
Captain Brent Jett (USN)	NASA	281-244-8433
Joe Tanner	NASA	281-244-8714
Randy Stone	NASA	281-483-2465
Dave Lengyel	CAIB Staff	281-483-7581
Dr. Bluford	CAIB Staff	281-483-7563
Milt Heflin	NASA	281-483-5428
Frank Benz	NASA	281-483-3199
Jim Kennedy	NASA	281-483-2999
Don White	CAIB Staff	281-483-7570
Lisa Reed	CAIB Staff	281-483-7815
Rick Burgess	CAIB Staff	281-483-7566
Tyrone Woodyard	CAIB Staff	281-483-7565
David Kral	CAIB Staff	281-483-7571
Dan Diggins	CAIB Staff	281-483-7814

Les Reingold	CAIB Staff	281-483-7539
Ari Simon	CAIB Staff	281-483-7539
Dwayne day	CAIB Staff	281-483-7588
Chris Kirchoff	CAIB Staff	281-483-7821
Rick Stiles	CAIB Staff	281-483-7575
EJ Ripma	CAIB Staff	281-483-8574
Steve Poulos	NASA	281-483-9108
Dennis R. Jenkins	CAIB Staff	281-483-7589
Rob Ellison	NASA	281-483-2999
Wayne Gotsch	NASA	281-483-8554
Kelly Beck	NASA	281-483-8440
Elizabeth Fountain	NASA	281-483-5257
Doug Cooke	CAIB Staff	202-329-8844
Chirag Vyas	CAIB Staff	202-276-7014

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 23, 2003
These Minutes Contain No Sensitive Data

Purpose: Interim Return-to-Flight (RTF) Recommendations

Date: 23 May 2003 **Time:** 1000 - 1130

The list of attendees is appended to the end of this report.

Admiral Gehman opened by stating that the purpose of the meeting was to review interim RTF recommendations with the two following goals:

1. Establish priorities for accomplishing remaining work.

2. Identify any changes or new recommendations. The updates were captured via the Group Outliner tool (see attachment)

During the course of discussion Admiral Gehman noted that a source at United Space Alliance (USA) informed him that the long pole in the Orbiter turnaround process is repairing damage to the Thermal Protection System (TPS) tiles—most of which is caused by External Tank (ET) foam strikes. Ordinarily, USA would take steps to eliminate the cause of the problem at the source. However, the ET is outside the scope of the USA contract.

Admiral Gehman stated that the standard is no damage to the TPS; that is the goal by which we measure the system. Given that NASA will probably never be able to achieve that, the Board recommends that they should do the following:

1. Thoroughly understand the mechanisms causing foam to come off and strike the Orbiter, including the transport mechanism, the cryopumping mechanism, and the damage mechanism.

2. Treat foam strikes administratively in accordance with the rules the Shuttle Program has established, i.e. In-Flight Anomaly (IFA) or hazard. They cannot let success or repeated occurrences "in-family" overshadow the fact that they are violating the standard.

3. Fix the foam problem or mitigate it by making the Orbiter tougher.

4. Perform more testing and NDE on the entire system (not just foam) so that there is constant awareness of weaknesses or sensitivities.

5. Fix the organizational system, which allowed the foam strikes to go unchecked.

The Admiral also brought up the issue of trading lift capability to Space Station for increased safety margin. Col. Bloomfield pointed out that reductions in performance would result in having to add more flights to Station at the back end, and the Program Office mentality is that adding more flights means adding more risk to the Shuttle Program. This is fundamental to the thinking at the highest levels. (Note: it can be easily shown that increasing the probability of success for each individual flight can result in a reduction in total risk to the program despite adding more flights to the baseline). Admiral Gehman stated

that this will have to be resolved if the Board determines that NASA must include reductions in performance in the RTF trade space.

This meeting was adjourned at 1130.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 23, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff	CAIB	281-283-7511
Mr. Wallace	CAIB	281-283-7508
Colonel Bloomfield	CAIB Staff	281-283-9809
Mike Boulavsky	Recorder	281-280-8062
Dave Lengyel	CAIB Staff	281-283-7581
Cdr. Mike Francis	CAIB Grp 1	281-283-7574
Chris Kirchhoff	CAIB	281-283-7821
Dave Pye	CAIB	281-283-7549
Steve Schmidt	CAIB Staff	281-283-7577
Robert Cobb	CAIB	281-283-7806
Doug Cooke	CAIB	281-283-7576
Jim Mosquera	CAIB	281-283-7546
Dennis Jenkins	CAIB Grp 4	281-283-7589
Ari Simon	CAIB	281-283-7539
Larry Butkus	CAIB	281-283-7839
Dwayne Day	CAIB Grp 4	281-283-7588

Preliminary RTF Recommendations (Group Outliner)

Current list of RTF interim recommendations for consideration:

- Determine root cause of loss of foam on ET bipod ramp flange. Develop corrective action plan, which may require redesign of ET Bipod ramp.
- Understand history of foam loss and debris generation on the ET, SRB, and SSME. To aid in future determination of foam loss/debris generation location, make provisions for ET camera(s) (possibly 2).
- Develop inspection and repair techniques for RCC and tile damage. Options must include operations either docked or undocked to ISS.
  - Sense that NASA is doing some good things here, we should recognize and incorporate this awareness into the recommendation. Appropriate to issue the recommendation.
- Evaluate current ground-based camera assets to record launch activities. Provide adequate capabilities for all future day and night launches.
  - There may be reasons to separate this from foam...what the cameras can capture may go well beyond foam (essential diagnostic)
- Evaluate NDE techniques for foam on the ET. Focus must include, but not be limited to flange And PAL ramp areas.

General discussion on interim recommendations

- Because assumption by NASA that foam was not a danger, there was not a willingness to do weight tradeoffs
- May want to combine recommendations 1,2 and 5 from above (and possibly 4)
- One of our conclusions is that NO foam strikes are acceptable (that conclusion may not be shared by NASA). The standard is no damage to the TPS system.
  - Thoroughly understand mechanisms causing strikes
  - Need to treat all of these in accordance with the rules/specs (live by the standards)
  - Needs to be fixed; mitigate it by making orbiter tougher as well as fix what is originating the strikes
  - Need to do constant testing to assess
  - Need to fix the organizational issues that have allowed it to occur
  - Should likely keep on-orbiter inspection and repair issue separate
- Our comfort level seems high that we can go forward with communications to NASA about foam
- Some discussion around separation of mechanical issues vs. process issues. Also, some organizational issues may not be RTF issues and therefore would not be part of interim recommendation.
- Add placeholder reference to final report for process or longer term issues

- Organizational recommendations to be wrapped around a much larger set of issues/observations
- Goal: one paper about foam. Striking the TPS is unacceptable...recommendations should be around physical/mechanical issues (not organization at this time). Recommendations around testing (what's causing), the potential for redesign (e.g., trading weight for safety--expanding boundary of decision approach). We are, by this, raising the debris issue to a much higher level and we understand that it will bump against other constraints (Board needs to consider in context of overall risk)

Other possible recommendation areas...

- Number of government people inspecting turn-around process is handful of people...insufficient for number of process checks required. (per JY). This could be a RTF issue (provide sufficient oversight).
- Issue of whether ISO 9000 standards are applicable (probably not applicable)
- Backlog of engineering drawings--not current (good practice issue, probably not RTF). 'Digital shuttle'
- Need to consider issue of CRATER model...do we know enough now to issue interim recommendation?

Will revisit these revised recommendation areas next week (week of 05/26)

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
27 May, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation Meeting and X-33/X-34 Briefings

Date: 27 May 2003 **Time:** 1230 to 1445

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the DOJ CDS database.

There was 1 action item generated from this meeting that is listed at the end of this report.

Admiral Gehman convened the meeting at 1230 hrs. and provided the background for requesting this presentation. In its final report the board needs to set a tone for how urgent it is to replace the Shuttle. Since the board is largely unaware of previous programs to build a follow-on vehicle the board needs to be aware of the history and background for potential replacements.

Admiral Gehman then introduced Mr. Dan Dumbacher from Marshall Spaceflight Center (MSFC) who presented the X-33 Program briefing. Comments, questions and replies, and explanatory materials provided during the briefing are provided below and keyed to briefing chart number.

Chart 2:

Projections indicated sufficient growth in the commercial launch market to justify private investment in the development of future launch vehicles (LV).

Admiral Gehman asked if there were programs prior to the X-33 Program. ANS: Yes. The Admiral asked if these programs involved single stage to orbit (SSTO). ANS: Yes, everything was aimed at solving the technologies for SSTO.

MGen Hess asked whether the 1994 Access to Space Study was a joint NASA-Air Force effort. ANS: Yes, it was led by LtGen Moorman and consisted of 3 teams: an evolved Shuttle team, an SSTO team, and a team examining a bridge between the Shuttle and SSTO.

Mr. Wallace asked if it were contemplated that industry would operate the X-33. ANS: Yes, but the concept was never developed to any significant level of maturity. The idea was that the government would purchase rides.

Chart 4:

The X-33 procurement was not a typical cost plus award fee contract but was a cooperative agreement between NASA and Lockheed/Martin with a fixed government investment. The government had no formal commitments beyond the life of cooperative agreement. There was no guarantee that the government would but any rides but the LV follow-on, Venture Star, would be so far ahead of any competitor that the government would have no practical alternative if it wanted to avail itself of the reduced launch charges.

Dr. Widnall asked how many bidders were involved. ANS: Three, Rockwell, Mc Donnell-Douglas, and Lockheed/Martin.

Mr. Wallace then asked how the no-profit aspect of the endeavor was explained to stockholders. ANS: It was a research and development (R&D) project aimed towards exploiting the projected growth in the commercial sector launch market.

Dr. Widnall asked about the cost sharing. ANS: 90%-10% with any overruns carried by industry.

Admiral Gehman asked about the significance of the turn-around specifications. ANS: The project was trying to demonstrate operations as a technology and drive the operations philosophy into the design to support such areas as maintainability and accessibility.

Admiral Gehman then expressed concern over the number of technological advances that were being pursued. ANS: The project did "bite off more than it could chew". The philosophy was to push technology as far as possible under a projected business model.

Chart 8:

The major technology hurdle was the composite liquid hydrogen tank with its very complex geometry. The DCX-A successfully flew a composite liquid hydrogen tank but it was shaped as a simple cylinder. The complex geometry of the X-33 tank led to serious design issues.

Admiral Gehman asked a question about the linear aerospike engine. ANS: Mr. Dumbacher briefly explained the design concept for the engine. He went on to say that the three X-33 engines each had less thrust to weight ratio than the Space Shuttle Main Engines (SSME) but that the seven Venture Star engines each required greater thrust to weight ratio than the SSME and represented another large technical challenge.

Chart 9:

The metallic thermal protection system (TPS) was completely developed, fully ground tested in a high temperature wind tunnel, and all that was left to accomplish was to flight test the TPS.

Chart 12:

A major Space Launch Initiative (SLI) assumption was that the current flight demonstrators (X-33 and X-34) would meet their technology goals within their current cost and schedule commitments. The implication of the liquid hydrogen tank failure was that additional X-33 funding would have to come out of the SLI budget so NASA had a decision on priorities to make.

Mr. Buzzard asked what was meant by the bullet that the X-33 doesn't meet second generation reusable launch vehicle (RLV) goals. ANS: SLI determined that SSTO was not achievable, that a 2 stage vehicle was required at this time, and so the X-33 did not meet its needs. They also determined that the X-33 TPS did meet expected reentry environments. Simultaneously, it became apparent that the commercial launch business environment had been over-estimated.

When Lockheed/Martin (L/M) determined they were not interested in committing additional corporate funds, the responsibility for adding additional funds to the project fell to the government, which determined they were not interested in proceeding.

Chart 13:

This chart contains an error. The top line of the matrix is blank but should contain the following: X-33, X-34, X-37, Reusable First Stage, Orbital DART, Pioneer Company Demonstrator, Kistler K-1, F-15, F-18, Shuttle, X-38, SR-71. MSFC accepted an action to correct and replace the chart.

Chart 14:

Dr. Bluford asked how NASA contributed their portion of the project budget. ANS: There was incremental funding provided through the normal NASA budgeting process. NASA only provided funds after completion of previously defined milestones. The contractor also used a phased application of funds.

Chart 15:

Admiral Gehman asked this chart be skipped in the interest of time.

Chart 16:

The majority of the metallic TPS panels were fabricated and in stock. Portions of the aerospike engine testing, specifically the electro-mechanical actuators, were completed by SLI after the cooperative agreement with Lockheed-Martin was cancelled.

Dr. Widnall observed that she was astounded that anyone would try to justify SSTO with a business model.

Mr. Buzzard asked whether planning to deal with failure should be a lesson learned. ANS: Yes, the X-33 Project needed to recognize the risks and have backup plans in place. There were no backup plans in place for the liquid hydrogen tank failure.

Mr. Wallace asked what drove the push for SSTO. ANS: Significant savings from not having to integrate multiple stages as well as significant operations savings.

Dr. Bluford asked if the project was satisfied with the aerospike engines. ANS: Yes, many in the project office were surprised at how well the engine was progressing. The big issue was going to be achieving the necessary thrust to weight ratio.

Mr. Wallace asked if SSTO utilizes both lift and thrust. ANS: It uses mostly thrust. Everything going "up hill" is based on propulsion and the thrust component.

Mr. Mark Fisher then presented the X-34 briefing.

Chart 1:

The X-33 and X-34 were coincident projects in the same program office. The X-33 was a technology demonstrator while the X-34 was a technology testbed. Unlike the X-33 Project it was a fixed price contract with a very small project office of 4 to 6 people..

Chart 10:

The use of multiple ranges (White Sands, Dryden, Kennedy Space Center) coupled with the single string engine and avionics design of the vehicle raised safety concerns. This and the coincident failures in the Mars Program caused re-examination of the X-34 design especially the single string avionics and lack of human in the loop.

Chart 20:

MGen Hess asked if, as the result of X-33 and X-34 lessons learned, the Orbital Space Plane (OSP) project had a single requirements document. ANS: Yes, the program is essentially following the NASA Systems Engineering Handbook. Level 1 requirements flow from NASA Headquarters and drive level 2 requirements. At the Systems Requirements Review (SRR) the Level 1 requirements are validated and the Level 2 requirements are baselined. Similarly, level 2 requirements drive level 3 requirements that are validated and baselined respectively at the System Definition Review (SDR).

Col. Bloomfield asked if crew escape was a requirement. ANS: The reliability requirements enumerated by Code Q will drive these requirements.

Mr. Wallace asked why crew survivability was not a level 1 requirement. ANS: Code Q will have to be queried. Human rating requirements will drive the level 2 requirements.

Col. Bloomfield asked how meeting the requirements would be validated. ANS: Through analysis and test as well as through a probabilistic risk assessment which is specifically required by Code Q. The only way to meet the numbers in the Level 1 requirements is via a crew escape system.

Admiral Gehman then observed that he is surprised at the numbers of technological "leaps of faith" that are embodied in new NASA projects that are approved by Congress. The Department of Defense could never get projects like that through Capitol Hill. Mr. Dumbacher responded that the X-33 Project content was designed to push technology to get to SSTO. Many people at the working levels in the 1990's did not think it could be done. The agency and the administration sold the program.

This concluded the briefings.

Admiral Gehman then observed that the discussion was now getting to the reasons why these briefings were requested. The board needs to tell Congress and the Administration that if they continue to demand large technology leaps by NASA while simultaneously capping budgets and dictating schedules then the result will be continuing failure.

Mr. Hubbard then observed that of the three proposals for the X-33 effort, the Lockheed-Martin proposal was by far the most technologically aggressive. Mr. Dumbacher observed that the Rockwell proposal was for a Shuttle follow-on and the McDonnell/Douglas proposal was a DCX-A follow-on. Lockheed/Martin was selected because its proposal pushed technology to the maximum extent.

Dr. Widnall asked if the government got a reasonable return on investment from the X-33 project. Mr. Dumbacher replied that the value of the return "was in the eye of the beholder". NASA learned a significant amount from the program: Metallic TPS, aerospike engines, learned how to take the next steps for guidance, navigation, and control systems, trained young engineers in a hands on environment, and many other technologies.

Mr. Dumbacher was asked if he would recommend a cooperative agreement approach again. He responded that he would not because of the unrealistic expectations that the project faced.

Mr. Buzzard asked if any of the X-33 technology was used in SLI. ANS: Mr. Dumbacher enumerated a number of the X-33 technologies and how they were or were not being utilized in the SLI Program. Metallic TPS, operations concepts, composite fuel tanks, composite structures, advanced vehicle health management system, electro-mechanical actuators were all being used. SLI did not require the aerospike engines.

Mr. Shannon asked if the metallic TPS could be installed on the Shuttle. ANS: Not at this time. The metallic TPS was only tested to mach 8 and there are some issues from that testing that need to be worked. It is designed for mach 15 and there is some evidence that it would be applicable to the orbital reentry environment. A full flight test would be required.

Mr. Shannon then asked if Venture Star had planned to utilize the metallic TPS. ANS: Yes, they were willing to pay the weight penalty.

Admiral Gehman then thanked the presenters for helping the board understand the evolution of the business. A brief discussion on the near term schedule for the board was then held and the meeting adjourned at 1445 hrs.

There was one action item generated during this meeting:

1. MSFC to supply a corrected chart #13 from the X-33 presentation.

These minutes are hereby submitted for the record.

Approved
FOR
Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved
H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
27 May, 2003
These Minutes Contain No Sensitive Data

Attendees were as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Lengyel	CAIB Staff	281-283-7581
Mr. Hartman	Recorder	281-283-7591
Mr. Buzzard	CTF	281-483-8412
Col. Bloomfield	CAIB Staff	281-283-7809
Dr. Bluford	CAIB Staff	281-283-7563
Steven Schmidt	CAIB Staff	281-283-7577
Dave Pye	CAIB Staff	281-283-7549
Tyrone Woodyard	CAIB Staff	703-416-3532
Alex Adams	MSFC	256-544-4658
Dennis Jenkins	CAIB Staff	703-416-3373
Dwayne Day	CAIB Staff	703-416-3491
Chris Kirchoff	CAIB Staff	703-416-3121
Ari Simon	CAIB Staff	703-416-4485
Les Reingold	CAIB Staff	703-416-3551
Ann Towry	MSFC	256-544-5577
John Schmidt	CAIB Staff	703-416-3067
Doug Cooke	CAIB Staff	281-283-7576
Jim Mosquera	CAIB Staff	281-283-7549
Pat Garrett	CAIB Staff	281-283-7593
John Shannon	CTF	281-483-0716
Mark Fisher	MSFC	256-544-9503
Mike Ise	MSFC	256-544-4946
Dan Dumbacher	MSFC	256-544-6875

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 28, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 28 May 2003 **Time:** 1230 - 1615

The list of attendees is appended to the end of this report.

Admiral Gehman opened by stating that the objective of the meeting was to discuss RTF issues from the following perspectives:

- Flag all RTF issues even if they are not quite sorted out
- Combine information collected from presentations and discussions
- Get a "Board sense" of where we are

Preliminary RTF Recommendations (see attached)

1. Improve Inspection and Testing of RCC

MGen. Barry reported that NASA is now pushing back against using additional NDE techniques such as thermography to evaluate the integrity of the RCC as previously agreed on April 29th. Nonetheless, the Board stands by its recommendation.

Admiral German stated that he invited Lt.Gen. Stafford, Chairman of the Return-to-Space Task Group, and his team to sit in on CAIB meetings with the idea that this will help them understand the spirit as well as the letter of the CAIB recommendations. The CAIB will probably schedule periodic meetings with them after the move to D.C.

2. Fix On-Orbit Imaging Coordination with NIMA

Mr. Wallace stated that during the process of drafting the recommendation regarding on-orbit repair, he asked NASA/Paul Hill if anything needed to be added. Mr. Hill responded that he needed specific details on DoD imagery capabilities. Providing this information to Mr. Hill is problematic, it is complicated by the fact that much of this information is classified. Therefore all individuals who will have a "need to know" must have the appropriate security clearances just to look at the imagery.

3. Complete the Fault Tree

Admiral Gehman noted that this is not an RTF item. He has instead sent a letter to the NASA Accident Investigation Team (NAIT). MGen. Hess asked about dispositioning open items. Admiral Gehman suggested that open items would be noted in the final report and passed on to the Stafford Committee for dispositioning.

MGen. Hess stated that Group 2 would pull together the story to explain the key role of the hazard analysis process in the overall aspect of risk management, particularly as it relates to FMEA/CILs and accepted risk. Admiral Gehman responded that he would appreciate this because he understands accepting risk for micrometeoroid hits, for example, since this risk has been studied and quantified. However, he does not understand how NASA could accept the risk for something like foam hits without

defining what the risk is. Further, how do these "unknown" risks factor into the computation of the total risk number? MGen. Hess stated that NASA is not rolling up the individual risks to define the total risk. Group 2 will be writing a recommendation to address this.

4. Understand & Fix External Tank (ET) Foam Problems

Mr. Hubbard stated that there are two separate risk issues with foam. The first is with the small pieces from the belly of the tank region that come in at high angles and result in divots to the acreage. The other is the big logs falling off the bipod ramp that usually just skim by the acreage tiles but as shown on STS-107 can hit a weak spot and take out an Orbiter.

Dr. Osheroff made the following comments based on his own analysis of the mechanisms claimed to be the causes of the foam issues:

- Thermal heating due to aeroforces does not occur until +500 seconds or so for 1 inch of penetration into 2-inch foam. This does not explain the large piece of bipod foam coming off at +31 seconds
- Pressure buildup from cryo pumping would not result in a fracture that leads to ejection (popcorning) of the foam

He concluded that for several years these mechanisms were assumed responsible, yet they were never studied to the point that one could in fact make a conclusion.

Dr. Osheroff also observed that if you look at the results of the plug-pull tests performed to determine the tensile strength of the foam, you see the results vary by a factor of three. So the Marshall Space Flight Center conclusion is that this is a random material that can vary by factors of 3. They are not interpreting a low value as a signal that there is some part of this process that they do not have under control. Mr. Johnny Wolfe added that if a plug fails the test they try to localize the failure by doing other plug pulls in the area around it. However, due to the randomness of the foam and the fact that they are only measuring in a small area, they are getting a false sense of security.

Admiral Gehman asked if acreage foam popcorning is an RTF issue. The Board concluded that it is not, however, the explanations they have received from NASA indicate that they really do not understand the popcorning phenomena, and this is something that must be addressed.

Admiral Gehman then asked if the hand sprayed mid-tank areas are RTF. Mr. Wolfe responded that more divots come from flange foam hits than anything else. He added that inner tank flange closeout foam, in particular, comes off a lot. BGen. Deal stated that based on past history, flange foam should not be RTF. It causes lots of divots but not any great ones. The Board concluded that the flange foam is not an RTF issue but must be fixed.

Mr. Wolfe stated that the Board should be concerned with the Protuberance Aerodynamic Loading (PAL) ramp since it is made of the same material as the bipod. There is great potential for big chunks to come off and therefore big potential for disaster. The Board concluded that the PAL ramp is an RTF issue.

5. Incorporate Unincorporated EOs on Critical Shuttle Drawings

The Board concluded that this is not an RTF issue. Based on board discussion, Admiral Gehman directed Group 3 to add Computer Aided Design (CAD) in their write-up.

6. Fix KSC QA Deficiencies

BGen Deal stated that independent review of GMIPS and subsequent NASA implementation of recommended changes is an RTF issue. He added that, while some things are not value added, some critical things are being missed. The Board concurred and added that NASA needs to establish periodic review of GMIPS independent of Code M (Office of Space Flight).

BGen. Deal also noted that "processing debris" is a big concern among many of the KSC personnel he has talked to.

7. Fix MAF Defense Contract Management Agency (DCMA) Deficiencies –

Noting that this item is very similar to the above issue with KSC, Admiral Gehman asked if there are any RTF issues in this recommendation. BGen Deal stated that the issue is more "Return to Manufacturing" versus RTF. Otherwise every tank would have to be returned for rework. He does not see this bubbling up to RTF status.

Admiral Gehman asked what the RTF recommendations would be for the existing ready to fly ETs. BGen Deal stated the bi-pod ramps are RTF. The Board agreed that all existing bi-pod ramps are condemned and must be replaced with a new design as a condition of flight. MGen Hess asked if the PAL ramps fell in to the same category. Mr. Buzzard responded that there is less certainty that there is a problem or issue with the PAL ramps.

8. Conduct Reentry Risk Assessment

The Board decided that prior to RTF, NASA must address the results of an upcoming study regarding the danger to public.

9. Fix the Ground-Based Cameras

The Board quickly declared that this is an RTF issue. Admiral Gehman noted that cameras are old, some of them do not work anymore and still others are obstructed by buildings. Mr. Buzzard asked if this implies that launches should be daylight only. Admiral Gehman said that it does not.

10. Develop on Orbit TPS Repair Capability

The consensus of the Board is that this is an RTF issue and it applies to both ISS docked and free flight operations.

11. Ruggedize the Orbiter

Admiral Gehman noted that if making the Orbiter tougher were an RTF issue then it would be a long time before the first flight. MGen Hess expressed concern that, short of making this an RTF issue, NASA will not take the necessary steps to harden the Orbiter without a forcing function to make them do it. Mr. Buzzard suggested using a time constraint as a forcing function. This led the Admiral to suggest that the work must be done by the next OMM or else the Orbiter will not be certified to fly. He expanded on this by suggesting that NASA could be required to develop a plan of action and submit it to the Stafford Commission for approval prior to OMM. The Admiral also suggested recommending that Congress

earmark money specifically to fund the improvements. The Board decided that this issue needs more discussion and left the recommendation TBD.

12. Treat Tile Damage as an In-Flight Anomaly (IFA)

The record shows that sometimes the tile damage is considered an IFA and sometimes it is not. Admiral Gehman noted that the current process "muddies it up" so that the NASA leadership does not have to address the issue. MGen. Hess stated that tile damage is not a maintenance issue but a safety issue, and it must be treated that way. Therefore hazard analysis that considers tile damage must be performed as a condition for RTF.

13. Incorporate OI-30 Software and Improve Modular Auxiliary Data System

Software upgrades is not an RTF issue, nor is improving MADS. However, these items still must be addressed in the report.

14. Fix Abort Selection and Navigation

Admiral Gehman - This recommendation addresses CAPT John Young's idea that it is safer to attempt a contingency landing on the East Coast than it is to attempt a Return-To-Landing Site (RTLS).

Col Bloomfield - RTLS is a certified mode, meaning that it went through a lot of analysis to get there. However, what sticks in my mind is that the Shuttle Program had no choice but to certify it.

Admiral Gehman – CAPT Young has repeatedly stated that the program has a blind spot on abort procedures—that some day they are going to have to abort and they could have saved the crew, but because of lack of effort in this area the crew will not be saved. Is this one of those O-ring / foam strike potential kinds of problems that has been pointed out over and over again that action has not been taken on it? Is this an example of a problem that has been pointed out and NASA has decided to live with it?

Dr. Widnall - Is this something that could be done better? If so, then they ought to study it.

Col Bloomfield - When the program first started, launches went due east, so in an abort situation the East Coast sites would not be available. Now that they are going up to 51.6° they would have an opportunity to land on the East Coast rather than bail out.

Admiral Gehman - Part of CAPT Young's issue is that conditions have changed now that launches are to a higher azimuth, and the East Coast offers more choices than are currently approved.

Mr. Buzzard - Manual procedures were developed to perform East Coast landings. Further, on-board software provides automated capability to land at four or five sites up the East Coast. We have the landing sites loaded in the computer.

Col Bloomfield - CAPT Young's issue is that there is not continuous coverage to an East Coast landing if you launch in the middle of the launch window. If you launch at the end of the window it takes the flight path further to the west, and now you do not have any zones where the crew is put into a bailout scenario. Right now what we do is we do the abort, get back into the atmosphere, blow the hatch, and everybody

jumps out if we cannot make it to the runway. So CAPT Young is pushing two things. First, eliminate doing the RTLS. Second, launch at the end of the window so you have continuous coverage.

Mr. Buzzard – The adjustment to the ground track protects against two failures but reduces cargo capacity by 10,000 lb. [Note: providing continuous coverage to protect for an East Coast landing requires a more northern flight path angle. If the launch is nominal, the Shuttle must subsequently perform a midcourse correction to achieve the proper orbit for rendezvous with the Space Station. This midcourse correction, coupled with launching at the end of the launch window, consumes propellant and subsequently reduces the amount of cargo that can be delivered.]

Admiral Gehman – CAPT Young thinks that any RTLS is a joke. It is dangerous because you have to do this loop back and fly through your own exhaust amongst other things.

Col Bloomfield - RTLS is designed for one engine out. CAPT Young's concern is what happens if you lose a second engine during an RTLS situation? It is not survivable. If instead of doing an RTLS you decide to go up the East Coast, if you lose a second engine you have the ability to head for one of the East Coast sites.

Mr. Buzzard – Did any of the other reports that you have looked at have opinions similar to CAPT Young's, or is he a voice crying in the wilderness?

Admiral Gehman – I am not aware of any.

The Board agreed that this issue requires more study

15. Fix the Infrastructure

The Board agreed with minimal discussion that this is not an RTF issue unless they can identify a specific problem.

16. Fix NASA SR&QA Management and Training Issues

The Board agreed that this is not an RTF issue. However it must be addressed in the report. MGen. Hess stated that there is a need to standardize the safety organizations across the various sites, and give them more independence and control over standards.

17. Fix the CRATER Model

The Board quickly agreed that CRATER must be replaced with a physics-based analysis tool. Dr. Widnall commented that NASA needs to have a tool to fly and they cannot use the old tool. The Board agreed that this is an RTF issue.

18. Conduct Specialized Training for MMT

MGen. Hess stated that based on the way the Mission Management Team (MMT) performed during the STS-107 mission, they need to have crisis management training and simulation prior to RTF.

Admiral Gehman's "Cats n' Dogs"

Admiral Gehman provided additional guidance on the process for developing the report. Mr.Dennis Jenkins will be the Admiral's representative for negotiating edits with fellow board members. Board members are to argue content with Mr. Jenkins and the Admiral, and not Mr. Reingold or Mr. Kirchoff. The Admiral also cautioned that authors would be relinquishing ownership of their inputs once the second draft is released.

Admiral Gehman mentioned that he told Sean O'Keefe that the NASA management system in place right now is OK for RTF but it is the Board's opinion that you cannot safely operate the system for another twenty years with this management system.

Admiral Gehman polled the Board on the subject of having another session with the safety professionals. His thought process is that the Board has become much smarter on the subject of safety, therefore they could have discussions that are more insightful than those of the Safety Symposium held a couple of months ago. The Board agreed that this would be a good thing to do. The level of discussion is TBD

Dr. Osheroff asked if this is a safety issue or is it a management problem in that NASA does not have an independent research organization that studies the stuff? Admiral Gehman replied that it is both.

MGen. Hess expressed concern that all the X programs to develop the next generation space vehicle have been cancelled without anything to show for the efforts. This puts more pressure on sustaining the Shuttle.

Admiral Gehman noted that at twenty plus years into the Shuttle program we should be ready to knock on the prototype of the next vehicle, and we do not even have viewgraphs.

MGen. Hess replied that they do not have good processes to sustain the Shuttle over a long haul period of time, and yet they have on several occasions made decisions that they are going to fly it longer than the original 10 years. They were doing developmental efforts on various vehicles that basically led nowhere. Nor did it give any technology to transfer over to this vehicle.

Admiral Gehman concluded by stating that this will be addressed in the section where they lecture to Congress that you cannot design space vehicles on Capital Hill.

This meeting was adjourned at 1615.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr. FOR
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 28, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Hubbard	CAIB	281-283-7517
Dr. Osheroff	CAIB	281-283-7511
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Tetrault	CAIB	281-283-7509
Mr. Wallace	CAIB	281-283-7508
Mr. Buzzard	CTF	281-483-8412
Dr. Widnall	CAIB	281-283-7579
Dr. Bluford	CAIB	281-283-7563
Lt. Colonel Bloomfield	CAIB	281-283-9809
Mike Boulavsky	Recorder	281-280-8062
Dave Lengyel	CAIB	281-283-7581
Paul Wilde	CAIB	301-775-6797
LCDR Johnny Wolfe	CAIB	281-283-7543
Dwayne Day	CAIB	281-283-7588
Pat Garrett	CAIB	281-283-7593
Steve Schmidt	CAIB Staff	281-283-7577
Dennis Jenkins	Grp 4	281-283-7589
Doug Cooke	CAIB	281-283-7576

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
29 May, 2003
These Minutes Contain No Sensitive Data

Purpose: Solid Rocket Booster Fault-Tree Closeout

Date: 29 May 2003 **Time:** 0900 to 1055

The list of attendees is appended to the end of this report.

Presentation Materials used at this meeting can be found on the DOJ CDS database.

There were no action items or requests for information generated from this meeting.

Admiral Gehman convened the meeting at 0900 hrs.

Mr. Randy Stone introduced the meeting by reviewing the status of the closure of the various fault trees. He said that this was the third of the five major elements whose fault trees will be presented for closure. The External Tank would be handled the week of June 2nd and the Orbiter fault tree the week of June 9th. Both meetings were scheduled to be held at Johnson Space Center (JSC) in Building 1, Room 945.

Mr. Lambert Austin then made several statements related to the integrated fault tree. He indicated that approximately 50% of the integrated multi-element items are completed with the Solid Rocket Booster (SRB) Thrust Vector Control (TVC) briefing coming soon. Payload items will be presented to the NASA Accident Investigation Team (NAIT) next week. Admiral Gehman indicated the board was very interested in the integrated fault tree.

Mr. Rick Schmidgall from Marshall Spaceflight Center (MSFC) presented the status of fault tree closures. Forty closure blocks were designated multi-element. Everything to be seen at this meeting ties into the integrated fault tree. All but 4 faults related to the bolt catcher and 2 faults related to the Booster Separation Motors (BSM) are recommended for closure by the board.

Mr. Schmidgall then distributed and reviewed a chart that summarized the status of the fault trees for which MSFC was responsible. That chart is attached to these minutes.

Mr. Pete Rodrigues then presented the MSFC fault tree briefing for the SRB.

Admiral Gehman indicated there are two issues with which the board is struggling. These issues are the lists of potential hazards that are not closed and lower level hazards that did not occur during this flight but still exist. Mr. Stone responded that fault tree analysis is being utilized in both return to flight as well as to provide guidance for future work.

Admiral Gehman observed that the fault tree analysis is extraordinarily useful.

Chart 3:

The four open items shown on the chart are related to the bolt catcher plus two additional items opened May 28th related to the Booster Separation Motor (BSM).

Chart 14:

Admiral Gehman asked if the recovery of the Orbiter data recorder (OEX) changed anything done for this fault tree. ANS: That event had no impact to either the processes or findings.

Chart 15:

Dr. Widnall asked if MSFC already utilized the format they used for these fault trees or whether they had to invent the format. ANS: United Space Alliance (USA) has an existing format for fault trees that is used for anomaly investigation and this format was used for the investigation.

Dr. Widnall indicated she assumed a process similar to fault trees was performed after each flight and there was a relationship between fault trees and the flight readiness reviews (FRR). ANS: A thorough process for post-flight review and evaluation is utilized but it is not a fault tree. If something off-nominal is detected then a fault tree process is utilized for further investigation.

Admiral Gehman indicated the board was considering an idea that the size of the catalog of critical items list (CIL) entries and hazards was so large that it was very difficult to utilize in an effective manner.

MGen Hess asked if the quality of hazard reports was considered as part of the review. ANS: This was not accomplished but there is an action item to do this. There is also a requirement to review all CIL's and hazard reports that change during a year.

Chart 16:

Admiral Gehman asked about the length of the critical items list (CIL) and hazard reports. ANS: There are 507 CIL items. There are more hazard reports than CIL items but the exact metric will have to be determined and provided. There are approximately 50 hazard reports but each report has multiple causes.

Chart 20:

Mr. Rodriguez indicated that in the interests of completing the briefing on time he would only review the subsequent fault tree summary sheets unless there were questions or comments.

Chart 22:

Mr. Larry Clark presented a video demonstrating SRB environments. This video was not STS-107 specific but was a montage of multiple flights.

Forward Skirt Assembly – B.1.3.4

Dr. Hallock asked how MSFC knew a nominal separation had occurred. ANS: The SRB side of the separation equipment had been recovered and was observed to not have any anomalies. Additionally, there were no anomalistic indicators on the launch video.

Admiral Gehman asked what the mach and QBar numbers were at separation. ANS: Mach is 4.5 and QBar is 20.

Admiral Gehman observed that things that do come off would be at a high relative velocity to the Orbiter. ANS: Relative Delta V is very small. Admiral Gehman then observed that the board had been told the same things about the External Tank foam but calculations later proved the foam was traveling as fast as a bullet; 750 to 800 feet per second.

Admiral Gehman asked about "allowable debris". ANS: A piece of cable used during separation was shown as an example of allowable debris.

Frustrum Assembly - B.1.3.2:

Dr. Widnall asked if "sooting" occurred at separation and whether it was evenly spread around the vehicle. ANS: While the whole vehicle is sooted, it is not evenly distributed around the vehicle.

Col. Bloomfield observed he had heard that a cover seal had "dinged" the reinforced Carbon-carbon (RCC) on STS-45. ANS: MSFC had never heard about the cover seal theory. There was a ding on the RCC after STS-45 but it contained metal fragments and the cover seal is made of silicon. The cause of the ding has never been determined.

Although there is no evidence that BSM ejecta caused loss of the STS-107 mission the block has been reopened because the size of the ejecta is not known. The item was reopened and may never be closed.

Admiral Gehman asked about the BSM's generating ejecta. ANS: BSM plume does hit the window and it was not sufficient force to break it. RCC motors are now fired when the BSM ignites and the problem with the windshield has been overcome. MSFC was talking about contamination of the BSM during fabrication resulting in unburned propellant. This is an area with which MSFC has had trouble in the past with BSM contamination.

Col. Bloomfield asked if the BSM plume hit the wing. ANS: From the audience; MSFC knows the plume hits the windshield but are not sure if it hits the wing. Determining the answer to this question is open work.

Water inside the BSM is the second fault tree block that was reopened on 28 May 2003.

At this point Mr. Stone indicated that the Orbiter Project would not accept previous history as rationale to conclude that something is not a problem. On STS-100 water intruded into the BSM

and caused some small amount of propellant not to burn. A process change and thorough testing indicates the chances of this occurring again have been significantly reduced.

Admiral Gehman asked if the water intrusion problem had been fixed. ANS: NASA believes the problem has been fixed. There is an extensive program that tests the installation of the BSM and any motor that passes the test has never gotten water in the motor.

Aft Skirt – B.1.3.7:

No questions or comments.

Tunnel Cover/Floor Plate:

No questions or comments.

ETA Ring – B.1.3.6:

Two porta pull plugs were lost on the bottom side. The two plug pulls were not performed properly. There are a total of 8 pulls, eight on forward side and four on aft side. This is not the first time these plugs have been lost.

Mr. Buzzard asked if the loss of the porta pull plug thermal protection system (TPS) material was on the aft side. ANS: Yes. Mr. Buzzard then asked if this was a return to flight (RTF) issue. ANS: Yes, a corrective action report (CAR) has been opened. Dr. Widnall asked how large these plugs were. ANS: A four-inch diameter cylinder by 4 inches high. Dr. Widnall asked if there was an inspection of the plug before it was refilled with TPS material. ANS: There should have been. Mr. Buzzard then asked if it was the Shuttle Program Manager or SRB Project Manager who dispositioned the CAR. ANS: The prime contractor (USA) dispositions the CAR but the disposition is reviewed by NASA Safety and Mission Assurance (S&MA). Mr. Buzzard asked if this debris was considered to be a safety of flight (SOF) issue. ANS: It is not a SFO issue because of its location for STS-107. Mr. Buzzard asked what transport mechanism analysis had been done to assure it was not a safety of flight issue. ANS: The analysis has not been done but once the pad had been cleared the vehicle is moving away from any of this type of debris. The only way the fault could become a SOF issue would be for it to occur before clearing the launch pad. This item will be part of the matrix to be reviewed prior to RTF. Mr. Buzzard observed that it is not clear to him that USA is the correct authority to disposition this paper. He observed there should be no debris and this needs to be fixed. ANS: It is an issue of insight versus oversight; who should be reviewing the paper. The correct solution is that these plugs should not be coming out. Dr. Widnall asked if the debris had come off the other side would the disposition have been different. ANS: Yes, if it came off the front it would have been considered as an inflight anomaly.

Admiral Gehman then observed that he is surprised the prime contractor is dispositioning paper that reflects on their performance. ANS: The NASA review is not at the project level but at the S&MA level. He continued by indicating he had heard this fault had occurred before. ANS: It had occurred before but NASA believes all previous occurrences did not have sooting and were the result of impacting the water. This may have been the first occurrence of this event.

Nose Cap – B.1.3.1.1:

Admiral Gehman how it could be proven the nose cap was not at fault since the nose cap was not recovered. ANS: This is done by extrapolation to other elements that use the same TPS and experience much harder environments but come through unscathed.

Extreme Environments – B.1.1.1:

Admiral Gehman said he wanted to revisit a previous question on the use of the orbiter recorder data in view of the fact that STS-107 experienced harsher than normal environments. ANS: The SRB systems performed well within specifications. Even though small out of family events were experienced, there were no excess loads transferred to the Orbiter.

Loads – B.1.1.2:

Dr. Widnall asked if the SRB provided telemetry. ANS: Yes, telemetry is passed to the Orbiter and received via the Orbiter Instrumentation Downlist.

Thrust Vector Control – B.1.2.2:

No questions or comments.

Admiral Gehman concluded the meeting by observing he liked the MSFC process whereby the working group chairpersons were not part of the project offices.

The meeting adjourned at 1055 hrs.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees were as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Mr. Wallace	CAIB	281-283-7508
Dr. Widnall	CAIB	281-283-7579
Mr. Lengyel	CAIB Staff	281-283-7581
Mr. Hartman	Recorder	281-283-7591
Mr. Buzzard	CTF	281-483-8412
Col. Bloomfield	CAIB Staff	281-283-7809
Randy Stone	NASA JSC	283-483-4653
Michael Wyckoff	USA	321-867-7903
Larry G. Clark	USA	321-867-7581
Phil R. Taylor	USA	321-867-9695
Donna Freeland	USA	321-867-8011
Lisa Guthrie Dobbs	USA	321-867-8012
Alan Fertig	USA	321-867-7970
Randall Tucker	NASA MSFC	256-544-0640
Lambert Austin	NASA JSC	281-483-0969
C. Bennett	DCMC MSFC	321-862-1408
Malissa Meadows	NASA MSFC	256-544-3248
Darrell Davis	NASA MSFC	256-544-7257
Tina Malone	NASA MSFC	256-544-2593
Renee Wilson	NASA MSFC	256-544-7176
Chantel Jacob	NASA MSFC	256-544-3540
Joe B. Davis	NASA MSFC	256-544-7019
George Story	NASA MSFC	256-544-7618
Kendall Junen	NASA MSFC	256-544-2530
David Martin	NASA MSFC	256-544-3549
David Wood	NASA MSFC	256-544-3285
Brian Pung	NASA MSFC	256-544-9346
Don Ford	NASA MSFC	256-544-2454
Rusty Jones	NASA MSFC	256-544-1497
Jeff Digg	NASA MSFC	256-544-1646
Pat Pilola	CTF	281-244-7071
Steve Poulos	NASA JSC	281-483-9108
Ruth Harrison	CTF	281-483-8550
Rick Schmidgall	NASA MSFC	256-544-7166
Pete Rodrigues	NASA MSFC	256-544-9335

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
May 30, 2003
These Minutes Contain No Sensitive Data

Purpose: Daily Investigation

Date: 30 May 2003 **Time:** 1230 - 1400

The list of attendees is appended to the end of this report.

There were three actions resulting from this meeting. They are listed at the end of this report.

Charts for this briefing are found in the Group 1 "Matrix" located in the DOJ CDS.

Admiral Gehman opened by stating that he keeps track of the money spent and he projects that the cost of conducting the investigation will total approximately $18 mil by the end of September, which is good considering that the budget for the effort was $50 mil.

End Game

Admiral Gehman – What is the end-game for the Board after the report is turned in? What is our getting out of town plan? As part of his negotiations with the congressional oversight committees I told Mr. Tom Carter to make sure that the committees understand that it is not "us against them". We are on the same side, and as they prepare for hearings, the CAIB will be glad to help them with their research. The question is—who is going to do that? Also, as we prepare for hearings we will need a small nucleus of people to search databases, help prepare briefing materials, or assist Congressional staffers with research. At some point in time all of the CAIB's "stuff" will be transferred to the National Archives. But for some period of time—thirty to sixty days, we will pay for a small office to support Congress and support us. Congress does not want to deal with NASA because they feel there will be an adversarial relationship and for some reason they do not want to work with the National Archives.

RADM Turcotte – I learned that lesson with the MV-22. I went through blue ribbon panels, Congressional testimony and other things. Everything was done at the end because many people had not read the report.

Admiral Gehman – As we go to testify in front of Congress that will be the rule rather than the exception. They will not have read the report and then they will challenge us on everything.

Action to Steve Schmidt and Dave Lengyel to determine the size and makeup of the post-report support staff.

Dr. Osheroff - How will travel expenses be covered when coming to testify before Congress?

Admiral Gehman – I suspect that you will not have to pay for travel expenses but I will take that as an action item—I will ask Mr. O'Keefe to cover it out of the $50 million that was budgeted.

Mr. Wallace – What is the life expectancy of Carter's office [CAIB Government Affairs]?

Admiral Gehman – At least through September.

Mr. Wallace – Will the CAIB maintain continuing presence through Logsdon and his Space Policy Institute (SPI)?

Admiral Gehman – Better ones would be NRC, National Safety Center, or the Air and Space Museum. We need to find a group that is more neutral than SPI.

Investigatory Matters

MGen Barry reported the following:

Analysis of carrier bolts examined to date indicates that they fractured on breakup—there is no evidence of manufacturing defects or corrosion.

A small shim on a right wing spanner beam was found cracked with the center pushed in. This will be passed on to Mr. Tetrault to see if this is indicative of some problem. They will also take some shims off from current Orbiters. Not overly concerned yet.

Reinforced Carbon-Carbon (RCC) panels were pulled from Discovery and shipped out for Non Destructive Evaluation (NDE). The chit directed the vendor to perform eddy current, radiography, and ultrasonic testing. It does not include anything about thermography. The CAIB has a firm commitment from KSC to do thermography on every single RCC panel and T-seal. KSC says this one got away from them because it was already enroute to the vendor. Group 1 will coordinate rewrite of the chit to include thermography.

Approximately $300K will buy equipment that reduces the time to perform Computed Tomography (CT) scans at KSC from one panel per week to one panel per day. The lab operators have repeatedly attempted to secure the necessary funds for the equipment upgrade but have not been successful. Admiral Gehman stated that he would work this informally through Mr. O'Keefe and follow-up with paper. It will cost approximately $160k to upgrade from the VAX computer and $250K for scanning equipment that provides 4 times the resolution. Also, they received better thermography software at KSC that allowed them to detect voids in a test panel.

The approach for performing Shearography on the flange area foam appears to work.

More RCC panels are being ordered at $800k and six months effort per piece.

RADM Turcotte – They have one complete shipset of spares minus panel 8. And they have a full set of T-seals.

Mr. Wallace – Are the spares identical for the three remaining Orbiters?

RADM Turcotte – Yes—they blend them by performing step and gap with a laser instrument to align it and then they shim it. It takes a considerable amount of time to take panels off for CT.

Dr. Osheroff – This is a very complex issue—if you take these things off and put them back on you could cause misalignments or cracks. On the other hand, it is nice to know if all the bolts are tight too.

Mr. Wallace pointed out the irony of spending over $800K per panel and yet refusing to spend money to upgrade CT computer.

Admiral Gehman stated that he would like the CAIB to have their own set of eyes dedicated to watching over testing and verifying results. Since some within NASA have reservation about performing these tests, he would like to have physical presence at a representative number of tests to ensure that they do not get "flavored" results. That is the whole reason for having an independent analysis.

Unexplained Anomalies – Presented by MGen Barry (notes below are intended to clarify or supplement the information contained in Attachment 1)

Introduction: This was an attempt to look at possible solutions to explain the cause of the mishap if you could not pin it down. It was briefed to Mr. Ralph Roe, and the Orbiter Vehicle Engineering Working Group (OVEWG) has the action to follow-thru on the implementation.

Solid Rocket Booster (SRB) Bolt Catchers

This is part of the SRB Fault Tree closeout activity. On most missions NASA takes a picture of the Bolt Catcher Assembly to verify that it is intact post SRB separation. For STS-107, the in-flight picture is completely black for some unknown reason. Therefore they could not eliminate the bolt catcher from the fault tree using a photograph. The other way they attempted to eliminate the bolt catcher was by test. Review of historical data revealed that the system was not in the flight configuration when it was tested and certified back in 1979. It was not tested with the SLA-561 ablator/insulator on the dome nor the aluminum honeycomb within the dome. Further, the test article was mounted to the fixture using thru bolts vice the inserts that are used in the flight configuration. They simply put the dome under a static pressure test fixture and pushed to failure. The failure was in the weld attaching the dome to a flange and was unexpected. The system was subsequently certified on the basis of analysis and similarity.

Under normal circumstances, when the separation bolt blows, the average pressure into the bolt catcher is 45k pounds. Since the bolt catcher is attached to the External Tank (ET) there is no way of performing analysis after the fact. Therefore tests in the flight configuration are being performed at in an attempt to eliminate the bolt catcher from the fault tree. The result from the first test firing was nominal, with the average pressure measuring 45k pounds. However, when the static pressure test was performed on the flight configuration (minus SLA) the weld failed at 51.6k pounds, significantly below the expected 68k pounds. This implies that the safety factor is approximately 1.2 versus the claimed 1.5.

The conclusion was that the bolt catcher should not prevent closeout of the fault tree. However, the Board is concerned about the practice of certifying flight hardware based on analysis/similarity to hardware that was not tested in the flight configuration and in a representative operational environment. In the report this will be carried as an "observation".

ET Foam Production

Admiral Gehman – regarding "recommendations" (pg 3 of 12): the phrasing "NASA should continue to pursue" is too vague or open-ended. The recommendation should be more specific, or it may be more appropriate to turn it into a finding that "the Board views with concern the lack of science, lack of knowledge, lack of understanding, and the lack of urgency by which this is treated".

RADM Turcotte – This is another example of a system failure. Back in 1995 KSC NDE personnel attempted to work this issue through the program and got nowhere. This links back to programmatic system safety.

ET Foam – Launch and Ascent

- Chart 1 – Issue: Cryopumping & Cryoingestion

MGen Barry – The theory is that foam shedding is caused by cryoingestion (escape of N2 from intertank region into SLA or foam) or cryopumping (entry of ambient air through cracks in the foam)

- Chart 2 – Findings

MGen Barry - We went through the recent dissections and cracks and saw no evidence of SLA coming off beneath the foam. Test #6 (cryoingestion) at Marshall Space Flight Center (MSFC) conditions did not simulate the operational environment completely. It goes from vapor to liquid to solid, but it doesn't get warm enough again on launch to become the gas that vents out.

- Chart 3 – Findings (cont'd)

MGen Barry – Test #2 at MSFC (combined thermo/cryo/vacuum environment) had similar results. Conditions during tanking favor the formation of liquid and/or solid N2, but it does not become warm enough to become a gas. Therefore it cannot explain "popcorning" because it does not go back to vapor. This is an anomaly now, because they do not have an explanation why the bipod pops off. We know there are voids underneath from the manufacturing defects that occur during spraying. Can aeroforces get underneath to pop off the large chunks? That is the problem they are trying to figure out.

Dr. Osheroff – With the popcorning I think the thermal time constants are short enough so you could explain that. My test suggested that when the pressure builds up in the foam it does not cause a fracture that would eject material.

BGen Deal – The chart should say "does not cause foam loss" instead of saying it does not contribute to foam loss because that disregards the cumulative effects of aeroloads, cryopumping, voids and debonds, and pressure

- Chart 4 – Recommendations

MGen Barry – The problem here is that they (MSFC) have to explain to people why the bipod came off. They have been hanging their hats on this for years.

MGen Hess – We have to pick this up too when we talk about the hazard reporting system.

- Chart 7 – Progression of Cryopumping from Ambient Air

MGen Barry – The theory was that liquid caught underneath the foam goes to solid and then back to gas, causing divots to pop off. In reality, instead of divots we are finding cracks where it vents.

Admiral Gehman – The big problem with that cartoon is that you have created two exit paths for the pocket to vent itself.

MGen Barry – Mr. Leroy Cain and his colleagues are trying to explain why the right bipod does not come off. The reason given in the past is that it is protected by the Liquid Oxygen (LOX) line. But there is a crack that naturally forms there that allows the venting, when they were trying to explain it with cryopumping

- Chart 10 – MSFC Test #6

MGen Barry – They still have a list of things to investigate or characterize. This is key because they have to explain to the families how the foam came off

Admiral Gehman – Cryopumping—nobody understands it so nobody can contradict it.

Dr. Osheroff – I would regard this as an In-Flight Anomaly at this point. It was certainly the initiating event, and we do not understand it.

<u>RCC Maintenance – Orbiter Maintenance and Modification (OMM) in 2000</u>

- Chart 1 – Issue

MGen Barry – Determine if left Wing Leading Edge (WLE) maintenance actions could be a contributing cause of the accident.

- Chart 2 – OMM in 2000

MGen Barry – After RCC components were re-installed post OMM, step and gap measurements were found to be unacceptable. The left WLE subsystem had to be completely removed, after which numerous issues were discovered. Spar fitting shims were not per design; nutplates were debonded, nuts were damaged. They evaluated 152 fasteners and found that 48 (32%) had low torque values.

Admiral Gehman – That is disturbing. That says something about government inspections and QA.

- Chart 3 – OV-102 Fastener Detail

Mr. Chuck Babish – This is an installation schematic. The issue was that the bonded aluminum nutplates on the wingspar would come off and they would have to do a Maintenance Request (MR) to make repairs. The MR turned out to be a bad installation that led to some of the loose bolts that were found (The MR eliminated the nutplate that provided the necessary thread relief). In addition, they did not have a controlled torque sequence. They ended up going back to the design configuration for all leading edge hardware for OV-102.

- Chart 4 – OV-102 Left Wing Torque Check Results

Mr. Hallock – It bothers me to see so many "reds" in the (RCC panel) 6-7 area.

Mr. Babish – (In response to an observation that there were some obvious patterns to the torque values on most of the RCC panels). They did not have a proper torque sequence so they always went in the same patterns.

Admiral Gehman – And the result was bolts he thought were torqued became untorqued.

MGen Barry – They need a sequence like you have on your car

Mr. Babish – They are doing that now. They did not have that control in place prior to this discovery.

- Chart 5 – Shank-out Condition

Mr. Babish – Shank-out is when you run the threads all the way in the nut and you still do not have the right torque, or maybe the bolt is not seated. In this case it was due to not having the right shimming or right number of washers.

- Chart 7 – RCC Maintenance After STS-109

MGen Barry – Discoloration on the upper right wing was noticed during post-flight processing. Upon further investigation a ball of masking tape was found in the RCC cavity forward of the spar.

Admiral Gehman – It apparently burned and leaked gas.

- Chart 9 – RCC Maintenance Before STS-107

Several horseshoe gap fillers in the left wing were replaced during the OMM in 2000.

Mr. Babish – After STS-109 one of them was found torn. This is significant because the gap filler only lasted through one mission.

- Chart 10 – RCC Angle Seal 1L Removal.

Mr. Babish – Procedures for removal of the angle seal were not followed, so there was concern that fittings were overloaded. When they went back to check on the fittings they found that the clevis fitting was damaged during removal of a bushing, so the hardware had to be reworked.

RADM Turcotte stated his belief that this was where hydraulic fluid was used to loosen the bolts. This is an old trick from the aircraft industry but not something approved for Shuttle maintenance.

- Chart 11 – RCC Maintenance OMM and Flows

MGen Barry – The bottom line is that a lot of maintenance was performed on the left wing. We thought it necessary to address these issues to preclude any "why didn't you look into this?" type questions in the future.

Tile Design & Certification

- Chart 1 – Issue: Debris Impact Resistance

MGen Barry – One of the current design requirements for the TPS is that it must withstand impacts perpendicular to the surface with a kinetic energy no greater than .006 ft-lb. Yet tile damage occurs on every flight.

- Chart 2 – Background / Facts (cont'd)

MGen Barry – Capt. Robert "Hoot" Gibson's picture from STS-27R is the best picture we have found so far. It shows 3-dimensionally how far it went into the Strain Isolation Pad (SIP) and down to the bottom. This was one panel. We are still saying that loss of two panels next to each other will cause loss of the Orbiter.

- Chart 4 – Composite of Post-Flight Damage

MGen Barry – The graph indicates where the hits have been. It will be useful for determining the areas on the Orbiter that need to be hardened.

Col. Bloomfield – Criticality needs to be factored in.

MGen Barry – Right now they are looking at areas around the doors and around hydraulic lines.

RADM Turcotte – Many tiles were repaired with plugs made of material much denser than the tile itself. It sets up a differential load transfer. This needs to be addressed in our recommendation.

Admiral Gehman – Is there enough existing data on that for us to make a comment?

RADM Turcotte – Its one of those "when trees get big it is simple physics".

- Chart 5 – Background / Facts (cont'd)

MGen Barry – There was a Boeing effort in 1998 that assessed TPS damage on STS-87 to try and establish potential damage on STS-89. So there is some work being done by NASA to figure out where they can strengthen the tile.

- Chart 6 – Background / Facts (cont'd)

MGen Barry – TUFI is a coating. It is not a tile

Admiral Gehman – When an old tile is coated with TUFI it becomes a TUFI tile.

MGen Barry – The BRI-8 tile that was designed for X-33 and 34 is supposed to be a one for one replacement for the LI-900. Ninety-five percent of the tiles on Columbia were LI-900. They have not finished verifying the BRI-8, but it has great potential.

- Chart 7 – Background / Facts (cont'd)

MGen Barry – The difference between LI-900 and BRI-8 is astounding. TUFI coated AETB-8 tiles on the back of the Orbiter where the engines are and get hit by the blast of launch are pristine. The TUFI tiles on Atlantis have 5 flights on them and they look like they have just been put on brand new.

Admiral Gehman – Knowing that the tiles in the main engine and body flap area, which we know are subject to terrible abuse, come out looking good after launch tells the whole story.

- Chart 8 – Findings

MGen Barry – Loss of a single tile is bad news. Loss of two tiles is worse. Loss of some tiles poses more risk than others—some of it has to do with location, around hydraulic lines and main landing gear doors and things like that. And, the Orbiter has been subjected to hits from the very beginning. Some take it better than others.

- Chart 9 – Findings (cont'd)

MGen Barry – The Boeing study of the consequences of impacts shows they have not been ignoring the issue. There has been some good work done on it. History has shown 10 tile loss events since STS-1. That is an average of one tile loss event every two years or 11 flights. This is one of those "are we listening?" kind of things. This was the reason for the mishap.

Col. Bloomfield – Is a tile loss event the loss of an entire tile?

MGen Barry – Most of them were up at the top by the Orbital Maneuvering System (OMS) Pods. From all indications there were only 4 like Capt. Gibson's where an entire tile was lost.

- Chart 10 – Recommendations

After MGen Barry summarized the recommendations, the Board discussed where and how to fold the recommendations into the report. MGen Barry suggested that this falls into the "Significant Other Findings" section since these issues did not contribute to the incident. Admiral Gehman stated that the issue here is not that it caused the accident. The issue is that this supports the argument that we do not have an organization that is always looking and catching these things.

Around the Table

Admiral Gehman – Group 1 has an action to determine whether or not we need to have personal representation periodically, once in while, or continuously on the development of the NDE process.

MGen Hess – We are continuing to chart out the safety organization, and it really is "one step forward, two steps back", which fuels the argument that nobody really understands it. In the process of working this we asked people what things are not being listened to, and from various people we have put together a list of things to look at, such as Space Shuttle Main Engine (SSME) nozzle leaks, Solid Rocket Motor (SRM) performance pocketing, Reaction Control System (RCS) thruster coating chips, Solid Rocket

Booster (SRB) hold down bolts, and we will also look to see how they are addressed in problem reports and hazard analysis.

Mr. Wallace stated that there have been some email discussions on using the ISS as a safe haven for the Shuttle crew. People are asking if it that will be a Return to Flight item. It should be on the list of long term concepts to be developed.

Admiral Gehman – I made a list of all the debris formers, whether they closed them out or not. The number one item that is not closed out is the bolt catcher. But I have six more that were closed out, and I am still scratching my head—such as SRB separation hardware. They used terms like "it all operated as designed" or the "allowable amount of debris" came off. The SRB separation motors "ejecta" is allowed to have debris in it. Sometimes they come back with missing closeout ports or foam patches on the ETA ring.

Dr. Hallock – They tried to close out the bolt catcher too but the OVEWG directed them to keep it open.

After a discussion on the schedule of upcoming activities, Admiral Gehman closed the meeting.

This meeting was adjourned at 1400.

Actions:

1. Determine the size and makeup of the support staff after the final report is delivered. (Actionees: Mssrs. Steve Schmidt and David Lengyel)

2. Determine how travel expenses will be covered for Congressional testimonies and the like after the report is delivered. (Actionee: Mr. Steve Schmidt)

3. Determine whether or not we need to have personal representation periodically, once in while, or continuously during the development of the NDE process. (Actionee: Group 1)

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Attendees are as follows

NAME	ORG.	PHONE
Admiral Gehman	CAIB	281-283-7537
Major General Barry	CAIB	281-283-7526
Brigadier General Deal	CAIB	281-283-7507
Dr. Hallock	CAIB	281-283-7518
Major General Hess	CAIB	281-283-7512
Dr. Osheroff via telecon	CAIB	281-283-7511
Rear Admiral Turcotte	CAIB	281-283-7557
Mr. Wallace	CAIB	281-283-7508
Dr. Bluford	CAIB	281-283-7563
Colonel Bloomfield	CAIB	281-283-9809
Mike Boulavsky	Recorder	281-280-8062
Dave Lengyel	CAIB Staff	281-283-7581
Chuck Babish	CAIB	281-283-7840
Dwayne Day	CAIB	281-283-7588
Pat Garrett	CAIB Staff	281-283-7593
Steve Schmidt	CAIB Staff	281-283-7577
Chris Kirchhoff	CAIB	281-283-7821
John Shannon	CTF	281-483-8408

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 05, 2003
These Minutes Contain No Sensitive Data

Purpose: External Tank Working Group Fault Tree Presentation and Review

Date: June 05, 2003 **Time:** 1300-1600 EST

This meeting was conducted by video conferencing between the ANSER facilities in Arlington, VA (Suite 700, Room 7052) and the Johnson Space Center, TX (Building 1, Conference Room 945).

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA website.

There were four action items generated from this meeting and are listed later in this report.

Mr. Paul Munafo, Chair of the External Tank Working Group (ETWG), gave the presentation on the Fault Tree. The presentation consisted of executive summary, introduction, Fault Tree Block closure, a summary of base closure notes, development of the fault tree path, and summary.

The ETWG process involved 5 complementary elements: the fault tree top-down approach (scenarios of possible events and "cut sets" – chains of events that may or may not be straight paths on the fault tree), testing (coupon/bench and full-scale simulations), analysis, consultation with outside experts, and independent S&MA assessment (separate from the fault tree).

The Fault Tree analysis is complete and all of the 3470 boxes have been dispositioned. A total of 142 basic events have been determined to be possible contributors to the loss of STS 107. Six of the basic events are possible contributors to major release of debris. In response to a question from Admiral Gehman, Mr. Munafo indicated that a coupon test would be something that you might call a tensile test—a small specimen that has no relation in the way that it is tested to the actual hardware. The data from it requires some kind of correlation methodology to get to a hardware configuration. A bench test is a bigger coupon, but still does not look like the actual hardware.

The purpose of the briefing was to present the results of the Fault Tree investigation and identify specific ET data relevant to the loss of STS 107. Mr. Munafo described the ETWG structure and the process methodology. The Fault Tree is the primary process driver. There was very little physical evidence to support debris "branches." This necessitated probabilistic treatment. Performance data was available to support the interface branches. On March 3-4, there was a technical exchange forum—the best set of experts came together for an excellent exchange. The relationship with these people has continued, particularly with respect to some of the scientific aspects. An "Emeritus Board" (group of people who had worked on Shuttle) was used to

"bounce" ideas. There was a separate S&MA assessment of non-conformances, failure modes and effects analysis, critical items, and hazards. The Fault Tree blocks were categorized as possible and impossible. One of the teams was historical data assessment. In response to a question, Mr. Munafo highlighted the composition of the S&MA assessment team: an engineer (generalist outside of Shuttle), Mr. Dennis Griffin; a retired S&MA NASA person, Mr. John Green; and two others, variable depending on the subject.

At this point, Mr. Munafo introduced the members of the ETWG that were present at the meeting.

Mr. Munafo described the Fault Tree process flow. If the response was "yes" to the orbiter left wing priority zone (diamond block), the process was extensive: identify detailed bill of material and build paper for review, generate review criteria sheets, collect ET-93 engineering and build documentation, perform review against engineering requirements, perform requirements review, re-evaluate non-conformance documentation and in process rework, institute a test program (if required), document findings and observations, go to Fault Tree team review and approval, S&MA approval, and ETWG Board approval.

Mr. Munafo showed the ET structure that was reviewed: the bipod area, intertank station 852 to 1129, station 553 to 852, nose cone spike to station 553, aft of LH2 I/T flange to station 1254, interfaces outside of the debris zone, and TPS acreage spray areas. Data evaluated included system requirements, design requirements, STS 107 loads and environments, and ET-93 build records (BGen Deal noted that KSC also looked at some of these specifications). Flight performance data was also evaluated. Some additional assessments were done on personnel training records, and inspections and dissections of "sister" external tanks. Early on, an electronic database was developed to manage the closure process. Multiple tools and related data tables were developed. Mr. Munafo showed an example of the Fault Tree Block Closure screen that would come up upon login. The Fault Tree was developed using Relex FT software (3470 total blocks).

Mr. Munafo provided a summary overview of the ET Fault Tree. A lot of work was done on two of the possible contributors: ET TPS Debris Strikes Orbiter TPS, and ET non-TPS Debris Strikes Orbiter TPS. Work was also done on a third possible contributor—ET Interface performance "compromises" orbiter reentry systems. Mr. Munafo walked through the TPS Debris Fault Tree and discussed the development of the TPS Debris Fault Tree Branch. There were 2788 total blocks in the TPS Fault Tree Branch.

The scope of the TPS Debris review included review of the design, processing, acceptance, and build paper, interview with practitioners associated with critical processes, development and comparison of trend data for ET 93 TPS as compared to the 25 previous tanks, and performance of experiments to understand critical processing parameters. Mr. Munafo presented a diagram of the possible TPS debris sources and showed a typical closure sheet of the Fault Tree Branch. He

noted that one could walk down the entire fault tree to the closure rationale. The TPS Debris Review found 129 possible/improbable basic events. There were six possible/remote basic events associated with bipod ramp debris and STS-107: 3 for design methodology; one for manufacturing process plan; one for MAF material, and one for undetected anomaly. A combination of some or all of the six possible/remote basic events led to the generation of debris from the STS 107 left hand bipod area. Mr. Munafo reviewed the categories of possible sources: inadequate design methodology, manufacturing process plan, improper storage of materials, improper application, inadequately defined acceptance testing, and undetected anomaly due to processing at a vendor, MAF, or KSC.

Admiral Gehman asked a question re cryo-pumping: As part of fault tree closure, was there any coupon or bench testing to verify the common understanding of how foam is popped off by cryo-pumping? Mr. Munafo said yes; parameterized tests have been done on certain thicknesses of foam. Two other test series are about to be run.

Action: Board members would like to better understand the testing. It sounds like there has been some good testing work, and the Board would like to understand the testing that has been done or is being done. MGen Barry asked about correlation between bumping up against boundaries and bipod shedding. Sparks answered that no negative or positive correlation was found. The overall spray takes about 45 minutes. There is a film that shows this process being done.

An assessment of likely contributors was further performed. Likely events were the TPS debris loss observed at 81.7 seconds during STS 107 ascent, which most probably originated from the left hand bipod ramp. Data included the 81.7 second event. However, lacking that data, this cause would still have emerged from the bottom up review. Admiral Gehman asked Mr. Munafo to address whether there were any discussions about why it is the minus bipod that always fails. Mr. Munafo indicated there are a couple of obvious cases—the right hand ramp is shielded from aerodynamic loading; there is a thin section that could serve as a pressure release mechanism. Mr. Ash Pravacar stated that during the wind tunnel testing, there was no data measured at the bipod ramps themselves to see if there was any difference between the right and left hand ramps. The loads from level 2 are assessed for the left hand bipod ramp as being the encompassing case. Mr. Ray Gomez (JSC) is looking into the details of flow variations between the left and right hand ramps. Preliminary data indicates that there are pressure differences between the two ramps. Aero-loads appear to be higher on the left hand side. Admiral Gehman posed several questions: Are the thermal gradients the same? Is heating approximately the same on both sides during ascent? Is everything the same except the aero-loads? Lee Foster stated that we do look at the environments to the different areas. External aerodynamic heating is not a factor until after 80 seconds into flight. The temperature on the foam within a half-inch of the outer surface doesn't know what the heating variation is. Admiral Gehman observed that we have had seven instances on the left side and none on the right. Because of the oxygen line, there is something different. This is puzzling.

MGen Barry added that it would be important for the Board to get a comparison between left and right sides. Action: start working on this.

Mr. Munafo discussed the Non-TBS Debris Fault Tree Branch. Debris potential on STS 107 of ET-93 flight hardware other than TPS was investigated. The Non-TPS Debris Fault tree logic was based on the hardware breakdown structure. There are 498 total fault tree blocks. Possible debris courses were determined by assessment of unverifiable, possible events. Mr. Munafo reviewed the Interfaces Fault Tree. First tier (three digit) was partitioned by functional systems: structural, propulsion, electrical, and transportation and handling. Each system was evaluated for interface functional performance. There are 184 total blocks in the Interfaces Fault Tree. Admiral Gehman noted that the interfaces fault tree links are good links to keep in mind when working with Lambert Austin. All of the interface fault tree blocks have been completed/dispositioned. With respect to structural interfaces, no significant issues were identified with performance. Five structural items were identified as "possible/improbable" contributors to the mishap based on detailed paper/design review. Based on the interfaces review, there was no evidence of anomalies through ET separation related to propulsion, electrical, and transportation and handling interfaces.

Mr. Munafo discussed the "worst-case combination of events." The design and verification of the ramp likely contributed to a major piece of foam coming from the bipod ramp area. There was major test series to determine if a torn piece of foam would entrain slough. The samples were subjected to tensile and shear loading under static and dynamic conditions. For the shear test, all of the failures occurred in the BX250 foam. There were mixed results in the tensile test. Maximum SLA temperatures possible at 80 seconds were analyzed to determine the maximum worst-case multi-event material loss. Dissection of six bipod ramps indicated similar patterns for geometry-induced defects. Critical locations (areas at risk for producing debris) were identified—the near edge of the machined foam surface. A combination of multiple large voids, geometry induced defects, and critical location is needed to produce significant foam loss. The analysis was coupled with the test data to estimate a worst-case foam loss. A worst-case scenario includes 7 simultaneous and interactive adverse events.

Mr. Munafo concluded the presentation with a summary. The Fault Tree analysis is complete and all of the 3470 boxes have been dispositioned. A total of 142 events have been determined to be possible contributors to the loss of STS 107. Six of those basic events are possible contributors to major release of debris from the left hand forward bipod region. Engineering analysis of those six basic events has been performed and a graphical description of the "worst-case-credible" STS-107 debris configuration was presented.

Questions/comments:
MGen Barry: Was any information provided on the composition of the SLA and foam?
Mr. Munafo: We have the temperature distribution and hardness. As far as the effects of that, one of the major test series was dedicated to establishing the characteristics of the impacting material in a dynamic environment. The results of the test show very little difference whether the foam cracks and disintegrates or crushes. Hypothetical mechanisms have been identified where the SLA could have been enhanced, e.g. ice. We have excluded this possibility. We are continuing to pursue the hypothetical analysis. The tests that we are doing now assume the presence of a condensate. We have been unable to make the path go where it is supposed to go to accumulate in a reservoir. We are assuming that the slough is a sufficient reservoir. We are trying to effect a pressure release mechanism that would cause the material to fail.

MGen Barry: Are there any common elements among the known bipod releases that point to the six basic events?
Mr. Munafo: We are looking at the data
Mr. Segura: The answer is no. The most probable scenario relies on random events.

MGen Barry: Trying to address this issue (e.g., digging down one more layer) would be worthwhile. Why did the bipod come off? A lot of work has been done, but we need to be able to answer this question. We are going to a different bipod design, which is the right action. Is there something else up there that is inherently dangerous that we need to monitor?
Mr. Stone: Even after the ETWG completes its activity, there will be a continuing effort to identify a common thread. This will make it easier to feel comfortable with other parts of the tank.

Dr. Hallock: The database represents a lot of very good work. We have names and phone numbers in case we have questions in some of the areas.

Admiral Gehman thanked the ET Working Group for a complete set of works and briefings. He noted two reservations:
(1) The Board has been very sensitive to auditing or tracking any fault tree closeout that tosses items over the transom to the integration working group. There are several of these that need to be closed out later and they need to be tracked.
(2) Since we don't know what caused the bipod ramp to come off, we can't be sure of several other sources of debris that are upstream of the leading edge of the wing. There is a short list of 6 to 8 other debris sources that we have significant questions about, since we don't understand the bipod ramp failure. This is a big outstanding issue. We are ready to close this fault tree one and move on to the next one.

Actions:
1. The Board wants a discussion on cryo-pumping

2. The Board is interested in the left hand versus right hand bipod ramp and wants to understand the mechanisms
3. Look for common root causes for all of the bipod losses to date. MGen Barry suggestion: develop a matrix; list the seven that we know. Add other factors. Any data on the aero that can be applied should go through the listing. The amount of time between foam application and launch should also be a factor.

This meeting was adjourned at 1600.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 05, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Hal Gehman	CAIB	
Dr. Jim Hallock	CAIB	
Dr. Sheila Widnall	CAIB	
MGen. Ken Hess	CAIB	
MGen John Barry	CAIB	
BGen. Duane Deal	CAIB	
Mr. Frank Buzzard	CTF	
Mr. Mike Wetmore	NASA KSC	
Mr. Jim Kennedy	NAIT	
Mr. Randy Stone	NAIT	
Mr. Paul Munafo	MSFC/ETWG	
Mr. David Lengyel	CAIB Staff	281-283-7581
Mr. Steven Schmidt	CTF	703-416-8488
Ms. Ruth Harrison	CTF	
LtCol Larry Butkis	CAIB Staff	
Mr. Mike Quigglev		
Mr. Lee Foster		
Mr. Jim Speely		
Mr. Gene Gleed		
Mr. Pat Powell		
Mr. Scotty Sparks		
Mr. Neal Laudy		
Mr. Donn Hunnicutt		
Mr. Dan Callun		
Ms. Pat Rogers	NASA	
Mr. Rob Wingate	NASA	
Mr. Ash Pravacar		
Mr. Larry Nemachek		
Mr. Steve Gentz		
Ms. Dodie Terrick		
Ms. Wanda Segura		

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 06, 2003
These Minutes Contain No Sensitive Data

Purpose: CAIB/NAIT Working Scenario Update

Date: June 06, 2003 **Time:** 0800-0850 EST

This meeting was conducted by video conferencing between the ANSER facilities in Arlington, VA (Suite 700, Room 7052) and the Johnson Space Center, TX (Building 1, Conference Room 945).

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA website.

There were no action items generated from this meeting.

The purpose of this videocon/meeting was to review the status of the Working Scenario. Mr. Leroy Cain reviewed the outline what is included in the narrative and the work to be done. He noted that the Team has reviewed items in a long list, with the help of several Board members. Earlier this week, they went to the Orbiter Vehicle Engineering Working Group (OVEWG) and reviewed the working scenario and narrative.

Mr. Cain reviewed the significant forward work remaining: in the narrative, there will be numerous editorial and technical changes. Several are already completed but not yet in latest version. Other work will include removal of "references" from the narrative body. These will be listed elsewhere. In section 3, there will be new updated information from systems integration on new flight experiences, inclusion of RCC panel 6 impact test results, when available, flight correlation data, several updates to text and figures. Section 4 will include the review of the SAMS accelerometer data, the review of KSC lost and found items and assessment of ballistic coefficient of those items, and a discussion on the ability to detect orbital debris with SAMS data and shuttle sensors. In Section 5 the supply and waste water temperature response will be added, the sync times with the entry timeline will be included. This section will factor in any remaining analysis and testing, including RCC panel impact test results and internal plume work. Section 9 is yet to be done (there will be a briefing on Monday from KSC on processing of Columbia, although most significant part on the wing and ET is already in hand). In Section 10 (left wing processing) there will be a new section on the uncharacteristic number of carrier panels, addition of diagrams and pictures, and addition of the schedule for inspection. Section 11 (external tank) will include minor updates, including differences between the –Y and +Y bipod, addition of description of contributors to stored strain energy, addition of history on the bipod strut removal and replacement, and addition of history on baffle changes. Section 12 (summary and conclusions) will be in the next version of the narrative.

There will be narrative updates resulting from the review today. Briefing charts will be available a week from today (June 13). This will include a working scenario section. There will be ongoing updates to the working scenario. Completion (narrative and briefing) is scheduled for the week of June 23.

Mr. Cain reviewed the schedule for the rest of the month. The final working scenario briefing will be made to the OVEWG on June 23.

Mr. Cain walked through the status of each of the sections:

Section 2 (Launch Countdown) is complete. No items appear to be significant or contributory in the accident. No unusual debris or damage was noted during the post-launch debris walk down. Widnall asked about the meaning of "interesting," relevant to the 3 IPRs. [Mr. Cain noted that "interesting" means worthy of addressing but not significant.] She suggested that the terminology be more specific. MGen Barry asked about the tanking as part of the launch countdown. Mr. Cain said that this is included, but the decision was made not to discuss management decision processes in this scenario development. No additional work is planned in the launch countdown section.

Section 3 (Launch) is in work and a great deal of data has yet to be added. Ascent data has been reviewed in detail, including photographic analysis, transport analysis, MADS data, ascent radar, new flight experience events, ET Sep yaw rate, and flight correlation data.

Section 4 (Orbit) is nearing completion. Several events in the SAMS data are still being examined. The pertinent milestones and information are available on the FD2 event. Dr. Widnall asked whether the team was aware of the Lincoln Labs work. Mr. Cain indicated that this has been reviewed within the principal group. They have asked that the report be forwarded to the working group and it is expected this coming week. This review should be done at the OVEWG. Dr. Widnall indicated that two calculations were done on T-seals. The plan is to do one more calculation and wrap that up. Dr. Grant Stokes would be glad to brief the OVEWG. One more set of analyses will be coming from Lincoln Labs. Mr. Cain proposed not adding any of the relevant data from Lincoln Lab until it is reviewed by the OVEWG.

Section 5 (Deorbit/Entry) is nearing completion. It includes the deorbit/entry timeline of events; forensics evidence; debris footprint; aero moments; aerothermal; MADS data; location of breach; and testing. Mr. Cain indicated that he was anticipating the RCC test yesterday (it was postponed to today).

Section 6 (RSRM) is complete. RSRM has been cleared as not being a contributing factor for the accident. No future work is planned.

Section 7 (SRB) is nearing completion. To date, no SRB items have been identified as contributors to the accident. Once all of the reviews and testing have been completed, the results will be incorporated into future releases of the working scenario.

Section 8 (SSME) is complete. No SSME items have been identified as contributors to the accident. No future work is planned.

Section 10 (Left Wing) is nearing completion. There has been a lot of discussion on RCC design. There is no evidence that the condition of the RCC or LESS on Columbia contributed to the accident.

Section 11 (External Tank) is nearing completion. This is a significant section. The history of foam changes and debris events is included. The section includes the ET-93 chronology (bipod TPS configuration, ramp certification, build process, shipping and handling from MAF to KSC, KSC processing and environment, prelaunch inspections, and launch/assent discussion of bipod loss). It also includes the STS 107/ET 93 Worst Case TPS Debris. Cracking, debonding/delamination, divots, and shear were identified as the primary contributing failure modes/aspects of foam. Cryo-pumping may contribute to the loads that induce the failure mode, but it is not a failure mode itself. This section includes the discussion of the work in progress on the debris test programs, as well as test results for BX250 material. The ETWG worst-case credible TPS debris summary shows the best estimate of size and weight of STS-107 bipod ramp debris to be 870 cubic inches, 1.3 pounds.

Admiral Gehman asked about Section 9 (not addressed in the detailed walk through of the sections). Mr. Cain indicated that this section hasn't been written yet. Admiral Gehman asked whether the history of the stack (how long Columbia was delayed, mating/demating) would be in section 9. Mr. Cain indicated that the most compelling aspects are included in the left wing or ET sections. Information about weather and other process events will go into section 9. MGen Barry commented that the damaged foam issue needs to be put to rest and should go in the narrative. The PR should be in there. Mr. Cain indicated that this would be included.

With respect to management issues being handled elsewhere, Admiral Gehman noted that although the Board has not discussed this among themselves, he agrees that this approach is appropriate. This report is a factual recounting, not an analysis. Dr. Hallock added that this document will be an appendix to the Board's report. It sets a good stage for writing the Board report. It may be worthwhile to start sending this report out a section at a time. Admiral Gehman agreed and added that we want to have both of the teams agree on this scenario. At some point, we will need to have a process for changes so the NAIT and CAIB agree on the final text. He urged the prompt release of drafts, recognizing that there may be changes. There is some urgency to have even a preliminary draft on the sections that are not done yet. Regarding the timeline, Admiral Gehman asked Mr. Cain to see if there is anything in the timeline that appears to be too slow or taking too much time. If so, it can be renegotiated. A key milestone is the Monday (June 9) review of Section 9. Admiral Gehman asked Mr. Cain to try to put a preliminary draft out by the middle of next week.

MGen Barry commented that the amount of time the orbiter was on the pad needs to be included (in context). Address how that compares with other orbiters. This would be good to be included in the reference documents. Regarding the references, Dr. Hallock noted that they will be a separate list. This document may get wide circulation, and NASA would get swamped with requests if the references are included. Other environmental conditions, e.g., rainfall should be included. Dr. Widnall added that understanding of the timeline would be improved if the reentry parameters were plotted as a function of time. One graph could show both the dynamic pressure and temperature as a function of time. This would help to relate the beginning of entry to the time something is expected. The two important parameters on a single graph would help relate the off-nominal temperatures. She noted that "Stagnation Point" is misleading—call it a "dividing line" or "dividing streamline". MGen Barry stated that the other two bipod separations need to be included (five are already there). Admiral Gehman agreed, noting that there are seven bipod separations and the accounting needs to be done.

Mr. Cain stated that what is envisioned in section 9 is an "environmental" section. A great deal of data in climatology has been collected and analyzed. Some of the information that Barry was talking about will be included. MGen Barry added that some of the testing done this week (on rainwater) should be included.

Admiral Gehman thanked Mr. Cain and his group for a tremendous amount of work. It will be a good front-end scenario for the Board's report. Mr. Cain indicated that he would keep sending updates, including a first version of Section 9, by next Wednesday (June 11).

This meeting was adjourned at 0850.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 06, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Hal Gehman	CAIB	
Dr. Jim Hallock	CAIB	
Dr. Sheila Widnall	CAIB	
MGen. Ken Hess	CAIB	
MGen John Barry	CAIB	
Mr. Frank Buzzard	CTF	
Mr. David Lengyel	CAIB Staff	281-283-7581
Mr. Steven Schmidt	CAIB Staff	703-416-8488
Ms. Ruth Harrison	CTF	
LtCol Larry Butkis	CAIB Staff	
Mr. Leroy Cain	NASA	

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 11, 2003
These Minutes Contain No Sensitive Data

Purpose: Interim Report – Columbia Accident Investigation Fault Tree (CAIFT)

Date: June 11, 2003 **Time:** 0900-1215 EST

This meeting was conducted by video conferencing between the ANSER facilities in Arlington, VA (Suite 700, Room 7052) and the Johnson Space Center, TX (Building 1, Conference Room 945).

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA website.

There were seven action items generated from this meeting and are listed later in this report.

The purpose of this briefing (presented by John Muratore) was to provide an interim report on the results to date of the CAIFT team. The final report is expected by September 2003. About 71% of the Fault Tree has been closed to date. Admiral Gehman noted that the CAIB will probably make a complete closure of the Fault Tree as a return to flight (RTF) item, and Tom Stafford will review the September report.

The Fault Tree interim report does not contain any big new insights. The Fault Tree is a classic tree structure; limitations will be noted. There are 234 total events on the fault tree; 166 are closed through the technical review team; 136 are closed through the OVEWG/NAIT; 84 are closed through the CAIB. Sixty-eight blocks remain open at this time. Sixteen of these are in a potentially permanently open (PPO) status. In addition to the PPOs, two potentially contributing factors (PCF) have been identified. Progress has been steady (15-20 blocks per week). There is a written report in addition to the briefing report. There are 3 levels of fault tree: the CAIFT (today's report); Shuttle integration; and element trees. Muratore showed how the levels relate to each other. Some of the items at the element level feed directly into the CAIFT; some go through the Shuttle integration process. At the top-level tree, all blocks were assigned to owners. The technical review examined the technical rationale and evidence. If the block affected the integration area, it went to Lambert's team. Muratore explained the color-coding of the blocks in the Fault Tree. The Fault Tree focused on identifying the initiating events. The CAIFT team felt that some of the events could be contributing factors, although they were not initiating events. These were tagged "PCF." Muratore walked through the history of the Fault Tree. The report presented today was Version 8.0.

The most obvious visible event was the aerodynamic breakup of the vehicle. The team spent quite a bit of time working off the boxes associated with the speed/attitude curve. This was where the inadvertent stick bump by the flight crew would have been considered. (Data has

already been discussed extensively.) There was nothing that indicated the vehicle was flying out of control. The team then started to examine how the breakup could have occurred. Two cases were considered: (1) pure structural breakup; and (2) a structural failure that did not by itself cause a structural breakup, but caused a disturbance leading to loss of outer mold line. The team found significant evidence that all structural components were healthy after loss of signal (LOS). Recovery debris was examined extensively. The team concluded that the structural failure of the wing was not the initiating event, based on the health of the components located in the wing and that instrumentation in the wing was still functioning when the internal heating in the wing had risen to abnormal and fatal levels. In response to a question from Gehman regarding the location of the leading edge system on the Fault Tree, Muratore indicated that it was developed under the outer mold line.

All of the subsystems were examined, and the team was able to clear everything but the wing. The team concluded that the structural failure was due to loss of the outer mold line (SFOML). This disturbed the aerodynamic flow which caused loss of flying qualities and loss of control. Gehman agreed, but noted that on Feb 15, there was talk about landing seals, premature deployment of landing gear, open doors, etc. Muratore indicated that all previous discussions have been closed out. The block is closed but is in the path yet to be presented. He noted that all of the landing gear scenarios were developed under failure of the outer mold line branch.

There were four major categories under SFOML: wing overload; over pressurization or collapse; thermal overload or burn through; or weakened wing structure. Muratore walked through each of these blocks. In the first case (wing overload), there were four possible causes. One was early landing gear deployment (telemetry showed that landing gear remained up until after LOS). Gehman agreed with the analysis, but he noted that there were four separate indicators of gear up and locked and door closed, and one of these indicated that the gear was down and locked. If the wire is cut and sensor fails, you have to select which way you want the indicator to show. The sensor should fail as gear down and locked. Muratore explained that the original design rationale was that if a wire was cut, it would force a dilemma in the indication (both up and down). A single instrument failure should move you into an unexplained state. Gehman suggested that the team should discuss this further. Following this rationale, it should be two and two, not three and one. This should be captured. Muratore agreed that the team would write up a finding on this.

The next discussion was whether there was a load environment different than design. The integrated loads analysis is not complete, but preliminary indications are that there were no errors in load computations. This isn't closed, but there is a strategy to close it. The third cause was flutter. Research into the flutter clearance program showed that the vehicle was flown well within any flutter boundaries. MGen Barry noted that there was a question from MSFC on whether the left wing was working harder than the other, both on this flight and any others. Muratore could not answer the question, but he took action to find someone who had worked

through this and could answer the specific question. Steve Barber (KSC) noted that a presentation package next week would discuss that entire story.

The last major cause was outside of the envelope. Telemetry showed that the orbiter was flying a nominal entry trajectory. Based upon all of this, it was concluded that wing overload was not an initiating event. The team will track closure of the block noted.

With respect to structural failure due to over pressurization or collapse, there were four cases. The first was blown tire (not yet closed, but there is a strategy for closure). Gehman noted that the CAIB agrees with all of the team findings on over pressurization or collapse. Muratore continued with failure due to weakened wing structure. The team examined five cases. The first was configuration not per design. Most of these are closed out and there is a strategy for closing any item. No "red flags" have been identified in this area. The next thing examined was whether micro meteoroid and orbital debris (MMOD) could have caused the failure. There was no evidence that a structural failure occurred prior to start of burn through. The MMOD is still open on whether it could have hit TPS. With respect to space weather, the team looked at all types of space weather events. Preliminary results indicate the solar flare and other related events were not the initiating cause. The team also examined plasma/electrical discharge. The EMI team did a comprehensive review and looked at every electrical instrument on the orbiter. There was no evidence of any unusual electrical activity in the vehicle. They also looked at the possibility of an electrical strike during ascent. There is no evidence that this happened. The team is still waiting on the final report, and this should be closed out. Finally, the team looked at whether there could have been a fire in the wing. There was no environment where there was enough oxygen to support a large enough fire to affect the structure of the wing. Based on all of this, the team concluded that the structural failure was not due to weakened wing structure. Barry noted that there were concerns about the wing route bending elements. This was not being tracked for life capability. There are concerns that the fatigue spectra may need to be updated. There are two types of aging: mission aging and chronological aging. Muratore indicated that the observations are consistent with what the team found. There was nothing to indicate that at 28 flights any of these were initiating event. Barry commented that we need to develop the capability to determine life for each orbiter based on usage. In response to a question from Gehman regarding pyros in the wing, Muratore stated that the only pyros in the wing are in the landing gear system. If these are fired, there is a rapid pressure drop that is very observable. The hydraulics people were able to prove that the pyros were not fired. The pyros are exclusively covered in the landing gear section.

The main event was the case where there was a thermal protection system breach, allowing heat into the wing. Three cases were examined. The first was a malfunction of the TPS system; the second was thermal damage due to inadvertent opening in the wing; the third case was thermal damage due to a higher heating environment. As of today, the only place where there is any open item is in the TPS malfunction block. The system telemetry indicates that systems were performing in a way that was incompatible with an inadvertent opening in the wing. With

respect to higher heating environment, there were six possible causes: off nominal trajectory (three sources of data show that the orbiter was on trajectory); unusual aerodynamic phenomena (data show no indications of abnormal aerodynamic effects as the initiating cause); heavy entry weight (analysis of the data showed that everything looked the way it was supposed to); unexpected flow due to surface roughness, or step/gap (orbiter measurements showed that this orbiter was one of the smoothest in the fleet and step/gap was not a factor); asymmetric transition (pressure measurements and telemetry show no indication of asymmetric flow); and increased surface catalysis (analysis showed that at 100% catalytic levels, the surface heating was still within design levels). All of the blocks associated with a higher heating environment have been closed or strategies are in place for closure. The team believes that the orbiter was in a normal heating profile.

This leads to a TPS malfunction of some kind. The team identified four cases where there is a malfunction of the TPS: reinforced carbon-carbon (RCC); tiles; blankets; and thermal seals. Muratore went through each of these. The only PPO items are in the RCC block. Muratore walked through the other cases. The top of the wing, where the thermal blankets are, is not a high temperature area. Even if all of the blankets were gone, heating in this area would not be sufficient for the aluminum to fail or to explain the high temperatures observed inside the left wing. With respect to the seals (other than RCC seals), the temperature on the seals indicated that they were not exposure to the high temperature (2700 degree) environment. Widnall observed that if gas is ingested into a wing, the temperature would be 7000, and the 2700 is misleading. Muratore agreed and commented that if there had been an opening, the temperature would have been much higher. With respect to tile failure, the only tile that can affect the front side of the spar are the leading edge carrier panels. Leading edge carrier panels or tile have been recovered. Tiles show evidence of backside heating, which can only occur if the break occurred in the wing causing internal heating prior to breakup. Evidence shows tile was released in the breakup sequence. Instrumentation in the wing was active until late in the accident, and this indicates that this part of the wing surface was still there. There are very limited regions that are not covered by instrumentation or recovered debris. Analysis is underway to determine if there is a viable flow path from the potential burn through areas to the location of the first observed heating on the front side of the leading edge wing spar. Based upon all of the evidence, there is a compelling case that loss of tile was not an initiating event. Blocks have been closed or strategies are in place for closure.

The remaining PPOs are in RCC failure. The team looked at what could have happened to the RCC: a crack or hole greater than 0.25 inches; failure due to loss of RCC panel; improper installation; improper RCC repair; degraded coating; environmental outside RCC certification; a crack or hole less than 0.25 inches; manufacturing/material defect; RCC substrate failure (due to mission cycles or ground cycles).

Muratore walked through each of the following blocks:

- RCC panel improper installation: this block is still open and is identified as a PCF. Records show that the entire RCC was removed and installed twice due to procedure error. Analysis is required to determine if any installation error could have survived STS-109 entry but then provide an initiating event on STS 107. Analysis has not been completed. There is a strategy for closure, but it is not yet closed. At this point the team cannot say there couldn't be an installation error that combined with some other event, could be an initiating event. It is therefore carried as a PCF. Gehman noted that in a preliminary briefing from the Palmdale experience, when RCC panels were removed, there were government inspected points (torque measurements) where the attachment bolts were not properly torqued. It is possible that if the RCC alignment problem had not manifested itself, we would have flown with improperly torqued hardware. This indicates that maintenance cannot be ruled out as a contributing factor.

- RCC improper repair: here the story is fairly good. There was no repair of any significance on these panels. Gehman noted that the CAIB had no argument with anything in this section.

- Damage criteria were validated. The criteria of 0.25 inches on bottom (the most critical part) and 1.0 inch on top were used. Damage below this criterion was determined to be survivable and therefore not an initiating event. The results of the NRC activity were given to aeroscience team. This team revalidated the aerothermal assumptions. Muratore's team closed any hole less than this size as not an initiating event.

- RCC failure due to environment outside RCC certification: all of the data combined to show that the RCC was being operated in the proper flight environment.

- RCC manufacturing/material defect: There was no evidence of original manufacturing defect that would have failed the manufacturing criteria. This is still open, but there is a strategy for closure. Ground or flight cycle effects could have caused the material to go outside of tolerance. In an induced environment, it could have been a PCF. The CAIB agreed.

- RCC failure due to degraded coating exposing the RCC substrate: There was significant amount of data that showed that the coating was not essential for a single mission. Coating damage on a previous flight would be noted upon inspection. The team concluded that loss of coating was not an initiating event. Barry noted that in the CAT scan of silicon carbide, around the T-seals it is below spec. There is indication that it is as low as 5. The books say 20-40 mil. Around the bends of T-seals it is less than 20. About 20% were out of spec. Widnall commented that she would like to see the data that shows that the RCC can survive reentry without coating. Action: Muratore will provide

this data. Muratore will amend the block closure to include a discussion of the out of spec/degraded coating issue raised by Barry.

- RCC substrate failure due to mission cycles: there is no history or data that say that this wasn't the case, so it is being carried as PPO. Barry noted that research is being done by GRC that could provide more information or close out this block. Muratore will get data from the GRC research on aging.

- RCC substrate failure due to ground cycles: there is no evidence that this didn't exist, so it is being carried as PPO.

- RCC failure due to impact causing crack/hole greater than 0.25 inches on bottom, 1.0 inches on top. The team looked at prelaunch and in flight impact cases. In prelaunch, the Team considered launch pad, VAB, OPF, and transportation. Based upon inspection audits, problem reports, and debris walk downs, the VAB, OPF, and transportation blocks were closed. Turcotte questioned where the team has put the test on the T-seal (#9)? Muratore indicated that a block could be added for test cycles to cover just this. The team will work this block. If there was no NDE inspection, it would remain open. Research will be done on this item and a note will be made in the report to be compatible with the CAIB findings. The ice team does a 100% inspection on the RCC. They feel that they could detect anything of .25 inch, but couldn't be 100% confident. There is a small possibility that the RCC damage was undetected or that damage could have occurred due to FOD after the ice inspection. The pad impact block is PPO, but is has a relatively low possibility of being an initiating event.

- In-flight impact cases that the team considered were: on-orbit, ascent, entry, and contact with element or launch pad. External Tank (ET) and Solid Rocket Booster (SRB) recontact has been closed by the MEIT. Vehicle contact with launch pad and bird strike has been examined and a strategy is in place for closure. Gehman agreed with the closeout. With respect to on-orbit impact, the team looked at icicles forming on the orbiter (nozzle redesign has eliminated icicle formation and impingement on other parts of the orbiter); ET attach causing impact (debris could not have moved forward to damage the wing leading edge); access panel causing in-flight impact (all panels except water servicing panel were recovered in the debris in Texas, indicating that they were attached until breakup; systems behind the water servicing panel showed nominal performance); other orbiter debris (remains open as a placeholder for other types of debris); Space Shuttle Main Engine (SSME) induced impact; and MMOD impact (probability computed on leading edge of left wing was one in 13,800; expert estimates a one in 10,000 chance of MMOD impact). Analysis of in-flight data detected 13 incidents of unexplained rate changes that could have been induced by a MMOD impact. Although the probabilities are low, there is still a possibility of an MMOD impact, and this item is open.

- Potential sources of ascent impact are: ET debris impact on ascent (open); Reusable Solid Rocket Motor (RSRM) debris impact on ascent (closed); SRB debris impact (open); lift off (pad debris) impact (open); Thermal Protection System (TPS) impact (open); orbiter access panel (closed); SSME debris (strategy for closure); and foreign object damage (FOD) (open). There are some significant open items in ascent impact. Potential sources of entry impact are: ice formation (closed); lost orbiter access panels (closed); SSME debris (open); other orbiter caused debris (open); and loss of tile (open).

- RCC failure due to loss of RCC panel: this block addresses the case that a complete RCC panel, or a majority of an RCC panel, completely failed causing a thermal overload/burn through. There are strategies for closure for most of the causes of loss of RCC panel. Muratore walked through each of the potential failure scenarios. Those still open are: loss of RCC panel due to T-seal failure; RCC damage due to impact (wing 12-9 and wing 9-53); and loss of RCC panel due to RCC panel fastener failure. Gehman noted that this is very consistent with where the CAIB is.

- Summary: All of the PPO blocks are under four branches of the fault tree: SFOML-Wing 8-10 RCC failure due to impact causing crack/hole greater than .25 inch on bottom or over 1 inch on top; SFOML-wing 8-14 RCC failure due to loss of RCC panel; SFOML-wing 8-57 RCC substrate failure due to mission cycles; and SFOML-wing 8-58 substrate failure due to ground cycles. These lead to 16 PPO bottom-level events. The team can now start to "ANDed" things together. There are 16 PPO's and 2 PCF's.

Muratore showed a rating in terms of likelihood of an item being an initiating event. High likelihood items are: ET debris impact on ascent (launch photography and MADS/OEX documents impact and testing indicates capability to damage RCC); loss of RCC panel due to T-seal data (small amount of T-seal 9 indicates it as initiating point); and RCC damage due to impact causes sneak flow causing loss of panel. Anything that could have caused an impact could be a major cause of a panel coming away. In response to a question from Barry regarding the seal in the report that is identified as T-seal #9, Muratore indicated that T-seal #9 is the T seal between 8 and 9. Barry stated that everyone needs to agree on a common nomenclature for the report and make it clear. The T-seal with all of the cycles was the one between 9 and 10. The T-seal between 8 and 9 should be referred to as #8. Muratore agreed to create a separate block "substrate failure due to test cycles", which will be PPO (medium). This will make 17 PPOs.

Several items were rated as medium because there is lack of data at present (Substrate failure due to test cycles, mission cycles, ground cycles). Some forward work is needed; these may move to low. SRB debris impact on ascent (SRB bolt catcher & SRB separation motors) is medium likelihood of being an initiating event.

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An amended written version of the report will be released next week. Gehman noted that this report is in almost complete agreement with the CAIB mental roadmap. There is an item from previous fault tree: issue of booster separation motor ejecta. Muratore indicated that this is in the PPO block "SRB debris" (medium likelihood). There was a discussion regarding paint contamination in the SRB motors in the report.

Actions:

1. Which one of 4 main landing gear doors failed? Assess and write up a finding on the design rationale for conveying information on a single instrument failure
2. Flutter – review left wing working harder than right
3. Concerns with vehicle fatigue spectra regarding overall life. Need assessment
4. RCC bolts identified as not being torqued properly (maintenance issue)
5. Coating around T-seals below spec; provide data that shows the RCC can survive entry without coating
6. Get data from the GRC research on aging
7. Add block for test cycles on T seals

This meeting was adjourned at 1215.

These minutes are hereby submitted for the record.

Approved

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Columbia Accident Investigation Board

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Major General Barry	CAIB	703-416-3570
RADM Steve Turcotte	CAIB	703-416-3015
Dr. Sheila Widnall	CAIB	703-416-3445
Dr. Hallock	CAIB	703-416-3272
Roger Tetrault	CAIB	703-416-3591
Steve Schmidt	CAIB	703-416-8488
Theron Bradley	CAIB	703-416-4469
Frank Buzzard	CTF	202-358-1401
Frank Delgado	ER	281-483-9077
David Petri	EA	281-483-9622
John Muratore	EA	281-483-4467
Randy Stone	AB	281-483-2466
Steve Poulos	EC	281-483-9108
Jan Railsback	NX	281-483-7265
Bob Bobola	NA	281-244-1963
Jim Wetherbee	NA	281-244-8918
David Bawcom	CAIB	281-283-7838
Elizabeth A. Fountain	MV/CTF	281-483-5257
Kathryn Packard	MS3	281-244-5378
Frank Benz	EA	281-483-3199
David Bowers	MS2/USA	281-280-3769
Steve Bauder	MS/USA/KSC	321-861-3102
Kevin Mellett	CB	281-244-6652

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 11, 2003
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Purpose: Space Shuttle Program Return to Flight – ISS Considerations

Date: June 11, 2003 **Time:** 1300 – 1345 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 700, Room 7052).

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA website.

There were no action items generated from this meeting and are listed later in this report.

Admiral Gehman noted that this briefing on ISS is background information for the CAIB; it will not be in the report.

Mark Uhran (Staff Director for Space Station) briefed the principal considerations for Shuttle Return to Flight (RTF) are: risk of loss of station; International Space Station (ISS) assembly on hold; international partner commitment; and reduced science capability. ISS is currently stable. It is being operated nominally on a day-to-day basis, managing circumstances as they arrive. There are three mission critical areas: crew presence; spares resupply mission; and consumables resupply mission. The Progress launch schedule is uncertain. NASA has a contingency plan to de-crew. Onboard crew is critical to maintaining the health of ISS, particularly for unplanned maintenance. In response to a question, Uhran noted that a typical orbital replacement unit (ORU) is a pump. There is planned change out and unplanned change out (e.g., failed pump). Crew are in the best position to diagnose false alarms and software upload anomalies. Crews allow ISS to be maintained in an assembly-ready configuration. The program has undertaken a probabilistic risk analysis. The analysis indicates loss of station (LOS) 5 times greater without crew. We have expended in excess of $22 billion (on orbit) to date. Critical spares are currently pre-positioned to support the first ORU failure. There is no single string at this time. There have been cases where we have responded to unpredicted failures, but there is limited capability to respond to these types of failures. With zero crew on orbit for 6 months, there are a number of scenarios where this situation drives LOS. Propellant for re-boost is non-critical; there is sufficient propellant on orbit (over 2 years). Food, gases, and hygiene items are critical, but upmass for these items is not a driver. Water is the constraining consumable. Uhran showed the projection for the baseline sequence before the accident. On orbit stores need to be kept above the 45 day threshold. Normally, water is not delivered with Soyuz; they are used for crew rotation and do not have additional cargo capability. In response to a question, Uhran indicated that there was not a plan to haul water on 13P-M1. The crew consumes about 2 liters per day per crewperson. This is the driver. At the time of the accident, a water conservation program was immediately implemented. NASA looked at the available Russian spacecraft and what they

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could do to alleviate the situation. The most obvious change was to replace 3 crew with 2 crew. There was some question as to whether a 4th Progress in 2004 would be necessary. The launch schedule replan is still a work in progress. The program is looking at the windows in which the Progress would have to be launched. Russian funding is uncertain. Logsdon noted that the US is prohibited by law from buying Russian vehicles. The Automated Transfer Vehicle (ATV) was estimated to be available in late 2004. There is a question whether it would be available on schedule and a lot of work would be required to prepare the ATV for docking. Russia does not have a standing inventory of Progress vehicles.

Based on the accelerated Progress schedule, Uhran showed the best case analysis. About 60 days prior to the encroachment into the 45 day water threshold, NASA would make a decision regarding crew return. Several variables are in the trade space. The program gets very close to the margins within the first half of next year.

The IPs have been very supportive throughout this process. They are most concerned with what the Shuttle down period will be. The partner contribution is about $10 billion for the primary elements. The Russians are under a severe funding constraint, although they have been supportive to date. Prior to the accident, government support of the other partners was in question due to NASA cost overruns. Since the accident, Europe has unblocked funding and Japan delivered the JEM in June. It will be tested and stored until launch.

The trade space is a complex environment. The variables include consumable usage rates, ORU characteristics, ATV Extravehicular Activity (EVA) requirements, vehicle schedule constraints, Russian funding, vehicle production levels, and the Shuttle's RTF. The first quarter of 2004 will be the most challenging period.

There is a fairly high accuracy in water usage predictions. The electrolysis of the Shuttle fuel cells generates more water than is necessary. Another factor is the downmass capability that is lost without Shuttle. There must be a crew return capability for the number of people on board. Most of the productivity is gained when crew size is increased. Between now and 2006 is completion of assembly. During 2010 and beyond, NASA plans to have the National Space Plane. The period in between is the challenging period. The partners launched a program plan to provide additional crew capability, and the Soyuz is the most logical solution. In response to a comment, Uhran agreed that RTF is not related to crew size beyond 3; it is constrained by other things. A requirement to provide a repair capability on Shuttle would involve the upmass requirements and would change the overall flight rate. Gehman observed that if there is an on orbit repair capability, it would probably be brought up only once. The program is looking at repair of both reinforced carbon-carbon (RCC) and tile; no other components are being considered for repair on orbit. If the Station assembly were complete, reboost capability would still be dependent on Progress resupply. If there were only two orbiters available for Station, NASA would develop a contingency plan to address that scenario and manage risk. The actual vs. planned water consumption continually changes.

Gehman observed that there is a question whether or not the program can even meet a schedule with two operational orbiters (assuming one is in Shuttle Orbiter Major Modification - OMM). He indicated that he would like to see a two orbiter flight schedule. It appears that it would be very challenging. Hawes noted that a two orbiter flight scenario would be built around resupply; the assembly schedule would be stretched out. Gehman was concerned about the schedule pressures with a two orbiter flight schedule. He noted that the science capability is not compelling in terms of getting the Shuttle flying again. Critics have said that not much science can be done with even 3 crew. Also, the international partner commitments are not compelling on the CAIB. The political initiative has been turned into an American imperative. Some costs are already in the past and are irrelevant to the discussion of the future. As an investment argument, risk of LOS is not a reason to take Shuttle risks.

This meeting was adjourned at 1345.

These minutes are hereby submitted for the record.

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BGen Duane Deal	CAIB	703-416-3349
Steve Wallace	CAIB	703-416-8405
Dr. Sally Ride	CAIB	703-416-8497
Dr. Hallock	CAIB	703-416-3272
Roger Tetrault	CAIB	703-416-3591
Dr. Doug Osheroff	CAIB	703-416-3490
Dr. John Logsdon	CAIB	703-416-3057
Scott Hubbard	CAIB	703-416-3109
Steve Schmidt	CAIB	703-416-8488
Frank Buzzard	CTF	202-358-1401
Mike Bloomfield	CAIB	281-483-7809
Mark Urhan	NASA HQ	202-358-2233
Doug Koupash	NASA HQ	202-385-2294
Doug Cooke	CAIB	281-283-7576
Dennis Jenkins	CAIB	703-416-3373
Tom Carter	CAIB	703-416-3461
Dwayne Day	CAIB	703-416-3491
Mike Hawes	NASA HQ	202-358-0242
Randy Stone	NAIT	281-483-2466
John Shannon	CTF	281-483-0716
Jeff Hanley	JSC	281-244-0202
Chris Kirchhoff	CAIB	703-416-3121
Les Reingold	CAIB	703-416-3551

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 11, 2003
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Purpose: CAIB afternoon report review session

Date: June 11, 2003 **Time:** 1400 – 1500 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 700, Room 7052).

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB PBMA website.

The action items and are listed later in this report.

Admiral Gehman reviewed the agenda. It is important to know what the Board wants to communicate in each chapter. Board positions are needed on some key statements. This will help the writers/editors.

Investigation matters:

A. Foam shooting [Scott Hubbard]

Scott Hubbard showed the reinforced carbon-carbon (RCC) Test Setup at Southwest Research Institute (SwRI). The target wing segment includes panels 5 – 10. Total cost was about $1 million. Clocking angle has yet to be investigated. A number of high-speed cameras (5000 frames/second) were added on the inside of the structure. The projectile was BX250 foam, 1.68 lb. The projectile broke-up into multiple pieces. Actual measured velocity was 768 ft/sec. The angle relative to the test article was 20.6 degrees. Clocking angle was 0. The only variable left to test is whether hitting at a point or the edge is greater transmitted force. The projectile ink streaks start on RCC panel 5, continue across T-seal 6 and onto fiberglass panel 7. Foam debris was caught between RCC panel 6 and T seal 6. There was a 5 ½ in long through thickness crack, located on the lock side approximately 6 inches below the stagnation. It transversed the entire rib width, extending through the lock side channel and onto the panel lower face. It showed up on the surface as a ¾ inch crack. This test has shown that foam that approximates the accident can crack an RCC panel. Photos show the crack extends across the rib, lock and onto the panel surface. RAdm Turcotte noted that this crack is in the rib curvature where the two panels overlap. There was another crack in the upper-outboard flange that didn't appear to be through the panel thickness. It begins above the upper shear fitting and is 3/8" long. The T-seal crack is about 6" below stagnation point (near the panel crack). It is about a 2 ½" through crack on the RCC T-seal 6 lower outboard rib. The crack starts at the rib and continues into filets. The T-seal broke under tension. There were panel and T-seal displacements. The step was changed about 30 mil. Hubbard showed two videos. The test mechanism shattered the foam, although debris

pieces were larger than those seen on STS-107. The test was conducted in ambient temperature. The tendency of the foam to break into many small pieces was greater in vacuum. The rib of the T-seal broke under tension. This test was only a single data point. The crack growth and effects of the first shot are not completely understood, and it is too early to extrapolate. Overall impact loads were within analysis predictions. The rib crack occurred at almost 5000 psi (just above the "allowables"). However, in the face sheet, the gauge recorded almost 15,000 psi and there was no crack. The T-seal crack occurred at 14,500 psi. The actual stress levels were as predicted by the Sandia group. Failure of the rib panel was much earlier than expected due to more complex load interactions.

We still want to establish whether the foam could create a breach of sufficient size to allow observed thermal and structural damage. Before conducting tests in the panel 8-10 area, we need to verify that the models accurately predict the test article behavior, the location of the foam strike reflects the panel loading range, the clocking angle is tested for possible effects, and the systems response informs the need to have RCC adjacent panels instead of fiberglass. We will return to fiberglass tests on panel 5-7 before going to panel 8-10. Panel 8 will be instrumented to measure the extent of the stress wave. Panel 6 will be impacted at a location about 3 inches below the first shot. Clocking angle will be rotated 30 degrees to establish maximum loads. We will follow up with lessons learned to conduct fiberglass panel 8-10 tests. There is an important decision required on impacting panel 8 vs. 9. Spares have been ordered. Roger Tetrault observed that lack of spares may influence engineering decisions. Fiberglass tests will be resumed on June 16. The second fiberglass test will be on June 18. Panel 8 is the only flight hardware in the system. The Board discussed whether to use panel 8. Gehman noted that all of this is non-conclusive; it is not definite proof. Panel 8 has the greatest span; it is a trapezoid, an unusual shape. It is an equally hard decision to put up panel 10. Tetrault felt that there is enough time (8 months) to make a new panel.

The Board agreed on the need to shoot two adjacent RCC panels, either 8 and 9, or 9 and 10. The majority of the Board felt that 8 and 9 should be shot, since it represents the most probable cause. Hubbard suggesting collecting some additional data before the Board makes a decision. It was noted that panel 8 has been inspected; the next step is instrumentation. **The Board voted to go ahead with shooting panels 8 and 9 unless some of the tests next week presented some counter-arguments. Panel 10 should go into NDE. Hubbard indicated that he would send an email direction on this.**

- Report on bolt catcher [Tim Bair]:

Tetrault had some comments re the bolt catcher: the testing has increased the probability. Gehman noted that this came up in the Fault Tree closeout—it was not closed and it was rated as "medium" probability. This could be a RTF issue. A lot of problems were encountered in the attempt to eliminate the bolt catcher from the Fault Tree. There is no OEX data, no photo evidence of it intact. There is radar evidence of something coming off the stack at 125 seconds.

More testing needs to be done. The original design of the bolt catcher was certified in 1979. There were several minor differences, particularly in performance data. Tests were conducted at MSFC. Test 1 was a dynamic test (passed). The dome was put under slow onset pressure until failure. The weld failed at 54000 kips. Test 2 (dynamic test) actual pressure was 46,000 kips. In test 3, the pressure was 44,000 kips. There is less than a 1.0 safety margin. The weld is inadequate. These welds were on the shelf, certified for flight. However, they did not meet specs. The x-ray film of the actual used on 107 also failed. The manufacturer for the shelf items was the same as the ones on 107. The dome could have failed and the ablative could have struck. It is denser than the foam. Gravity could make something that weighs 40 lbs fall toward the orbiter. Slipstream could add to that. The implication is that a portion of this could have impacted the wing. The transport analysis is being worked—bolt, ablative, entire assembly. There is a reason to eliminate the uncertainties in this subsystem. **There should be a portion of the report entitled "possible other sources." Gehman noted that there are at least six other possible sources of debris. The system needs to meet the 1.4 safety factor for RTF.**

Conclusion: There is now another serious source of debris (but not ranking as high as foam). There are quality and government inspection issues. These welds passed and they didn't meet spec.

- Report on hold-down post cable anomaly:

This issue came in through a PIA, and comes under the category on how to prevent the next accident. There have been repeated problems on timing, and the stack has been held for a split second. There have been a series of corrective actions to prevent the problem from happening again. If the A system cabling failed AND a B system initiator failed, the result would be catastrophe. Cross-strapping has been considered, but this created complications. This may be a potential for catastrophic failure. The biggest problem has been with integration. Bair's recommendation to NASA would be to reconsider double redundancy.

B. Test and Analysis Matrix

Gehman reviewed the Test and Analysis Matrix:

- Foam shooting (Hubbard) – this is well along.
- Aerothermal analyses (Widnall) – this will be presented on the 18th.
- Wire burn-through (Tetrault) – test complete. The test simulated atmospheric conditions around 300,000 ft. 100 mil face sheet and wire burned through consistent with what the Board is seeing.

- Instrumentation circuit analyses (Hallock) – complete. No further tasking for NASA.

- Hypersonic wind tunnel testing (Widnall) – the wind tunnel test is done. They are still doing structural analysis. Expect to get this on the 18th. **Action: Get back with Gehman if NASA needs to do more.**

- Thermal analysis of RCC panel 9 (Widnall) – this is analysis of the sensor. The thermal analysis of the breach hole size has been completed. Analysis on slough will be done on July 2. **Need various shapes, including slots in particular. Tetrault was asked to see if his people are satisfied that this is done.**

- Arc-jet testing (Tetrault) – started on June 11; this is needed.

- Cryo-pumping (Deal) – NASA doesn't understand what is happening to the foam. Testing done.

- Bolt and attachment fixture testing (Barry) – will not be finished by June 13, still happening, still need it.

- Bolt catcher test (Bair) – **report was on 2 tests. Need more tests. Questions about transport analysis should be answered. Group 1 will keep pressing on this.**

- TPS Report (Widnall) – done as far as NASA is concerned.

- Debris modeling (Wilde) – will be complete by July 4.

- JASONS work (Ride) – **ask them for status report and estimate of completion.**

- Foster/Olsen assessment – done. The assessment found no detrimental activities related to the contract performance incentive aspects of the contract. The incentive aspects did not result in negative behavior; however, philosophically, the migration of expertise away from the government is being encouraged. They tried to substitute clever contracting for technical oversight. It doesn't have to be US government employees, but it cannot be a profit center. USA and NASA point to a declining trend in IFA, material rejections, etc. This could mean a doing a good job or biased reporting. The safety caveat is not rewarded and relies on independent checks and balances. The Board looked at two other high-risk enterprises (launching rockets) where the owner of the contract is not the operator of the vehicle. NASA needs to keep in-house quality and technical assurance. This issue could be in the Board statement. The Foster/Olsen assessment goes in the source document archives.

If there are outstanding tests, Gehman recommended citing these as return to flight items and have the Stafford group approve the repair/fix.

July 8 – 11 will be the final sign off on the narrative report.

C. Review of interim recommendations:

The first three are done. #5 has been broken into several ones. #6 (broken into two) is essentially done. Send recommendations to Steve. #8 is being broken into two types of on-orbit repair. The ultimate goal is autonomous capability. #9 - there is a new version. #11 - Tile damage is not an IFA; it is a flight hazard. **Add: vehicle health monitoring (Hallock).** On orbit repair is the long pole; the next one is NDE.

The Board reviewed the outline of each chapter of the report and developed "bottom line" statements—what the Board is trying to say in each chapter. [see separate "Bottom Line on Each Chapter" document]

This meeting was adjourned at 1500.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 11, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-8499
Major General Barry	CAIB	703-416-3570
Major General Hess	CAIB	703-416-8481
RADM Steve Turcotte	CAIB	703-416-3015
BGen Duane Deal	CAIB	703-416-3349
Steve Wallace	CAIB	703-416-8405
Dr. Sally Ride	CAIB	703-416-8497
Dr. Hallock	CAIB	703-416-3272
Roger Tetrault	CAIB	703-416-3591
Dr. Sheila Widnall	CAIB	703-416-3445
Dr. Doug Osheroff	CAIB	703-416-3490
Scott Hubbard	CAIB	703-416-3109
Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-483-7809
Doug Cooke	CAIB	281-283-7576
Dennis Jenkins	CAIB	703-416-3373
Dwayne Day	CAIB	703-416-3491
Tim Bair	CAIB	703-416-3337
Les Reingold	CAIB	703-416-3551
Paul Wilde	CAIB	703-416-3367

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 12, 2003
These Minutes Contain No Sensitive Data

Purpose: Meeting with Tom Young on the International Space Station Management and Cost Evaluation (IMCE) report

Date: June 12, 2003 **Time:** 1600 – 1815 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 700, Room 7052).

The list of attendees is appended to the end of this report.

There were no action items generated from this meeting.

Mr. Tom Young opened his talk with some comments about the NASA culture. There is not one NASA culture; there is a human space flight culture. A lot of what he talked about regarding the Space Station is human space flight culture. Admiral Gehman noted that some of the cultural differences are come by honestly—what they do at KSC is different than what they do at JPL, etc. Young agreed that there are reasons for doing things differently; however, its more that that—there are basic cultural differences. Aspects of the human space flight culture are relevant to what the CAIB is doing.

The IMCE came about because Mr. Sean O'Keefe, then the Deputy at Office of Management and Budget (OMB), was rather frequently surprised by the costs on Space Station. He was an initiator of the IMCE activity. OMB asked to see Young after he was asked by NASA to chair the committee. Young was surprised at the credibility issues that existed between OMB and human space flight/JSC. The congressional staff also asked to see him. The credibility issue here was even larger.

The IMCE was asked 5 basic questions: Was the "core complete" program cost credible? The IMCE's answer was "no." Could it be made credible? The answer was "yes," but with radical changes. Are the financial management systems adequate? The answer was "no, by a long shot." Within the budget, are there ways to maximize research return? The answer was "yes, with big changes." Were the cost estimates to go to the full up Station credible? The IMCE could not answer this question; there was not enough information to assess.

Young explained the underlying reasons why the IMCE came to these answers:

The way the International Space Station (ISS) was being managed was by FY budget, not cost to complete. Human space flight got a FY budget, did everything it could do for that amount, and pushed the rest to the right. There was no management to a total cost or cost at complete number. This was different from Earth Science, for example. There, you would see management to cost to complete. On Station, there were no program cost estimates. All the

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work was FY budgets; there were no cost estimates, only budget estimates. There was no work breakdown structure. There was limited use of earned value. The Boeing Company contract had earned value, but they were not effective at keeping up with it. If you asked a question pertaining to how they were doing, you would get an answer that related to the FY budget. Another item was a highly inadequate management information system. You could not get actual vs. planned; you couldn't even get how many people were on the program. The IMCE got copies of the reports that went from Johnson Space Center (JSC) to NASA Headquarters (HQ); there was no actual vs. plan. The data were there, but there was no way to get at it effectively. Tetrault noted that the civil service pool was used as a "sink" pool. If the program was overrunning, it would use civil servants instead of contractors because civil servants were "free". Another item was the type of management—it was more institutional than program (a human space flight characteristic). More than half of the people under contract that worked on the program did not report to the program office. Most of the civil servants that worked on the program did not report to the program. This was not an efficient means of operation; it made integration difficult; there was no check/balance between the program and the central engineering organization. JSC was lead center, Marshall Space Flight Center (MSFC) reported to JSC. At MSFC, the management approach was much the same. Another striking thing was that there were no agreed upon science requirements. The IMCE did not expect to get involved in this, but uncovered discrepancies piqued the group's interest. It found that the science requirements were almost non-existent; they were more like "marketing" requirements. No thought had been given to what the science requirements should be. There did not to appear to be a purpose to the Space Station unless you did the science, so it was imperative that the science be correct. The IMCE did a "first cut" at this and recommended that a competent group do a thorough review. There is only one reason to spend a large amount of dollars on Space Station—to understand long duration space flight so that humans can do something beyond what is currently being done in low Earth orbit. The group accepted this objective for the ISS. One of the critical items is that this objective cannot be accomplished without the Japanese centrifuge. However, the centrifuge was on the list to be canceled because of the budget at the time. The Japanese were building the centrifuge under a barter arrangement (in return for a shuttle launch). The IMCE felt that if there were no centrifuge, there was no reason to continue the Space Station. This was not put into the formal report, but was said privately to NASA.

Mr. Scott Hubbard noted that the Research Maximization and Prioritization (REMAP) Task Force said that the Space Station could not be called a science driven activity with only 3 crew.

The IMCE found that JSC and HQ had inadequate financial management staff and no independent cost estimating capability. The IMCE found that there was no real interest in outside reviews. These were the underlying factors to the conclusions. The Space Station is awesome; however, the difficulties were in the underestimation of the amount of work out in front; the program handled the technical challenges well, but their challenges were not anything comparable to the challenges that Shuttle had, e.g., a reusable thermal protection system. IMCE found enormous deficiencies in cost, management, and scheduling. There were a number of

recommendations. There was a period where the response to recommendations was slow, but there was a push and when examined a year later, many of the recommendations had been incorporated.

Young noted where the IMCE was a year later on the 5 issues. More dollars were added to the program. When the IMCE was involved, the ground rule was no new money. NASA got enormous support from the Comptroller and Auditor General (CAG) activity in the Department of Defense (DOD), and they did a very good job. The cost was then credible. NASA made a lot of management changes. Many of the science issues were worked. The financial management system was making good progress, but was still a work to be completed.

With respect to the management structure, Dr. John Logsdon noted that the IMCE wanted a separate Associate Administrator for Space Station. Now, we have a Deputy Associate Administrator (AA) that runs both Shuttle and Station. This was something that the IMCE had some skepticism about when proposed. Young commented that when there is an extraordinary problem, you often have to overkill it to make a point, and the IMCE did this. Although the IMCE proposal was that there be an AA just for Station, there was lack of support for this throughout NASA. Their proposal was to combine Space Station and Shuttle. The turned out to be a good idea.

The recommendation of only 4 shuttle flights a year was driven by cost. The IMCE could not get much help from NASA in working the cost problem, and this was a way to get that solved. Tetrault noted that there were a number of overlaps between Shuttle and Space Station, and the IMCE could see combining the two projects offices as a way to save costs. Senior project people admitted that they couldn't affect cost and schedule. This was the culture issue that the IMCE encountered.

Young indicated that there are still culture issues that have not been resolved. He recounted some of his observations on the human space flight culture. They have an extraordinary passion for space. There is an extraordinary commitment to safety. The cultural issue had to do with execution. Human space flight culture is a highly insular circumstance. The human space flight people have their way of doing business; they are not open to alternatives. A lot of things on the way programs are managed today have passed them by. Another human space flight culture characteristic is that they are very difficult to penetrate. It was hard to get a dialog on an issue; responses were typically defensive. It was hard to get good substantive answers to questions. The answers that were provided were usually the minimum that would allow one to move on. As noted earlier, another characteristic was the institutional management style. They were not enthusiastic about reporting up, or talking about problems and issues. They had more of an operational approach than an engineering approach to activities. There are a lot of good qualities to the culture that are important, but out of the IMCE activity, the negative aspects did not get corrected.

Young noted that he went to the space flight Associate Administrator regarding the credibility issue with OMB and congress. He wanted to sit with senior management and give them a heads up on this. The AA brought the senior people in and Young gave them a briefing on his discussions with OMB and congress. His observation was that these were good people, but this data dump didn't faze them. They were in denial. They saw OMB and congress as being wrong and not understanding what NASA was trying to do.

Young observed that the last few years of the human space flight program have been almost run by OMB. When OMB wanted a vehicle after Shuttle, they didn't fund Shuttle upgrades. There could be a crew rescue vehicle today, but there was an OMB policy that they wanted both an up and down capability. OMB had a tremendous influence on space policy. Logsdon noted that at this time, NASA found it had no political support at the political level in the White House—there was no counter to OMB. Space was a low priority in the President Clinton administration. Mr. Steve Isakowitz injected his views on what the space program should be. The Science Office didn't have any counterweight to it. There was a vacuum of national leadership that was filled by OMB. In contrast, the space science community had a very effective lobby on the Hill and in the Science Office with respect to robotic programs. There has been a rebalancing in NASA—robotic programs are now a larger part of the NASA budget. Gehman observed that NASA could not go around OMB like the other cabinet offices could. Young commented that in human space flight, OMB was intrusively involved. Logsdon added that among the organizations that could not penetrate the human space flight culture was NASA Headquarters. JSC was a world unto itself. Mr. Dan Goldin's reforms did not extend to human space flight. Tetrault noted that the IMCE actually got a letter from congress that said that IMCE should not come to a judgment about the number of people at JSC. Young noted that OMB had developed a lack of trust in Golden. They thought that he was not truthful with them. This was not the case; Golden didn't lie—the human space flight management system could not give a credible answer to his questions. O'Keefe has done wonders in working to rebuild OMB trust in NASA. However, we cannot rely on one particular person in a position to make up for flaws in the management system.

Gehman observed that management in the Apollo days was under a specific vision—a destination and time limit, but no financial constraints. Today, the mission is to go to space on a billion a year. A book, *The Secret of Apollo*, explains the systems engineering under Apollo. There was a very powerful engineering organization at JSC, but there was also a powerful engineering group at HQ. This was a system of checks and balances. NASA is now charged to develop systems more like how the DOD develops things. All of the management trappings have to be borrowed from DOD—NASA doesn't have any of the trappings of the systems for program development. Logsdon commented that Steve Isakowitz and O'Keefe are now trying to create this inside NASA. Young stated that if you take a program that is under funded, there are 3 possibilities that can happen. If there is a competent program manager and he has sufficient schedule, he will use schedule as the reserve. Space Station is the epitome of that. The inexperienced Program Manager or a program where the schedule is fixed is in a bind. Under

this situation, the tendency is to make risk the reserve. Risk is like radiation—you can take small doses for a long time, then it becomes catastrophic. The third outcome is like Apollo—the schedule is fixed and the risk is funded. The same thing happened on a smaller scale to the Mars rover program. NASA funded the risk on this program. Because of the Mars experience, Space Science is funding its risk across the programs. With respect to risk and funding it, Dr. Sally Ride noted that at the lower to mid levels at JSC, the Board has been running Shuttle people that were feeling pressure to meet the Node 2 schedule. Upper management says there was no schedule pressure, but this was not the perception at the working levels at JSC. Young stated that NASA and senior management had selected the Node 2 date to demonstrate credibility. Delivery of Node 2 was critical. It was obvious that the critical path was the Shuttle. IMCE commented back to NASA that it felt the Node 2 delivery was in trouble by 6 to 8 months. NASA had a different opinion. The IMCE looked at performance to date in making its assessment. Dr. Brad Parkinson led this conclusion for the group. Tetrault indicated that the problem with Station was cost and schedule credibility. The issue was for NASA to pass through some gates to demonstrate it was capable of managing the program. NASA had some selected some important dates to establish credibility. When OMB refinanced Station, it was still credible and the schedule slippages were reduced (to 6-8 months over the entire program, plus dollars had been set aside for this). NASA was making great progress in how they were managing the program and costs. There had been a push to make the schedules more credible. Tetrault indicated that the CAIB has not seen a relationship between the push to make the schedule more credible and the Columbia accident. Young commented that you have to be sure you have a system that can raise a red flag back up to management if something in the organization is causing detrimental action. Over the years, the space enterprise changed from a mission success culture to a cost culture.

Gehman noted that NASA has formidable program challenges. It has to finish the Space Station, operate the Shuttle (an under funded budget line), and fund a replacement vehicle. He asked Young for his opinion on the prognosis, based upon what he has seen. Young replied that assured access to space is one of the number one issues. From a programmatic or technical standpoint, the right way to go about space access is to separate crew and cargo. The problem with the integrated space transportation plan is that the right way to make it happen is for the NASA budget to go up about 25%. This is not realistic. The worst thing that could happen would be to get the entire program and no increase. This puts NASA right back in the same quandary: solve the problem with schedule delays or risk. One of the positive factors is that O'Keefe has a better relationship with the current Administration. The NAC has believed for some time that the replacement for the Shuttle is the Shuttle because there is no way to ever fund anything else. It was unrealistic to expect industry to fund a replacement, but this was the assumption and the only way that NASA could go forward with the studies. Even when the commercial manifest was at its peak, there was no way the industry was going to invest the dollars needed. If NASA is going to fly the Shuttle another couple of decades, a lot of things need to be looked out. As the National Space Plane goes through design, it will have a crew escape mechanism. The question is: Do we want to fly the Shuttle another two decades with no

crew escape capability? Bloomfield noted that a lot of options are being examined. Where the Astronaut Office is headed is in the short term, we can get to assembly complete with the Shuttle, but there should be some type of Shuttle crew escape system after that. Logsdon noted that the original choice for solid rockets was driven by budget. Dr. Doug Osheroff asked whether the reliability of the craft is such that it could be continued to be used for another 20 years. Things could be done to make it more robust. Young observed that over the next twenty years, the probability of losing another Shuttle is relatively high. Are three shuttles adequate to meet the human space flight demands that NASA will have? The answer is that it probably is not. With the integrated space transportation plan, you don't get the crew return capability until 2010; you don't get the up capability to 2012. There are two issues: (1) do we have the assets to support the ISS mission? (2) Another accident within a certain timeframe will terminate the human space program. Tetrault observed that good technical organization have cost pressures and schedule issues, but the organization mangoes those things and understand the balances. NASA did not have a history of those things. There was confusion within the organization on how to react to those things because it didn't have to manage them under Apollo. NASA is doing more conventional, program management types of things and needs to have the capabilities to sort through these. Young agreed but put a caveat on this: you can convince people to run a 4-minute mile; you can't convince them to run a 2-minute mile. Osheroff observed that NASA promised something that they had no idea what it would to cost. Young added that over time, human space flight lost interest in how much it was going to cost at complete. They were only interested in how much it was going to cost in a particular year. In the beginning, Shuttle was proceeding along the way Station did—it didn't have enough dollars and the schedule was moving to the right. President Carter demanded that the shuttle be ready by a certain date, and the big cost "bubble" appeared.

Gehman noted that when the Board makes recommendations, the advice is also aimed at OMB and congress. If we want to break out of the mold, we can't do business that way. We are in a programmatic death spiral—there are 3 orbiters that can be run for another 20 years if you do a, b, c, etc. Meanwhile, on a parallel track is the Space Station. It must have the Shuttle to get to core complete and sustain it. If the Shuttle gets in trouble, the Space Station is in trouble. The way out of the programmatic box is with the next vehicle. However, how can we believe that the orbital space plane will have any more luck than other similar programs? If it doesn't then the other two programs are at seriously at risk. The Board must lecture to congress and OMB: the next vehicle is extremely important. We must excite somebody about the dilemma. The short-term issue is the Shuttle flying again; flying the shuttle for the long term is a completely different set of questions.

Young observed that the "wild card" is aging; everything else we can handle. We have to get a handle on the metrics of aging for a reusable space system. This could be the Achilles heel. A large body of people is not going to be satisfied that the extent of human space flight is going up and down to the Space Station. There has to be some vision beyond that. For all of this to make sense, the country has to have a vision that humans will go beyond Low Earth Orbit (LEO).

Once the country says that is the vision (with all the caveats), a lot of the research makes sense. Space Station makes no sense if we are not going to do that. This needs to be done is a bold, non-budgetary sense. The whole program needs a vision for focus. With respect to the space plane, NASA's credibility is still not very high. If we are going to go forward with a new transportation system, somebody other than NASA must establish this as important to the country. This is too important to resolve in the budget process. There must be a policy and some outside group must say that the country has to have this if we are going to continue with human space flight. Gehman observed this is relevant to the CAIB; just fixing the brackets is a death wish—there are larger problems. We don't know what "long term" means. In some way, we need to express some degree of alarm about the replacement program.

Dr. Sheila Widnall observed that committees tend to stay close to their charters. She asked how all the previous committees missed the Shuttle operating outside of the anomaly envelope; e.g., how did they miss the foam? Young stated that there are advisory committees and they are just that. Advisory committees have little authority. On the Mars, launch vehicle, and IMCE investigations, Young indicated that he felt a responsibility for ensuring that what was in the reports was implemented. IMCE was difficult. In recent times, NASA had never had a Space Flight advisory committee. It was started in mid-2000. It was dominated by shuttle upgrades and the infrastructure issues. Several reports all came together at the same time, including Mars, Faster/Better/Cheaper, and the Dr. Harry McDonald report. There were 2 ways NASA responded to the reports. On Mars, NASA HQ (Code S) took the report and implemented those things that were recommended for Code S. Dr. Ed Weiler invited the review group to come in and assess what was done. The Jet Propulsion Laboratory (JPL) initially went through denial, but this changed over time. They implemented every bit of the report. This didn't happen with McDonald's report. NASA set up an activity under the Chief Engineer—Griner headed it—and wrote a report. There were about 150 recommendations in the report, including the McDonald recommendations. With this many action items, things lose their significance. There was no assignment of a champion to get it done. With respect to the foam, (20/20 hindsight) we were flying in an environment that we had never tested. We must have people that are constantly thinking about whether we are operating in an environment that we have never tested. On the Mars Viking Program, the basic policy was to never operate the vehicle in a way that wasn't as tested on Earth. This is the discipline that has to be in this business. Space Shuttle Challenger was flown under conditions that had never been tested. Mr. Doug Cooke added that the 20/20 hindsight must be done by the people who are most knowledgeable. Gehman observed that we must have the resources and technical competence to investigate these things. If NASA had been doing this on a continuing basis, they would have discovered these things 15 years ago. For various reasons, e.g., budgetary, healthy skepticism is weaned out of the program. People might ask questions, but there are no resources to follow up. Young observed that on a scale of difficulty, the CAIB's easiest job would be how to fix the shuttle; the hard job will be the management and cultural fixes.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 12, 2003
These Minutes Contain No Sensitive Data

This meeting was adjourned at 1615 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 12, 2003
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Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-8499
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Roger Tetrault	CAIB	703-416-3591
Dr. Doug Osheroff	CAIB	703-416-3490
Dr. John Logsdon	CAIB	703-416-3057
Scott Hubbard	CAIB	703-416-3109
Steve Schmidt	CAIB	703-416-8488
Frank Buzzard	CTF	202-358-1401
Mike Bloomfield	CAIB	281-483-7809
Doug Cooke	CAIB	281-283-7576
Tom Young	Speaker	

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 13, 2003
These Minutes Contain No Sensitive Data

Purpose: CAIB/NAIT Working Scenario – Leroy Cain

Date: June 13, 2003 **Time:** 0900 – 1415 EST

This meeting was conducted by telephone conferencing between the ANSER facilities in Arlington, VA (Suite 700, Room 7052) and the Johnson Space Center, TX (Building 1, Conference Room 945) and the Kennedy Space Center, FL.

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting were in "draft" form, collected, and destroyed after the conclusion of the meeting.

There were 30 action items generated from this meeting and are listed later throughout this report.

This presentation was the culmination of the working scenario. Mr. Leroy Cain also provided the narrative (draft), which will be a joint CAIB/NAIT document. This will be the source document for the CAIB report. Some editorial and technical changes will be incorporated to this release. Any analysis that is not complete will be referred to in the final report for follow-up by Tom Stafford's Task Group. **Action: Gehman to work the release of the working scenario documents.**

Cain reviewed the working scenario outline: ET-93, Columbia processing, launch countdown, launch/ascent, ascent timeline, ET TPS foam, RCC design/inspection/material considerations, orbit timeline/FD2 debris, deorbit/entry, summary/conclusions. The presentation organization is chronological. The narrative report is organized differently (important things first).

Comments on each section:

- ET shipping and handling: The report only talks about moving STS 112 and 113 ahead of 107 from a manifest standpoint.

- Mate/De-Mate/Re-Mate, and Crushed Foam: What is meant by contained? Did it provide a path for nitrogen gas? Cain: "contained" means not exposed; no visibility to the air stream. Gehman: was a potential void covered someplace? MGen John Barry: A dye penetrant test was done. It did not extend past the ¾" limit around the edge of the flange; it extended about ½" into the foam. Gehman: **Action: this crushed foam situation should specifically be in the Fault Tree (and closed out) and this report should reference that.** Col. Mike Bloomfield: there could be a better choice of words

on page 14. Cain indicated that the report would use "inconclusive" to describe situations where no imagery was available for confirmation.

- ET Prelaunch operations: no comments

- Left Wing Processing (J3OMM): Barry noted that the last item on page 20 (all wing leading edge hardware removed and installed twice) is still an open item. **Action: change this.**

- Left Wing Processing (STS-109 & STS-107): Reference the tape that was left in the wing from Palmdale—this is in the narrative and is closed out. Barry: we need to include this in the briefing. Dr. Sheila Widnall: the CAIB report will likely be broader and will talk about things that were not done. There is a concern about things from this document being lifted out of context, e.g., the statements regarding no evidence contributing to the accident. Cain agreed and noted that the narrative lends itself better to a public/press release. Barry: outline the purpose of the document, what it entails and does not entail. Gehman: this is a factual narrative. The CAIB will be on the lookout for conclusions that do not belong in the document. Cain: for future uses, the briefing will be properly framed up front.

- Launch countdown: The tape left on the ET was highlighted on the launch countdown chart and covered in the narrative.

- Ascent wind shear: The graphic figures will be more legible in the final release. In the narrative, there are full-page plots. Widnall: it would be helpful to put in the reference parameters (dynamic pressure, mach number, etc.,) on the ascent. **Action: the team will add a plot for ascent.** Barry: would like to see the historical loadings (a 2 sigma or more on the "I-load" envelope)—will talk off line with team. It is definite that the negative beta angle increases the aerodynamic load on the left bipod. This could have been a contributing factor to the loss of foam. Gehman: this section of the report does not need to be analytical. Cain: **Action: The statement re "no evidence" will be eliminated or rephrased.**

- ET Slosh: There are several factors that go toward slosh. There is a theory that a number of factors (wind shear, slosh, etc.) lined up to contribute to loss of foam. The narrative says "maybe", but there is no way to know for sure. From a vehicle dynamics standpoint alone, what was seen can all be explained by the winds and the SRB burn rate. "No evidence" statement should be removed; it is misleading. All of these factors could be contributing, but there is no direct evidence.

- Ascent SSME & SRB Nozzle Positions: There will be more detail in the flight correlation section.

- Launch plus 70 sec to SRB separation: Minor inconsistency in chart 35 and chart 36. Cain: In the final report on the imagery analysis, at least two smaller pieces were spawned. **Action: Will go back and check on this.** Gehman: in the narrative in section 3.1 there is no discussion of cameras (launch criteria, cameras that didn't work or were not there)—this should be added.

- Image analysis: Gehman: Will review the consistency regarding panel numbers. Yellow arrow is not in the report and is confusing.

- Launch imagery analysis - summary: Cain: impact time was updated just yesterday to 81.86. **Action: Will verify the observed pieces of debris.**

- Transport Analysis – ET project inputs: Mr. Scott Hubbard: the ramp angles varied across the tank. Will have to figure out how to handle this. **Action: The word "allowable" should be taken out.** Should say that ramp angle was noted to vary between "x" and "y". This should be a footnote.

- Transport Analysis – Estimated Weight/Volume Range: Hubbard: the external tank (ET) project is a minority opinion. The transport team is another opinion. The test is using 1.67 lbs (1200 cubic inches) at 775 ft/sec. Cain: the charts are telling the story as it developed. There is more detail on what people zeroed in on for the test. Hubbard: in the test report, there will be references to transport analysis and the ET project, but the report will state the value that was chosen as most representative. Cain: there is a discussion on radar and several items that could not be characterized. The goal with respect to the ramp information is to agree on the inputs, and there will be a section in Hubbard's report that discusses what was used in the test and why. Hubbard: the briefing does not include the work done by Mr. Ray Gomez to synthesize all of the inputs. Cain: the potential sources are those that have been in discussion. It is a matter of emphasis. Part of the challenge is how much to leave out of the briefing that is contained in the narrative. Gehman: we are looking for a factual account of the front end of the accident. This is not where we are going to discuss foam testing or the results of the foam testing. Barry: did not read in the report about spectral analysis being inconclusive. Hubbard: the narrative is fairly straight forward and there are no issues with it.

- Image analysis trajectories: no comments

- Kulite pressure measurements: no comments

- RCC panel configuration: no comments

- Cartoon on Panel 8 & 9 CAD representation: no comments

- Possible RCC panel 9 ascent temperature increase indication: no comments

- Panel 8/9 damage thermal analysis: no comments

- RCC Panel 6 impact testing: no comments

- Ascent data: no comments

- Launch radar analysis: Dr. Doug Osheroff: Was there any ice or slough in the debris? Could this have been detected by radar? Gehman: backup chart 12 shows a radar event at 81 seconds after launch; this raises a red flag and needs to be explained. Mr. Frank Buzzard: because the separation rate is so low, it is a plume artifact (something that causes a radar scatter). There are two radar events that occur at SRB separation. Cain: this type of analysis with this radar has been done before, but it was stopped around the STS-56 timeframe. Gehman: How were they able to differentiate among the cataloged items? The report needs to be expanded to explain this. **Action: the team will summarize the explanations behind the events that are worthy of note.**

- Ascent loads – predicted vs. actual: The team will be careful about the words used in the narrative. **Action: The "no evidence statement" will be reworded.**

- ET Separation Yaw rate: We can definitively say that the orbiter and ET did not re-contact. Gehman: in the bipod joint, there is a lot of force. The bipod ramp foam is not covering that joint. How much of that force is being transferred into the foam? Randomly, many of the peaks (on thirty or so tracked items) could line up. We don't have any way of reconstructing all of those things. Foam appears to pop off at random due to a lot of things lining up at the same time. We will probably never analytically prove why the foam comes off. There are more things happening than we know about.

- Flight data correlation – LWT and PE: PE stands for "performance enhancements".

- Flight data correlation – bipod foam liberation: We don't think that these things contributed to foam loss, but cannot rule it out. There are six flights, with a seventh under review (STS-32). Barry: the ET closeout team has been asked to go back one more time and look at everything possible that could be associated with these seven. Osheroff: there are additional aero stresses on the bipod ramp that don't cause foam ejection every time. Barry: the issue is that it has to be in the report: five of the seven known bipod events are Columbia. Cain: Why it is on some flights and not others? Things don't line up. There is variability that may lead to foam shedding in some cases and not others. Gehman: the words in the narrative help. **Action: The explanation needs to be in the chart. There needs to be a bigger chart including more factors.** Cain: The roll maneuver is another variable. Hubbard: on page 3-37 (in the narrative),

there are inconsistencies with the briefing. **Action: The briefing needs to be adjusted before it is given to Ralph**. Cain: the team will start by deleting the last statement ("no evidence") on every chart. Barry: we can't conclusively say why the bipod came off. The question will be: Can other items come off of the stack? Gehman: the value of what the CAIB can do for NASA is to identify what else NASA should look out for. All of the detective work on the bipod foam is excellent.

- History of Foam Changes: no comments

- ET Debris Summary: Gehman: in the report (11.1) there is a discussion about the design. **Action: There is nothing about the requirement for debris generation. Add this.** The bipod ramp represents the source of largest pieces of historical debris (make this change). Hubbard: the angle of impact on the tiles is crucial. There are two classes of debris and they create different kinds of potential damage. Cain: in the narrative, this is addressed; it can be expounded upon.

- Bipod ramp design summary: Barry: list the dates on when changes were made to the bipods.

- Bipod ramp TPS design: no comments

- Bipod certification: no comments

- Bipod ramp build process: the overlap timing verification, if it was done, was not documented. MSFC is doing some testing on variation in the timing. The general consensus is that the timing does matter. Gehman: **Action: there is a problem with conclusion on p. 68—we need careful examination of words (reserve judgment).** Osheroff: how variable is the acreage foam that is applied by machine? Cain: the plug pulls are from acreage foam; the data on this can be provided. The intent was to present a fair statement from the project. Osheroff: it appears that the limits were improperly chosen.

- Bipod ramp foam acceptance/NDE: Widnall: design, material, process, acceptance, etc.—all have some "holes" in them. Gehman: the statement regarding efforts to implement NDE techniques is factual.

- Bipod Foam Failure modes: potential contributor: no comments

- Test results for debris assessment: Cain: for the narrative, the team can look at the testing details and see if it is depicted different graphically. Osheroff: **Action: we have to know the dimension of the piece.**

- Bipod SLA temperatures (80 seconds MET): no comments

- Bipod Ramp as-built hardware assessment: no comments

- Worst Case Credible TPS debris: Hubbard: has problem with words -- use some other phase that doesn't sound pejorative or judgmental. Gehman: **Action: This part of the narrative (11-18) has to change; it needs a rewrite, starting with 11.4.6.** Cain: Will take action to make sure the words in the narrative are the ones that Hubbard agrees with. (Hubbard to provide appropriate words.) Cain: There is no attempt to give bias or weight. In the narrative, there needs to be a well-balanced discussion.

- Left and Right Bipod ramp differences: no comments

- Launch Pad Environment: Gehman: **Action: The six or seven foam events should be on the graph. Time should be made clearer on the chart.**

- Ascent ET Environments: no comments

- ET LO2 Slosh Baffle Changes: Widnall: **Action: add a key/cross reference for ET and STS. [general discussion on baffles]**

- Strain energy at ET separation: Cain: This has been seen before and is repeatable (negative polarity). There is something that is worthy of being looked at. If we talk with the experts in integration and the experts on the structural side and they tell us that there is something, then we do not have enough instrumentation. Gehman: this may be an area where the CAIB has "other observations."

- Reinforced Carbon Carbon (RCC) Design: Gehman: the narrative conforms with our understanding of history. It was never tested to design. Buzzard: the structural loads were taken to 1.2 not 1.4. By analysis, it was certified to a 1.4 safety measure. Gehman: we don't want to attribute any kind of heat insulating characteristics to the RCC.

- RCC Inspections: no comments

- Impact resistance: For our purposes, delete "significant" from the line.

- RCC Impact Damage: the criteria is applied at OMM. Cain: will check on the maximum allowable hole size. Through hole limit is .25 inch.

- Corrosion/oxidation: normal mission mass loss is mass loss that can happen as a function of the environment flown through on that mission. Gehman: **Action: change statement to "normal mission to mission mass loss."** There is a problem statistically with limiting

the service life. Barry: NASA knows how the strength diminishes with life. Gehman: It appears that there is a contraction in the paragraph—it says that no oxidation occurs at the pad, then there is a presentation of all these things happening at the pad. **Action: Check the narrative (not a complete story).**

- Supporting Evidence of Early Left Wing Leading Edge Failure: Tetrault: **Action: deposition is not necessarily all-metallic—it is slag (metallic and non-metallic)—change words.**

- WLE Phase II Sampling results: Tetrault: **Carrier panels are not missing—change "locations" to "gap."** Carrier panel 8 lower is not discussed. These are pristine because the RCC far rib had to be there (even though it was not found). This should be on the chart. The slag is thin, but it is not "uniform" (don't use this word). We do have slag on the right wing, so there are 2 different sources of heating—event heating and reentry heating. The hole is not near apex (narrative does not say this). We cannot rule out a tee seal, but it is more likely that the damage was in panel 8, between tee seal 7 and tee seal 8. We should not include 4-7. Seven has pristine spanner beams that have no slag. The damage could not be upstream of panel 7. The charts still include the damage at panel 7. Debris evidence only indicates damage area between Tee seal 7 and Tee seal 9. OEX data eliminates panel 9 from consideration.

- Forensics Assessment Summary: Widnall: **Action: take out statement "possibly held at both ends by field splice bolts". There should be nothing in the briefing charts that isn't in the text.** Cain: Will take action to make the narrative right. Flow enters hole/damage at panel 8 – add "or adjacent tee seals." Hot gas exits toward panel 9 tiles causing slumping. Narrative is extraordinary short and doesn't do justice to the situation.

- Pinholes: no comments

- Loose carrier panel bolts: no comments

- Overview of orbit phase: no comments

- Orbital debris assessment – debris risk: no comments

- Orbital debris assessment – IMU/Jet firing data: no comments

- Orbital debris assessment – SAMS data: no comments

- Flight Day 2 Event Specifics from radar tracking: [nothing new from last time]: results from Lincoln Lab are not in here yet.

- Orbiter data review unable to explain FD 2 event: no comments
- Why/how would object depart orbiter on FD 2: no comments
- FD 2 object RCS testing and ballistics analysis: no comments
- Orbit Summary: Widnall: evidence from Lincoln should be looked at and added.
- Entry Data: Period of Decreased Heating [nothing new]
- PNL 8/9 Damage Thermal Analysis: this is new, strengthens the story. [rest of the entry section already seen by Board; not discussed again]
- WLE Spar Burn Through Assessment: a range of times is given in the narrative. Widnall: **Action: The narrative is a little weak in the entire area of spar burn through. Put some of the chart information in the narrative.** Note: text has two different time scales. Osheroff: **Action: Give it in seconds after entry, then say what GMT and EST are if necessary.** The cartoon is not intended to be a literal flow.
- Wire burn through study for main wire bundles/MLG wall: [new chart]
- First off-nominal aero event roll & yaw: **Action: the red line is a significant unexplained event—need to spend some time/narrative on this.**
- Sharp change in rolling moment:
- Change in delta roll trend due to lower surface recession: Widnall: has problem with these words. The change is probably due to spar having a big hole in it. We are waiting for calculations to be completed. Gehman: there is a recession discussion in the narrative. Cain: we will caveat what is in the report today. This explanation is possible and based upon the limited data to date.
- Entry Summary: Cain: **Action: will make sure that if Tetrault has anything to add to the forensics evidence, it will be added.**
- Summary: This is an attempt to summarize the high points as we know them today. The fourth bullet is the opposite of what was said in the report, but agrees with the CAIB position. Third bullet: **Action: two thoughts (where, and enough energy to do damage), should be two bullets. Mention time rather than "second stage".** Sixth bullet: **Action: drop "although" and make two sentences. Include the tee seal issue.** CAIB: **Action: delete the next to last bullet in its entirety. "Preponderance of**

evidence" is a legal term; use "supports the conclusion". Last bullet: **Action: reword carefully.**

- Conclusions: For this report, no conclusions are needed. This is the CAIB's job. Cain: The NAIT may want to include some parts of the conclusions chart in the summary. If so, it will be re-reviewed with the CAIB.

This meeting was adjourned at 1415.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 13, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-8499
Major General Barry	CAIB	703-416-3570
Major General Hess	CAIB	703-416-8481
Steve Wallace	CAIB	703-416-8405
Dr. Sheila Widnall	CAIB	703-416-3445
Dr. Hallock	CAIB	703-416-3272
Roger Tetrault	CAIB	703-416-3591
Dr. Doug Osheroff	CAIB	703-416-3490
Scott Hubbard	CAIB	703-416-3109
Steve Schmidt	CAIB	703-416-8488
Frank Buzzard	CTF	202-358-1401
Mike Bloomfield	CAIB	281-483-7809
Doug Cooke	CAIB	281-283-7576
Dennis Jenkins	CAIB	703-416-3373
Dwayne Day	CAIB	703-416-3491
Ltc Tyrone Woodyard	CAIB	703-416-3532
Laura Brown	CAIB	713-416-3532
Robert Cobb	NASA IG	202-358-1220
Ltc Larry Butkus	CAIB	716-416-8492
Leroy Cain	JSC	281-483-0705
Dave Onkst	CAIB	703-416-
Mike Sarafin	JSC	281-483-4775
Jon Reding	JSC/MOD	281-483-2668
Mekher	JSC	281-244-6427
Jeff Kling	JSC	281-483-0677
Stitch	JSC/Flt Dir Off	281-483-8038

CMM009-0060

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 19, 2003
These Minutes Contain No Sensitive Data

Purpose: Code Q Safety Briefing – Bryan O'Connor, Associate Administrator, Office of Safety and Mission Assurance

Date: June 19, 2003 **Time:** 0900-1300 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 700, Room 7052).

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the CAIB DOJ database.

There were no action items generated from this meeting.

Mr. Bryan O'Connor briefed the Board on NASA's Safety and Mission Assurance Program. He noted that the Board's two preliminary recommendations are in work. Also, an assessment on quality at KSC has been started.

The NASA mission has three verbs: understand, explore, inspire. NASA is organized around these. The safety organization is an adverb; it is the bedrock under everything that NASA does. The Administrator has kept the core values, the first one being safety. There are five major implementing strategies; safety and mission assurance is imbedded in several of them. Code Q is at the same level as the program offices (Code M, S, etc.).

In response to questions, Mr. O'Connor discussed the NASA safety organization. The major programs (ISS, Shuttle) report directly to the Code M Associate Administrator (AA). MSFC programs are actually projects. Orbiter is no longer a "project"; it is under the USA contract, and this contract belongs to the program manager. The SRB was absorbed into USA. The other major orbiter elements (e.g., SRM) are still referred to as the "Marshall projects." They come into USA as GFE. At one time, there were four projects at MSFC. One of the program manager's staff is at MSFC.

Admiral Gehman observed that the Board is convinced that the integration function is weak everywhere. Functions are severely hampered by Center cultures, span of authority, or position in the command chain. For example, Mr. Lambert Austin is having a lot of difficulty at JSC. Mr. O'Connor noted that the Center Director will not be between the project manager and the program when it comes to certifying for flight readiness. There has been some discussion on what the Center Director is signing for when he signs off on the FRR. Projects have to argue their budgets to the program.

CMM008-0074

Admiral Gehman noted that the Centers have engineering departments, but the Center Directors are not signing off on behalf of their Center's engineering directorate. Mr. O'Connor stated that the Center Director has a matrix-manager type of function. NASA HQ is trying to get the Center Director to function in this way. At the design centers, they need to operate in the "systems command" mode. Admiral Gehman noted that if the Board is confused about the functional relationships, there is no way a safety person can work through that. Mr. O'Connor indicated that this is the reason for the independent safety assessment. There were two safety people on Shuttle and two on ISS. There was no confusion on ISS—the safety people all reported to the program person. However, on shuttle, the program manager wanted to have two inputs (center and program). There may be a reorganization based upon the new program manager's preferences, but there are obligations to the COFR process. It needs to be clear.

Mr. Steve Wallace indicated that what bothered him was the lack of "horsepower" by the safety advisor; this was striking. Mr. O'Connor responded that NASA HQ's suggestion was to simplify this and improve the integration (safety as well as engineering). There should be a single safety manager that looks a lot like the ISS model. That person has to have a better understanding on what is going on at KSC and MSFC. The safety manager must have credibility and be acknowledged as a useful member of the team.

There were a number of questions pertaining to responsibility and accountability. Mr. O'Connor stated that at NASA, it is common for people with the responsibility to delegate authority; however, the safety manager is still accountable. Mr. Wallace observed that there may be over-delegation of this function. There is give and take at the meeting and the safety person needs to be able to participate fully. Admiral Gehman observed that this gets to the unofficial interactions of the entities. For example, at top-level meetings where schedules and budget are discussed, the people don't send delegates.

Mr. O'Conner noted that in the reorganization, he wants S&MA to be more of an integration function across the program, and there should be a high credibility person there with more responsibility. This is a common problem in S&MA. As time goes on, the work force ceases to be "refreshed." The safety people get run down and there may be people in there who aren't that credible or as effective. After Challenger, S&MA started rotating people in and out. We need to keep doing that, but the HR system doesn't perpetuate the rotation very well. We need to rotate people from engineering and operations into the S&MA system. With respect to authority, they all have the authority to stop something; however, at this point in the career of the Shuttle, it is not used very often. It is not an authority issue—the question is whether the person will lose credibility if he exercises that authority. This is why it is important for the person to have credibility.

In response to a question, Mr. O'Conner noted that the program manager can be by-passed in a couple of ways—there is an appeal route through the safety organization, and the S&MA AA can go to the program manager's boss. RAdm Steve Turcotte raised the question regarding how to foster an environment where the safety person can go above the program manager. Mr. O'Connor replied that part of the answer is to foster it through the quality of the personnel. The program is still organized like a development organization. Operations is actually an element of the program. Admiral Gehman observed that it is not really a true developmental model either. If it were, the requirements and technical people would not be subordinate to the program manager. The rolling up of budget, schedule, manifest, as well as technical requirements and mission assurance into one person is very efficient and effective. If there are internal conflicts, the program manager resolves them. However, this is not very satisfying arrangement if there is a developmental or test model. There need to be checks and balances.

Mr. O'Connor showed the general S&MA support model. There is a line (program) organization. On the other side, there is a safety function that does three things: provide advice, produce products (white hat), and conduct auditing (black hat). Admiral Gehman observed that at some point, the program manager has to actively get the concurrence of someone on the other side. In theory, this happens at COFR. The question is: Is the person who has to concur with the program office robustly supported by an assessment team so that he can speak and document his concerns?

Mr. O'Connor showed the safety and independence levels: the contractor S&MA, the NASA Project S&MA, the Center (matrixed) S&MA, Center independent assessment, NASA HQ (Code Q, NAC, ASAP), and outsiders (GAO, IG, Congress, OSHA). Some years ago, the Program Director at NASA HQ owned the PRD. In the late 1980's, NASA decided to delegate authority for the Level 1 requirements to the program manager. Now, the program manager wears a NASA HQ "hat", but is doing the NASA HQ function at a lower level than it used to be done.

Admiral Gehman observed that the program manager also has schedule and budget pressures. In other high-risk organizations that the Board has seen, the program manager couldn't touch the Level 1 requirements. It appears that there is not enough muscle and "meat" on the right hand side (the functional side). It doesn't work the way it has been described by Mr.O'Connor. The Board is not going to tell NASA how to draw its wiring diagram, but will probably write something on the performance characteristics that should be present in the organization. The present organization is designed for efficiency and effectiveness. The Board is after safe operations. A number of forces have acted on NASA to get the organization more efficient and effective. Given the core values and mission statement, the Board is not convinced that putting all the eggs in one basket is the way to do it. Under the present structure, NASA cannot claim that the Center engineers are providing an independent look at the program. In other high-risk models, the independent body is robust and has real authority. In the case of NASA, the "second look" is essentially done in-house.

Mr. O'Connor indicated there have been iterations on this model, but the program manager has always been ultimately responsible for signing off and accepting the risk. Admiral Gehman stated that in human space flight, the AA is not getting an independent assessment from the Center Director—he is getting the program manager's input, reporting on his own contractors. The concern is that the program manager is also responsible for the budget and schedule. What the Board is suggesting is that only one of the parallel lines (the "line" organization) has real "horsepower." The whole concept is fundamentally unsafe.

Mr. O'Connor noted that NASA adopted the system that was fairly common in the aviation area. MGen Ken Hess reiterated that the issue is not where the "head" is. For example, the program S&MA person advises the program manager on the left side and gives advice on the right side. Admiral Gehman noted that roughly speaking, he agreed with the safety and independence chart. However, if the center S&MA depends on the project for funds, it is not really independent.

Mr. O'Connor emphasized that under the current organization, the program manager is (and should be) accountable for safety. Admiral Gehman opined that whoever is responsible, (either Washington level or program office), two independent and robust sets of analyses must come to him. Mr. O'Connor noted that the Program Director at NASA HQ used to own the Level 1 requirements and had the PRCB. At that time, there was enough engineering and safety support at NASA HQ to help him with his board. Admiral Gehman observed that the problem is that the person who owns the budget and schedule also owns the technical specifications and waivers. A robust engineering department at the Centers (and the Center engineers) could be responsible for their requirements and the waivers. Then, if the program manager and the engineers couldn't agree, it could be resolved at the next level. Mr. O'Connor did not agree with this model. He felt that engineering does not have the whole picture. Admiral Gehman stated that if the program manager has the responsibility, he needs to have an independent organization, not funded by the program or evaluated by the program. The Board has a problem with the way it is organized now. The program manager can trade off safety and engineering expertise against paying operations bills. Wherever it comes to a "head," whoever that is, that person needs to hear from two independent organizations that have no funding, personnel, or performance evaluation relationships with him. This does make things more expensive, and this is not good news to NASA or Congress. In the Board's opinion, the Shuttle is getting more risky, not less. If NASA wants to fly Shuttle for the long term, the entire management scheme needs to be changed. Mr. O'Connor observed that this is a major change that would have to be approached very carefully. The program manager should remain accountable for safety. He needs to have authority, responsibility, and capability.

Mr. Wallace agreed that the program manager should be responsible for the program and safety; however, at the same time, put in a safeguard so that if something is going to be waived, an independent person would do that. The "captain of a ship" model is not a good model for this type of high-risk program. This structure is why the program manager missed the extent of the problem on Columbia. The Board is finding that there are a number of technical problems that

the system doesn't appear to be paying attention to. It is partially safety, partially engineering, and a couple of other things. The authority can be given to the program manager, but under him, there must be two independent lines (independent of each other) reporting to him. Mr. Wallace noted that there appears to be a "career path" dynamic that make the safety person reluctant to go up against the program manager.

Admiral Gehman added that Code Q would be a third set of eyes, and that should be more robust also. NASA is the only center of excellence for human space flight. Part of the cost of doing business is independent analysis, robust engineering, robust safety and mission assurance. Because of resource pressure from Congress and OMB, NASA is trying to squeeze into a model of effectiveness and efficiency. NASA has been forced into a marketing style (e.g., ISS, a replacement to the orbiter, etc.). The program ends up as a marketing tool, not a product of good engineering. Mission assurance should be robust and independent. The Board has looked at several business models of how this has been done independently, and it is compelling. The safety organization is not sensitive enough to be demanding data and reviews that are statistically valid on mission assurance types of things. With respect to metrics, for example, the safety organization is not keeping track of GMIPs. These statistics need to be kept and the organization needs to delve into things and look into potential problem areas—a more robust safety organization on the government side. In response to a comment, Mr. O'Connor indicated that currently, about 95% of the safety organization is the contractor doing the job. About 5% is the government oversight.

Mr. O'Connor continued with his presentation. He reviewed the proposed changes to the Code Q organization. Admiral Gehman stated that if Code Q's job is to fulfill the core value of flying safety, Code Q should consider other assignments (e.g., safety R&D) an alien attempt to prevent Code Q from doing its mission assurance job. Mr. O'Connor indicated that this is not Code Q's job. Safety oversight of the various programs has been delegated to the program managers. The S&MA job at NASA HQ has turned into a policy/oversight job. Admiral Gehman observed that at the policy/oversight level, ~~it~~ there are some policy problems and that is Code Q's job.
HNG

In response to a question, Mr. O'Connor indicated that there is frequent and direct communication with the NASA Center S&MA directors (directors are SES level). The program manager determines how many safety people he wants and he buys them. The safety manager recommends, and the program manager negotiates this with the S&MA director. The safety manager can appeal through the S&MA director to the Center Director or Code Q. In response to a question, Mr. O'Connor noted that there has not been an appeal on Shuttle since he has been there.

Admiral Gehman observed that the S&MA function is designed to catch the tactical things; not to be a "second set of eyes" on what NASA or the program is doing. The Board has looked a little into the ASAP. The ASAP opines on things that members personally have experience with or are personally concerned about. However, they don't have the intellectual depth to build a

compelling case. Crew escape is a hot item now with the ASAP. Mr. O'Connor noted that there is no independent assessment capability at HQ; however, Code Q does pay for that elsewhere—there is a small cadre at each Center for an independent assessment team. Admiral Gehman indicated that the Board liked this model.

Mr. O'Connor showed the OSMA budget—the total budget for FY 04 is about $35 million (not including civil service). Early R&D activities for NDE are in Code R. Code Q has about $1 million for applications R&D. Mr. Wallace observed that the Code Q function is largely strategy, policy, and oversight, rather than the "final word" on "go" for the mission. The Code Q signature on the COFR means all the processes have been followed and the issues that the processes brought up have been dealt with.

Mr. O'Connor discussed the S&MA role in the COFR and cited the STS-113 COFR question on the foam at that review. With respect to reentry debris and hazard analysis, NASA had done nothing on public safety prior to the Columbia accident. Mr. O'Connor reviewed the safety policy. Admiral Gehman emphasized the importance of the second bullet on the chart—"systematically review processes and products for hazards, and address carefully all waivers and deviations to established safety, reliability, and quality requirements." In response to a question, Mr. O'Connor noted that the totality of all of the Crit. 1 waivers to requirements is laid out in the program office as part of the program documentation. The organization periodically goes back and looks at the waivers that pertain to lack of redundancy. There are several hundred Crit. 1 ~~sill~~ CIL waivers. Mr. O'Connor noted that one of the big flags is: How can the System Safety Review HW-7 Panel be more pro-active and relevant to the hazard analysis system? It should not be a reactive, paperwork drill. MGen Hess stated that anything outside of the family of accepted risk should trigger a review, and the SSRP should get involved. RAdm Turcotte added that there should be some mechanism that gets people's attention.

Mr. O'Connor discussed the Agency Safety Initiative that was started in February 1999. This has served as a good attitude adjustment for people. It does not deflect from mission assurance. The purpose of this is to save everybody's life, and doing this does not negatively affect flight safety. Mr. Wallace expressed some concern with this having a diluting effect. Mr. O'Connor noted that the PAR process is one of the more important things that Code Q does. The PAR process is direct interface to the COFR process. It prepares the AA to go to the COFR. The data elements reviewed in the PAR are all safety and mission assurance.

In addition to S&MA and return to flight activities, Mr. O'Connor added that there are things we don't know we know, i.e., the engineer at a low level knows something that doesn't get to the decision maker. Mr. O'Connor showed and explained the "risk iceberg". The "known knowns" are only 10% of the iceberg. The unknown knowns are like the unknown unknowns. Admiral Gehman stated that the Board has found a number of cases where NASA has accepted a test certificate as being tested when it has only been analyzed. Mr. O'Connor noted that within the program, there is a mechanism for communication of knowledge. We need to look at these

mechanisms to make sure they are working the way they are supposed to. Admiral Gehman raised the question about who has the job to keep the challenging unknowns, etc. alive and visible. Mr. O'Connor stated that people are doing the right things for return to flight. We need to have a strategy for the knowns and unknowns (risk management; research, test, and evaluation; and continuous process improvement). For instance, we should attack all of the models periodically.

Admiral Gehman observed that if there is an independent set of engineers and holders of requirements, there would be an independent group, independently funded, working on fixing problems. In the present system, where is this kind of independent research going to happen? Mr. O'Connor responded that this will happen at the engineering departments at the Centers. There is a good set of experience and capabilities at the NASA Centers, with links to Air Force labs, etc. We need to fire this up again. If we need to do more independent research, this will be added overhead expense to NASA. We need to put more priority on some of these things. Admiral Gehman emphasized that some of this requires continuous, daily investigation and healthy skepticism.

Mr. O'Connor highlighted some of the RTF S&MA related initiatives, e.g., improved data mining, improved independent trend analysis, human capital (job rotation and industry exchange), improved government risk analysis competence, hazard/FMEA audits, public risk assessment, etc. In response to a question, Mr. O'Connor stated that the definition of "accepted risk" is where the design does not take out a catastrophic hazard, and operations must work around it. The risk doesn't go away; there is some residual risk. For example, MMOD has been mitigated to 1 in 250 flights, and it is an "accepted risk." Admiral Gehman noted that the Board will have to have a discussion about accepted risk in its report. A layman would misconstrue the term. Mr. O'Connor added that the PRA is today's design with all of the accepted risk. It has a number (one in 250) and an uncertainty band. PRA is used by the program to do trades. The PRA identified TPA on entry as one of the biggest risk areas.

Admiral Gehman stated that the Board is looking at whether the system can be designed so that even if a person makes a mistake, there is a systemic backup that would prevent a catastrophic event. This is why the Board is pushing on the systemic processes and structure. With respect to rumors and morale within the Agency, Admiral Gehman suggested that NASA try to promote from within; this indicates confidence in the workforce. Bringing in outsiders to fill positions gives the opposite message.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 19, 2003
These Minutes Contain No Sensitive Data

This meeting was adjourned at 1300.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 19, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-8499
MGen Ken Hess	CAIB	703-416-8481
RADM Steve Turcotte	CAIB	703-416-3015
Steve Wallace	CAIB	703-416-8405
Steve Schmidt	CAIB	703-416-8488
Ltc Rick Burgess	CAIB	703-416-3292
Ltc Don White	CAIB	703-416-3225
Col Don Pitts	CAIB	703-416-4469
Dr. Jim Bagian	CAIB	281-416-3491
Dwayne Day	CAIB	281-416-3491
David Onkst	CAIB	
Frank Buzzard	CTF	202-358-1401

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 23, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Meeting

Date: June 23, 2003 **Time:** 1300 – 1745 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 800, Collbohm Room).

The agenda is appended to the end of this report

The list of attendees is appended to the end of this report.

There were two action items generated from this meeting that is list in the main body of the minutes.

Revision 7 Outline Discussions

Regarding the inputs, Admiral Gehman noted that there were good, thoughtful pieces, with lots of overlap. Chapter 6 (expanded model of causation) is still out, but it is coming along. It will be one of the key pieces. We have begun to conceptualize what draft 2 of the report will look like. Dr. Diane Vaughan provided some input on how the report could be improved, and it was worked on for clarity purposes. When the next review is posted, the Board can start with the cover page and work all the way through. Dr. Vaughn recommended having sections or parts. The outline has been reformatted in this manner. Part 1 is "What happened?" (Chapters 1, 2, 3); Part 2 is "Why did it happen?" (Chapters 4, 5, 6 plus an additional section at the end of 6—Vaughan is researching the issue of the history of NASA as another factor); Part 3 is "The future" (chapters 7, 8, 9). Chapter 10 is presently the investigation; this would move to be Appendix A.

The biggest changes are in Chapters 5, 1, and 4. Section 5.3 was the most important part and was broken into two sections. In Chapter 1, the proposal is to take the requirements up to Challenger, with Chapter 4 picking up the Shuttle program in the modern era (post Challenger). Dr. Vaughan suggested a new chapter (Chapter 7). Dr. John Logsdon noted that Chapters 4.2 and 5.1 are detailed discussions on the vulnerability in the design. If these are put in Chapter 1, it would be a fairly long section. Admiral Gehman stated that putting the accident in context is crucial. Dr. Sheila Widnall noted that Chapter 1 could be brief and all of the substantive material could be put in Chapter 4. Chapter 4 shouldn't be constrained to post Challenger. Dr. Logsdon felt that Chapter 1 should lay out the myth of what Shuttle should be and how it was shattered by Challenger and now Columbia. Dr. Doug Osheroff noted that there were a lot of things in the Shuttle program that should have been changed and that weren't changed. Admiral Gehman observed that the history starts back in the 1960's, but most of what the CAIB report will talk about starts with post-Challenger. NASA implemented some things, but the changes atrophied

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over time. However, as a report card, the CAIB has not addressed all of the actions that were recommended by the Rogers report but were not done post-Challenger. Dr. Logsdon commented that the attention shifted, even pre-Goldin. A goal was set to cut Shuttle cost 3-5% a year for 10 years. Admiral Gehman proposed waiting until draft 2, then take the Rogers Commission as a template and look at the CAIB report retrospectively and see how close it comes to doing a report card on Rogers.

In the Board's Statement, there is a discussion on the Board approach, the hierarchy of findings, etc. There will be a paragraph describing what Part 1 is. The first part of the Executive Summary could be the Board philosophy.

Summary action: Better define what Chapters 1 and 4 do.

There will be findings and recommendations in each chapter. Dr. Vaughan thinks there is a case to be made to have historical causal factors." Admiral Gehman noted that Chapter 3 also has a discussion of all factors, including those that are not causal. Dr. Vaughan thought this was worthy of a separate chapter. We need to lecture them about the process of replacing the vehicle—NASA should decide what it wants the Shuttle replacement to do—its objectives, etc. before designing the vehicle.

The next draft of the report will follow this outline [shown at the meeting]. Draft 2 will be in a separate folder and it will be much easier reading for the Board.

With respect to the report itself, the graphics and layout people are at work. [Draft versions of a report cover was distributed]

Issues: the title ["Columbia Accident Investigation Board Report," dark vs. light cover, stars (constellation *columba*) vs. no stars. The Board selected stars w/dark blue cover. Regarding the text layout, the Board approved the simplest one—allowing most words on page, double column, 10 pt font.

Action: Board members who are putting Word graphics, photographs, etc. into their inputs—these are not high resolution enough for printing. Please find the originals and submit them to graphics or give directions on where to go to get them.

Schedule:

July 23 – paper copy ready for press and to go to printing. Mr. Dennis Jenkins noted that July 10 is the last day for change/input to text (after some discussion, he indicated that the last few pages can be on 7/11). The Board must sign NLT 7/11. (For input after that date—there will be a text box held for "grab and replace.") Revision 2 should be at the 90% level. Dr. Widnall will continue to work 3.6 and push that. Roll out day will be July 23 or 24. Admiral Gehman would

like Board members here for "fan out" to Congress, White House, NASA, etc. Some people will be delegated to go to Houston and deliver the report to the astronauts and families. The White House representative (Mr. Brian Montgomery) and the Senate representative have been asked for their preferences regarding rollout of the report. Board members being paid will terminate employment at the end of July, but the Board will still officially be constituted and travel will be covered. The residual Board (Admiral Gehman, etc.) will still be working for about 2 months after the roll-out of the report, there will be an office setting with support, including people to help the Board prepare statements, etc. The Valador people (research assistants, etc.) will not be needed after 7/11.

Crew matters

There is no place in the report that says how the crew died. Do we need to say something? Dr. Jim Bagian and Admiral Gehman will have a telecon re this subject later this week. They considered having a true, but rather bland statement – e.g., the crew died of injuries typical of people ejected at high velocity. Does this need to be in report? Is it complete if report says nothing? The Board agreed that the report needs to say something—brief, no details.

Which are the Real Stories?

The foam? The emails? The witness statements? Or the other way around—the organization, the management issues, risk assessment, etc.?

The Board felt that the management structure and decision-making is the "story;" the other things illustrate the problem. The proof of the Board's story is why the in-flight anomalies (IFAs) go away. Mr. Steve Wallace suggested telling the factual story (foam, etc.), and this paints the picture of the management mindset, etc. The solid rocket booster (SRB) O-rings is another example. In this respect, the parallels between Columbia and Challenger are striking. If the management is not fixed, other things will pop up in the future. Mr. Roger Tetrault observed that NASA can fix the foam issues; if the cultural issues are not fixed, there will be another accident. Dr. Logsdon commented that the question is how to tell the story, e.g., inductively? Layer the evidence so that the conclusion is apparent. MGen John Barry felt that the story should start with what killed the astronauts. Start with the beginning piece, which is the tip of the iceberg. Admiral Gehman noted that structurally, the outline reflects telling the story in this manner. However, the real message is not the foam or emails; the real message is the organizational and management problems. Dr. Osheroff observed that the "constrained box" analogy (the reason for the failed Mars missions) works for also manned space flight—the deals that NASA struck in getting Shuttle (and Station) put them in a box.

Mr. Scott Hubbard brought up the issue of the reinforced carbon-carbon (RCC) panel test vis-à-vis the report schedule. There is a plausible failure scenario, but we don't have the breach. We have a flight panel we are going to test. Mr. Wallace noted that without the nondestructive

evaluation (NDE), we will be in a condition that NASA says is flight worthy. Dr. Osheroff commented that we can't prove that Columbia's panels were in bad shape, but Mr. Turcotte noted that previously, NASA would track any damage on the panels; that was turned off in the 1990's. We got a panel from OV-102 (after 16 flights) that showed pinhole damage. Dr. Logsdon suggested that we test an RCC panel that is as close to perfect as it can be. It provides one more piece of baseline. Mr. Hubbard noted that we are trying to duplicate as closely as possible the accident that we saw; that is why we insisted that they use a 26-flight panel along with the system. We can do instant reporting of the most obvious things, but cannot do a proper analysis in a 24-hour period. There was Board agreement to shoot without the Computed Tomography (CT) imaging; however, if they find any anomalies with the other three tests, then they should do the CT scanning.

Admiral Gehman summarized: Management, risk assessment, safety issues will be the bottom line. The other elements (the foam, etc.) are the supporting pieces of evidence. In a few places, there are summary paragraphs that are very compelling.

Other editing comments:

Admiral Gehman noted that 5 of the 7 bipod ramp sheddings were on Columbia missions. This can't be a coincidence. Dr. Osheroff opined that it has to be something to do with the Columbia. MGen Barry noted that they tried to find a common element, but couldn't find one through all seven flights. Admiral Gehman observed that the Board finds this to be a remarkable coincidence, and it is astounding that NASA hadn't addressed this. This is an example of the lack of healthy curiosity and engineering skepticism. Dr. Osheroff commented that there is either an incredible coincidence (unlikely) or there is some correlation that NASA didn't appreciate. RCC panels 8 and 9 were struck before on previous flights. Dr. Logsdon felt that if we don't understand what the mechanism is, then it can't be avoided. MGen Barry noted that there are manufacturing and application defects. We are left with vibrations, aerodynamic forces; it is not definitive. Dr. Osheroff indicated that it probably has to be a combination of weak foam and something else (e.g., sloshing in the external tank). The mass of Columbia may have pushed the overlap of these factors. MGen Barry posed the questions: How many times were they up against the boundary layers? Why was Columbia working harder than the other orbiters? All we have today is manufacturing and application defects and vibrations and aerodynamic forces.

Chapter 10: There is a slot left for group methodology. Were there differences among the groups that are worth mentioning? The Board's consensus was to eliminate this section.

Other editorial comments: Use of CAIB or "the Board." Wherever the report makes reference to findings and recommendations, use "the Board." Acronyms: introduce once, make them clear; however, the acronyms should be reintroduced in every chapter.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 23, 2003
These Minutes Contain No Sensitive Data

[Executive session: no notes]

Interim Recommendations:

Preliminary interim recommendation #3 (On-orbit/on-station TPS inspection and repair capabilities) was reviewed. Mr. Wallace is going to make some minor changes to the recommendation and it will be reviewed at the next Board session for approval. It was by unanimous vote by the board members to approve this recommendation. Preliminary interim recommendation #4 (Launch and Ascent Imaging) was reviewed. Mr. Wallace indicated the recommendation should be broken into two separate recommendations – one recommendation for ascent and another for on-orbit. These recommendations will reviewed by the Board at the next session. Mr. Wallace said that not all interim recommendations are return to flight (RTF) recommendations. Admiral Gehman commented the two recommendations submitted by BGen Duane Deal (Foreign Object Debris Characterization and KSC Quality Program Review) are not RTF and would be included in the final report.

This meeting was adjourned at 1745 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 23, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-8499
MGen John Barry	CAIB	703-416-3570
Steve Wallace	CAIB	703-416-8405
Roger Tetrault	CAIB	703-416-3591
RAdm Steve Turcotte	CAIB	703-416-3015
Dr. Jim Hallock	CAIB	703-416-3272
Dr. Sheila Widnall	CAIB	703-416-3445
Dr. Doug Osheroff	CAIB	703-416-3490
Scott Hubbard	CAIB	703-416-3109
Dr. John Logsdon	CAIB	703-416-3057
Steve Schmidt	CAIB	703-416-8488
Paul Wilde	CAIB	703-416-3367
Mike Bloomfield	CAIB	281-483-7809
Dennis Jenkins	CAIB	703-416-3373
Chris Kirchhoff	CAIB	703-416-3121
Les Reingold	CAIB	703-416-3551

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 24, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Meeting

Date: June 24, 2003 **Time:** 1500 – 1600 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 800, Collbohm Room).

The agenda is appended to the end of this report

The list of attendees is appended to the end of this report.

There was one action item generated from this meeting that is list in the main body of the minutes.

Admiral Gehman reviewed some administrative matters:

- Mr. Steve Wallace's next draft of recommendation #3 will be available either tonight or tomorrow morning.
- The Senate submitted questions for the record [these were re-directed to Board members to handle].
- We are in phase 2 of the editing process. The 2nd review will go relatively quickly. In the first draft, there were some comments regarding getting graphs, numbers, etc. There needs to be a point person from each group that the editorial board can talk to. Group 3 nominated Ltc Pat Goodman. Group 4's person is Dr. Dwayne Day. Who are the designated people from the other groups?
- Some entirely new sections have been submitted on sections that have already been reviewed. These will be returned—make your recommendations on the second draft. Due dates are still the same. Things still coming in now (e.g., Chapter 6) will get posted as if they are in the second draft.
- The editorial board says that we can't make July 23 for rollout; however, we will go as fast as we can. Text of the report will be done middle of July.

NDE issue

The CAIB Interim Recommendation # 1 said that NASA didn't understand the hidden characteristics (strength) of the reinforced carbon-carbon (RCC), and that they should go back and characterize the material. NASA is pushing back on this.

MGen John Barry noted that the nose cap is the tall pole in the tent. Since STS-103 (Discovery) was in Orbiter Major Modification (OMM), NASA wanted to pull off the nose cap and do a full nondestructive evaluation (NDE). In the course of doing this, they discovered a tubular void in the 1100 position of the nose cap. This flaw existed at production and wasn't caught (flown 30 times). NASA pushed back and thought they could continue. They felt that if Discovery was good, they could go forward. NASA doesn't want to pull nose cone on Atlantis. However, they did an eddy current and discovered that the silicon carbide coating was out of spec (it is less than .040 mm). On Monday, NASA will formally brief the Board on the issue. Another issue is the material requests (MRs – return to proof) on Atlantis that were approved by the vendor. In addition to silicon carbide issue, there is an issue on where the tee seal and nose cone connect. There is a briefing on the technical issues on Atlantis; right now, no one is feeling comfortable about not taking the nose cone off Atlantis. The fix will push the launch date to next summer instead of the February/March date.

Admiral Gehman observed that there are other ways around this. The basis of Recommendation # 1 was that NASA didn't understand the characteristics of the material. The Board's basic assumption was true. The policy issue is that the Board is not the enforcement mechanism. However, the Board's first recommendation is well founded.

MGen Barry noted that Tom Stafford will be here on Monday and will hear the intent of the Board. NASA is sending the panels to Dallas; they will do the tests, including thermography, on all of the panels. If any of them show an anomaly, they will do a Computed Tomography Imaging (CAT scan). The Board will send a representative to the factory to monitor the process.

Dr. John Logsdon suggested that Mr. Stafford have a representative attend the Board meetings on an as needed basis.

Admiral Gehman summarized that the Board will continue to press NASA to understand the material of the flight articles.

<u>Test and Analysis remaining open items</u>

Matrix – Rev. 7:

- Dr. Sheila Widnall indicated that the aerothermal analysis will be signed off.
- Mr. Roger Tetrault reported that the arc jet testing started last Friday, and they got unacceptable results.
- They have taken the test out and have put in some return to flight (RTF) issues. They should talk about this on Thursday. It is still an open item.

- The cryopump testing still open—8 and 9 should be done this week.
- Testing of bolts is still open.
- Bolt catcher test is still open.
- Debris modeling still open.
- JASONS work is complete.

Summary: There are five test and analysis items still open.

RFI remaining open items

- Dr. Widnall stated that both of her items are essentially complete.
- MGen Barry noted that the 13 open in his group are all valid.
- Admiral Gehman noted the B2 and B3 actions—review these and close out. If any of these are critical to the report, please pull them out and let him know about it.

Action for group leads: close out the ones that you are satisfied with; notify Mr. Steve Schmidt for the record.

Other outstanding issues: the common thread on the 7 foam events

MGen Barry noted that we still don't have a good answer on why the foam comes off. He asked advice from the Board on a direction to put a working group together to go over all of the data and try to identify some common thread other than manufacturing defect. RAdm Steve Turcotte opined that it could it be a harmonic resonance problem. Dr. Doug Osheroff noted that it happens on Columbia and not on the other orbiters. One of the questions is: There aren't going to be any more bipod ramps—how important is it? Dr. Osheroff stated that there is still foam elsewhere--are we exceeding the limits of the foam? Mr. Tetrault indicated that we don't know how important it is until we get the answer. Admiral Gehman noted that this is a compelling reason why it should be in the report and that the Board should stay on it. They have done some work, but have not found the common thread. MGen Barry added that they have not given us the 2-sigma answer (how many times did they push up against the 2 sigma?). Admiral Gehman observed that this is indicative of lack of engineering inquisitiveness.

There was Board consensus that this is an incomplete project. The Board does not have any confidence that NASA understands the foam. MGen Barry suggested that the Board direct them

to assemble a team to look at all of the data—the "foam detective story." Admiral Gehman indicated that he would direct NASA Accident Investigation Team (NAIT) to do this if the Board felt that it should be done. The Board is not satisfied that NASA understands the characteristics and mechanisms of the foam. It should be a RTF issue because there are other large pieces of foam that might fall off. We have proof that the foam can kill a vehicle and NASA does not understand the foam. Dr. Jim Hallock observed that the answer may be different depending on where they look. MGen Barry added that currently there are two potentially contributing factors that are on the overall tree and 17 items that cannot be closed.

In summary, Admiral Gehman indicated that he would tell NASA to keep working on it.

This meeting was adjourned at 1600 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 24, 2003
These Minutes Contain No Sensitive Data

AGENDA FOR TUESDAY 24 JUNE

29 DAYS TIL ROLLOUT

8:00 AM LINE UP

8:00 – 8:30 AM: Morning tag up meeting

8:30 – 2:15 PM: Group caucus and individual work

1:00 – 2:30 PM PRESS CONFERENCE

3:00 PM BOARD SESSION:

1. NDE issue
2. NASA personnel issues
2. Test and Analysis remaining open items
4. RFI remaining open items
5. Misc Board matters
6. Report outstanding issues

This week (6/23 – 6/27) all CAIB meetings will be in the Collbohm Room located on the 8th floor. There are some guidelines that we are required to follow:

- The Collbohm Room will be open from 0730 - 2000 each day
- **Do not** wander back into the Conference Center because there a classified conference in progress
- Staying within the confines of the Collbohm room and immediate area, has allowed us to forgo conference badging and signing in each day
- The Reception Desk is responsible for the entire Conference Center and is required to stay in the Center

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 24, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-8499
MGen John Barry	CAIB	703-416-3570
MGen Ken Hess	CAIB	703-416-8481
Steve Wallace	CAIB	703-416-8405
Roger Tetrault	CAIB	703-416-3591
RAdm Steve Turcotte	CAIB	703-416-3015
Dr. Jim Hallock	CAIB	703-416-3272
Dr. Sheila Widnall	CAIB	703-416-3445
Dr. Doug Osheroff	CAIB	703-416-3490
Dr. John Logsdon	CAIB	703-416-3057
Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-483-7809
Dennis Jenkins	CAIB	703-416-3373

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 25, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Meeting

Date: June 25, 2003 **Time:** 0900 – 1130 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 800, Collbohm Room).

The agenda is appended to the end of this report

The list of attendees is appended to the end of this report.

There were no action items generated from this meeting.

Preliminary recommendation # 3: On-orbit/on-station TPS inspection and repair

Mr. Steve Wallace reviewed the proposed changes: Wording changes were made to second bullet under FACTS and the first bullet under DISCUSSION. The Board agreed to take out 4th bullet of the original four-part rationale under DISCUSSION. It was noted that the first 2 points are not discussed in this recommendation. Admiral Gehman indicated that the same three-point sentence in the DISCUSSION will be used in the other recommendations. Mr. Wallace noted the changes made to the last bullet in the DISCUSSION (an inspection of the thermal protection system (TPS) accomplished as soon as possible after achieving orbit). Under RECOMMENDATIONS, the on-orbit TPS inspection was added. The last bullet was dropped (redundant).

Preliminary Recommendation #4: Ascent Imaging

Mr. Wallace noted the ground-based imaging has been decoupled from those things ascending. This is the ground-based recommendation. Ultimately, there may be a grand title of IMAGING, with three elements under it. "Ground-Based" was inserted in the title of this preliminary recommendation.

Under FACTS, bullet four should say camera "sites". There are multiple cameras at each site. At the 81 second point (when the foam came off), there were only two cameras that saw that event. Mr. Scott Hubbard suggested adding a phrase to say "two ground-based long-range camera sites provided data that was useable for evaluating…". The purpose of the fifth bullet in the DISCUSSION is to say that high quality images are needed. Admiral Gehman noted that in this case and in general, the lack of good imagery hurts the decision-making process. Good imagery is needed to assess the severity of the strike. Mr. Hubbard commented that nowhere do we talk about the quality of the imagery. Admiral Gehman stated that camera work on previous

flights has not been evaluated. This recommendation only talks about STS-107 (Space Transportation System –107). The bullet was reworded to be specific about STS-107 and the lack of quality imagery (bullet #6). Admiral Gehman indicated that we want to be able to evaluate the damage and make an assessment about successful re-entry. The genesis of this issue was a discussion in which it was reported to the Board that the camera with the "best look" angle to evaluate post-strike damage was out of focus. The Board felt that there shouldn't be a single point failure like this. The ability to validate models will be a separate bullet. A sentence was added to say that a third camera that would have provided a better view was unusable.

Under DISCUSSION, the third bullet in the DISCUSSION was modified to change "civilization" to "urban" and delete "issues". The "existing assets" are camera sites. Dr. John Logsdon noted that nothing has been added to the assets to provide meaningful imaging for launches to the ISS orbit. Admiral Gehman suggested that the fourth bullet be strengthened. The imaging system has not been upgraded to take into account the International Space Station (ISS). (This bullet will be further "wordsmithed.") Under FINDINGS, Dr. Doug Osheroff suggested using "high-speed, high-resolution cameras," and leaving "temporal and spatial imagery data" in parentheses.

Admiral Gehman observed that there were too many RECOMMENDATIONS; there should be only two or three. Regarding the first bullet, the Board agreed to specify three useful views. The first bullet refers to the capability; the second bullet addresses the correct paperwork. The first two bullets should be combined into one recommendation, and strengthened (use "must" instead of "should"). The Board agreed to delete the third bullet. Admiral Gehman noted that the first bullet does not preclude night launches. The first sentence should address the capability of the range (the imaging system), and not address weather limits, day/night, etc. As worded, the fourth comment is gratuitous advice and is not a solid recommendation. It could be put into the findings or the text of the report. The recommendations should be a "to do" list. The Board agreed to delete the fourth recommendation regarding night launches. The last bullet addresses providing offshore mobile assets to provide additional views of the Shuttle during ascent. Admiral Gehman noted that the intent is not to change the weather criteria; the recommendation is addressing the imaging system.

Preliminary Recommendation #6: On-Board Imaging

This recommendation refers to having cameras on-board. "Stack" was eliminated from the first bullet under FACTS. "Shuttle" is the common term for the orbiter. If pictures are wanted for all three components (external tank, solid rocket boosters, and orbiter), the collective term should be "Space Shuttle System." Admiral Gehman posed the following questions: Want do we want pictures of? Where do we put the cameras? A piece of hardware (camera) on the nose would be another hazard. MGen John Barry noted that there is a request for information (RFI) issue on STS-112; there is film, but it is blurred (the lens was coated). Everything that the Board has been concerned about happens prior to 2 minutes into flight. The Board wants images of the

underside of the orbiter and the corresponding side of the external tank. If the camera is attached to the external tank (ET), it must be downlinked. Dr. Jim Hallock noted that two umbilical cameras are used now (on the belly of the orbiter), but they are film, not downlinked. These are these useful for determining foam shedding, but only after the orbiter's return. Mr. Wallace indicated that the current camera provides crystal clear images; we should be careful not to eliminate this. Mr. Dennis Jenkins noted that there have been several positions have been considered on the ET. There are alternatives. There are positions where the cameras could be mounted looking through a window, with a real-time downlink. Admiral Gehman summarized that generically, the Board is recommending two things: (1) turning one of the two umbilical cameras (the digital) into a downlink camera; and (2) adding additional cameras to get a better view of the leading edge of the wing. He also noted that the crew cameras have not been addressed in this recommendation. For the crew cameras, there are two issues: (1) they should be high resolution, digital, and downlinked; and (2) there should be vacuum-certified cameras for use by extravehicular activity (EVA) crewmembers. This would be a useful recommendation and should be in the report.

After discussion, the Board agreed that the first bullet of the RECOMMENDATIONS should specify <u>what</u> we want them to take a picture of—downlinked, external imagery of the leading edge of the wings and the underside of the orbiter (the sensitive areas that see the most heat). It should not tell them <u>where</u> to mount the cameras. The intent of this recommendation is an alerting/detection process. The action in process (NASA Program Requirements Control Board Directive – PRCBD) will be put into the discussion. The Board discussed whether or not to recommend images of the nose cone. The degree of difficulty in imaging the nose cone would be greater. Anything that could image the nose cone would be mounted on the ET and could create an additional hazard. The Board decided to keep the scope of the recommendation on the wings and underside of the orbiter.

Admiral Gehman indicated that the revised recommendation #6 would be circulated to the Board members.

Preliminary Recommendation # 5: Foreign Object Debris Characterization

Admiral Gehman observed that at the Kennedy Space Center (KSC), they use two different definitions for debris—the industry definition, and "processing debris"—chips, metal shavings, etc., on the floor that are cleaned up when the task is completed or at the end of the day. Processing debris is allowed to lie around until completion of the task or the end of the day. RAdm Steve Turcotte noted that clean up should be "clean as you go". This is so glaring that it needs to be corrected for return to flight. Admiral Gehman stated that this is easy to fix, but it will take a long time to indoctrinate all of the workers. Mr. Hubbard added that this will be a change to the contract, and there will be a cost impact. RAdm Turcotte also commented that the contractor is pretty good at the launch pad. In response to a question regarding why the definition was changed, RAdm Turcotte indicated that he has not been unable to determine why.

Admiral Gehman concluded that this is an issue. More research needs to be done on it and an updated version of the recommendation will be circulated to Board members.

Causation Statement

This will be the introduction (first line) to chapter 3. Admiral Gehman noted that one of the underlying foundations of the report is that the management practices are just as much to blame as the foam. The Board agreed to use "physical cause" in this statement. The ramp is the foam; the correct term is the bipod attachment point, but the Board agreed to eliminate "point" and say "foam debris from the last bipod attachment ramp broke off at 81.7 seconds". The Board modified the statement to add words regarding "best available evidence" that led the Board to its conclusion. The damage allowed hot gases to enter the leading edge cavity. The damage caused by the incursion of the hot gas progressively worsened, breaching the leading edge spar, and migrating into the left wing interior, eventually deforming and weakening the wing... The Board agreed to change "catastrophically disintegrate" to "break up." This causation statement is a finding.

Comments regarding schedule:

Admiral Gehman reported that the publisher has indicated the final document cannot be produced by July 23. He emphasized that regardless of that, there is now a time schedule for the Board. By tonight, the four parts will be up for review. By Friday, Chapter 1 will be out; by Tuesday, Chapter 2 will be out. The second revision (draft 2) will be easier to read. On 7/11/03, the Board will sign the signature page and the second draft will be completely out. Realistically, the Board will need to meet one more time after that.

This meeting was adjourned at 1130 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 25, 2003
These Minutes Contain No Sensitive Data

AGENDA FOR WEDENSDAY 25 JUNE

28 DAYS TIL ROLLOUT

8:00 LINE UP

8:00 – 8:30 AM: Morning tag up meeting

9:00 - 1200 BOARD SESSION:

1. Review Interim Recommendations

    a. Rec #3 - On-orbit/On-station TPS Inspection & Repair Capabilities
    b. Rec #4 - Launch and Ascent Imaging
    c. Rec #5 - Foreign Object Debris Characterization

2. Causation Statement

3. Report Editing - TBD

This week (6/23 – 6/27) all CAIB meetings will be in the Collbohm Room located on the 8th floor. There are some guidelines that we are required to follow:

- The Collbohm Room will be open from 0730 - 2000 each day
- **Do not** wander back into the Conference Center because there a classified conference in progress
- Staying within the confines of the Collbohm room and immediate area, has allowed us to forgo conference badging and signing in each day
- The Reception Desk is responsible for the entire Conference Center and is required to stay in the Center

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 25, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-8499
MGen John Barry	CAIB	703-416-3570
MGen Ken Hess	CAIB	703-416-8481
Steve Wallace	CAIB	703-416-8405
Roger Tetrault	CAIB	703-416-3591
Scott Hubbard	CAIB	703-416-3109
RAdm Steve Turcotte	CAIB	703-416-3015
Dr. Jim Hallock	CAIB	703-416-3272
Dr. Sheila Widnall	CAIB	703-416-3445
Dr. Doug Osheroff	CAIB	703-416-3490
Dr. John Logsdon	CAIB	703-416-3057
Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-483-7809
Dennis Jenkins	CAIB	703-416-3373
Paul Wilde	CAIB	703-416-3367
Jim Mosquera	CAIB	703-416-3296

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 26, 2003
These Minutes Contain No Sensitive Data

Purpose: Briefing to Board: Strategic Management of Human Capital – Vicki Novak, Assistant Administrator for Human Resources and Lynn Cline, Deputy Associate Administrator for Space Flight

Date: June 26, 2003 **Time:** 0900 – 1015 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 800, Collbohm Room).

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the DOJ CDS database.

There were no action items generated from this meeting.

Ms. Vicki Novak commented that NASA faces a number of external and internal challenges that are impacting the ability to recruit and maintain a skilled workforce. External factors include a shrinking scientist and engineer (S&E) pipeline, increased competition for technical skills, and lack of diversity in the applicant pool. Contributing to this challenge are demographics and trends within NASA such as skills imbalances, lack of depth in critical competences, and significant loss of knowledge due to project retirements. Within the last year and a half, NASA has been focusing on these challenges. The Strategic Human Capital Plan will help deal with the issues. Ms. Novak showed a graphic depicting the decreasing undergraduate engineering enrollment. At the same time, there is an increase in employment opportunities in the national market. MGen John Barry commented that the Air Force Materiel Command (AFMC) is having the same problem. There may be some common benchmarking. Ms. Novak indicated that this would be a good idea and she would like to hear what that organization is doing.

The average age for the S&E workforce is mid-forties. There are almost 3 times as many S&E's over 60 years as under 30 years. It would take about 5 years of sustained, aggressive hiring to balance these numbers out. Currently, the retirement eligibility will rise to about 30% in the next 4 or 5 years. In the 1990's the workforce decreased about 25% due to downsizing initiatives during the last administration. The downsizing was particularly targeted in four administrative areas: budget, finance, procurement, and human resources. In addition, there was a goal to take out a layer of middle management across the board. Unfortunately, the Agency lost some people it shouldn't have lost. In 1999, NASA started recognizing that it had gone far enough and started hiring. The Agency is now looking very carefully at the workforce and will be using buyouts, etc. for specific, targeted areas.

CMM010-0019

All of this experience led the Agency to take a more strategic look at the workforce. About a year and a half ago, a group of senior management reviewed the data and issues and did a gap analysis to determine where the Agency was weak and where the workforce needed to be improved. The work plan was built around 5 pillars: strategic alignment, strategic competencies, learning, performance, and leadership. Nine improvement initiatives were identified. Ms. Novak talked about a few of these initiatives. The Office of Management and Budget (OMB) and the Office of Personnel Management (OPM) are looking closely at all agencies and have indicated that NASA is leading in several areas. NASA has recognized that its workforce planning capability needed to be improved. There wasn't a strong planning capability across the agency. A Web-based set of workforce analysis tools have been developed and made available to the field Centers. This is being coupled with the Agency competency management system. Across the board, competencies have been identified and for the first time, competency gap areas are being highlighted. The next step is a targeted recruitment program. There are a number of co-op programs and education programs. This strategic management plan will ensure that NASA education programs match a diverse population of students with projected NASA workforce needs. Competency bases will be tracked at the program and project levels. Another initiative, to increase utilization of flexibilities and tools, has resulted in delegation of tools to field Centers. In addition, legislation has been introduced in the human resource areas that would make hiring and attracting people easier. This year, NASA has been more successful with the legislative proposals. There will be a full Senate vote in the next few weeks. On the House side, representatives have introduced human capital legislation. NASA is optimistic that it will get something out of these actions. Ms. Novak showed some of the legislative proposals in the bills. The Scholarship for Service is a program whereby NASA pays for scholarship and the student comes to work for NASA. A number of the proposals would make it easier to hire, e.g., bonuses, enhanced travel and leave benefits for new hires. MGen Barry encouraged Ms. Novak to get in touch with the Air Force research laboratories. In Oklahoma, a great partnership is being done with the state legislature. He indicated that he would give Ms. Novak some contacts. There are a lot of initiatives for S&E. Novak noted that the Department of Defense (DoD) is pursuing its own legislative initiatives and NASA would like to have some contacts.

Over the last year, Human Resources has been focusing on mentoring and training. Program Manager training is done at the Wallops Island facility as well as around the country. There is heavy participation in this. Also, Human Resources has been working on "knowledge sharing" and there are some new programs that take the younger program/project practitioners and team them with the older, more experienced ones to talk about lessons learned, etc. The intent is to get a more robust knowledge-sharing program. MGen Barry noted that NASA does a good job at program manager training; what is lacking is training in system integration—we don't train people to be system integrators. He encouraged Ms. Novak to take a look at this area. A "college" on system integration is being put together at Wright Patterson Air Force Base. The Defense Systems Management Course (DSMC) would also be a good course to send people to. The Air Force has discovered that a lot of the fault with programs lies in the lack of systems integration training. Ms. Novak indicated that she would look into this.

The last initiative is leadership development. One of the problems is mobility. One of the things that Human Resources is doing is pushing the envelope on mobility, much differently than before. New criteria is being developed for entry into the Senior Executive Service (SES)—it will say that formal training (outside of NASA) and demonstrated multi-organizational experiences are important. The message that is being sent out is that if a person is aspiring to be in SES, that person should be willing to be mobile (temporary or permanent). Mr. Steve Schmidt commented that a six-month tour does not seem to be long enough. MGen Barry added that in the Air Force, the SES people are being moved every 3 to 4 years. One of the understandings for the SES promotion is that people have to accept this. Ms. Novak noted that this must be a gradual change for NASA, but the Administrator wants to get to where the Air Force is. In order to be competitive for the SES corps, there must be some diversity. She noted two sides to the problem: there are employees who don't want to move, and their supervisors who don't want them to go. NASA has to deal with the issue on both sides. However, the Agency is moving toward a more mobile workforce. There are some good leadership development programs in NASA. Also, a lot of money is being put into the fellowship programs. Human Resources is trying to push people outside of the NASA "comfort zone." Barry observed that the astronaut corps are very bright and talented people. One of the things that came out of Challenger was to put astronauts in management positions. This has been done; however, the astronauts are not being trained for it. The second issue has to do with the engineers. At NASA, it is difficult for PhD engineers to be program managers. They end up working for engineers younger and much less experienced who happen to have management degrees. This is creating issues that the Agency needs to address.

Ms. Lynn Cline talked about the Space Flight Enterprise (SFE). It includes Shuttle, International Space Station (ISS), launch services, space communications, and advanced systems. The Johnson Space Center (JSC), Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC), and Stennis Space Center (SSC) report to the SFE. Ms. Cline showed the S&E age distribution at these Centers. The SFE must address the depth in critical skill areas and workforce demographics. The tools being developed by Human Resources will be very useful. SFE is working on establishing succession planning—where the pipeline is coming from. It has moved a number of people around, but there is a lack of "heir apparent" for certain positions. The senior management has discussed succession planning. The larger Centers understand who they have and who is coming up the pipeline, but SSC needs to be focusing on GS 14's and 15's. With the Integrated Space Transportation Plan (ISTP) and the intent to fly the Shuttle longer, it became clear that SFE needed the Shuttle Life Extension Program (SLEP) and the workforce to go with it. Ms. Cline showed the critical skill areas. The SFE is trying to understand the depth that it has in each area in individual programs and at individual Centers. Within the SFE, a program has been put in place for executive development. It is intended to identify key leaders in the Enterprise and provide them mobility. The Center Directors have been asked to identify key positions that would be excellent opportunities for an SES manager to come into on a year's assignment. At the same time, they were asked to look at their SES personnel and identify the

"rising stars" and future leaders on behalf of the entire Enterprise. This was initiated at the SFE Board of Directors retreat. The Center Directors described positions and shared information. Human Resources is now looking at the pool of candidates. Ms. Novak noted that this particular program takes people in the SES who are looking for developmental opportunities. This might be implemented on an Agency-wide basis. MGen Barry commented that the Air Force has made a lot of progress on the SES and is are now looking at the pool of GS-14's and 15's to get them the right training and rotational experiences. Ms. Cline noted that the senior management at the Centers recognizes the advantage of mobility; the question is how to phase it in. MGen Barry noted that they have had the same issue in DoD. Ms. Novak stated that the message needs to get clearly delivered as to what the rules are.

The SFE wants to strategically plan how the fresh outs come in and are placed in the best opportunities for the long run. SFE also wants to take advantage of workforce flexibility by utilizing short-term hires, temps, and interns. In the past, the approach has been the Centers reporting to the Associate Administrators (AA's), and the AA's reporting to the Administrator. SFE is trying to clearly define the role of the Center Director, the Program Manager, etc., and the reporting channels. Everyone needs a common understanding of how they work and support each other. Another thing that the organization is trying to do is make sure that there aren't "stovepipes" of programs and institutional investments. A more integrated view is needed across the Enterprise. Because the Enterprise does a lot of support for the Space Science, Earth Science, Biological and Physical Research, as well as DoD, SFE wants to manage those relationships so that a Center or Project is not trying to manage things piecemeal.

MGen Barry commented that the Enterprise focus is exactly right—it is a cross-cutting element. One of the key points is integration—this is sorely lacking in the spaceflight arena. SFE must get rid of stovepipes. The integration must be horizontal—at lower as well as upper levels. The Board will offer some ideas, but not tell NASA how to do it. Mr. Bill Parson's idea was an Integration Office (about 20 people), including contractor people who integrate the Space Flight Operations Contract (SFOC) with other parts of the Shuttle. The integration must be worked. The Center Director should own the engineers and safety. Those people have to sit at a table as equals. If there is an issue, it then gets brought to the next level of authority. For example, the program manager could not change a requirement or spec without getting approval by engineering and safety. The safety people would have independent capabilities and resources. Ms. Novak added that Parsons is a good example—he has a diversity of experience. MGen Barry added that system integration is clearly a shortfall for some of the failures in the Air Force. Program managers must graduate to the next level and be system integrators. Full cost accounting is good, but shouldn't be driven to the last 10%. Don't spend time and energy trying to get the last 10%--the return on investment is not worth it. To do the checks and balances, there must be independent capability and funding. The CAIB will offer two examples. One of these is the nuclear Navy, where the program manager is paired with a technical expert and he cannot adjust the requirements or specs without agreement of the technical expert. Use benchmarking; try to get rid of the "not invented here" syndrome.

Barry provided the following contacts for Novak:

- Dave Taylor at AFMCDP
- AFIT at Wright Patterson for system integration training
- Dan Stuart at AFMCCD for SES and GS-14/15 progression elements
- Maj. Gen. Chuck Johnson at Tinker AFB (statewide partnership)
- Joe Keelon in Barry's office for additional contact and benchmarking information

This meeting was adjourned at 1015 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 26, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

NAME	ORG.	PHONE
MGen John Barry	CAIB	703-416-3570
Steve Schmidt	CAIB	703-416-8488
Frank Buzzard	CTF	202-358-1401
Vicki Novak	NASA HQ	202-358-0520
Lynn Cline	NASA HQ	202-358-1200

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 26, 2003
These Minutes Contain No Sensitive Data

Purpose: STS-107 Systems Integration Fault Tree Closeout Briefing

Date: June 26, 2003 **Time:** 1200 – 1430 EST

This meeting was conducted via videoconference at the ANSER facilities in Arlington, VA (Suite 700, Room 7052), the Johnson Space Center (Building 1, Room 945), and the Kennedy Space Center.

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the DOJ CDS database.

There was one action item generated from this meeting that is list in the main body of the minutes.

Mr. Lambert Austin noted that the Fault Tree closeout has been a multi-element and multi-organizational effort. With respect to the technical panel reviews, in additional to the normal technical support, they also called in a set of experts as a peer review for each technical area.

Mr. Steve Bauder provided an overview of the STS-107 System Integration Fault Tree. This Fault Tree is consistent with the Columbia Accident Investigation (CAI) Fault Tree and provides an interface map to the element fault trees. The multi-element faults fit into three primary categories on the CAI Fault Tree: induced and natural environments, integrated vehicle mass properties, and external impacts. Mr. Bauer showed where the system integration fault tree begins to spread out from the CAI fault tree. He also showed a breakout of fault tree branches associated with Integrated Fault Tree Ground Processing Induced Loads and Integration Fault Tree Ascent Environments.

The tool used for the closeout process was the Multi-Element Integration Closure Team (MEICT). The MEICT coordinated with the CAI team to identify multi-element items, developed closure rationale, conducted various reviews, and submitted the closure documentation to the NASA Accident Investigation Team/Columbia Accident Investigation Board (NAIT/CAIB).

Mr. Bauder provided a summary overview of how the tree was closed. Previous presentations of a small number of element closures were accepted by the CAIB with the caveat that integration would later address the integrated results as part of their closures. These items have been captured within the Integration fault closures. There are 295 integration unique multi-element faults on the STS-107 Systems Integration Fault Tree; of these, 102 were dispositioned by the MEICT and closed, 183 were dispositioned and closed with the closure of CAI Fault Tree Blocks at a higher level, 9 Debris Transport Mechanisms faults were left open (Potentially Permanently

Open - PPO), and 1 Stress exceeds Orbiter Capability fault is open pending closure by the Orbital Vehicle Engineering Working Group/ NASA Accident Investigation Team (OVEWG/NAIT). There were 128 CAI orbiter multi-element faults; of these, 45 were dispositioned by the MEICT and closed, 47 were dispositioned by the OVEWG at a higher level and closed, 9 Prelaunch Unidentified Impacts on Launch Pad faults are pending OVEWG/NAIT (dispositioned as PPO by the CAI Orbiter Team), 9 Liftoff (Pad Debris) impact faults are PPO (unlikely), 9 Orbiter Bird strike on Ascent faults are PPO (unlikely) and 9 external tank (ET) Attach Causes Debris faults are open pending closure by OVEWG/NAIT. There were 221 transfer gates to the Marshall Space Flight Center (MSFC) and Payload Fault Trees and associated element faults. In response to a question by MGen John Barry, Mr. Bauder indicated that both out of experience and out of family items were dealt with. MGen Barry noted that there was an issue on closeout of Space Shuttle Main Engine (SSME) fault E.1.3.3 Burn Through. Admiral Gehman indicated that this was a single element issue dealing with propellant leaks in the engine compartment. MGen Barry commented that the CAI Fault Tree had 17 PPO's. Mr. Bauder noted that there are 79 multi-element events for the ET alone. Admiral Gehman added that of those 79, a great number are list after list of possible debris sources that cannot be eliminated. Dr. Jim Hallock stated that they looked at all of the foam types that could geometrically impact the orbiter. MGen Barry indicated that he would look at the complete listing in Tech Docs (either 2.7 or 3.7 fault tree).

Mr. Tim Wilson discussed the Ground Processing Induced Loads. Closures are based on results of the Kennedy Space Center (KSC) processing review. The ground ops review team was chartered by the OVEWG. It reviewed all KSC work performed on OV-102 and external tank/solid rocket booster (ET/SRB) flight elements since Orbiter Maintenance Down Period (OMDP) (STS-107 and STS-109). The review addressed modifications, Problem Reporting and Corrective Action (PRACA) documents, Work Authorization Documents (WADs), inspections, closeout photos and videos, and flash reports. The closure rationale incorporates the review team observations and test data. Mr. Wilson summarized the ground interface closures. Data pertinent to the integrated vehicle ground interface was reviewed. No significant issues were identified as a product of the review. All test data is in spec and well within the historical family. There is no evidence of any ground interface fault or anomaly that could have caused or led to loss of the vehicle. Mr. Wilson also summarized the processing loads closures. Data pertinent to those operations that might induce a load on the vehicle was reviewed and no significant issues were identified. MGen Barry noted that hold-down capability had been identified as an issue. With STS-107, this didn't occur. Were there any changes made between STS-112 and STS-107? Mr. Wilson stated that the wiring design was not changed, but the inspection process was improved (some additional steps were taken). All of the cables and connectors were changed. MGen Barry observed that there is an issue about the redundant capability. While not pertinent to the issue of the mishap, the Board will probably list this as an item of significance.

Mr. Larry Purtle discussed the integrated vehicle environments. He provided an illustration of the shuttle vehicle's certification with the other elements and an illustration of the integrated vehicle assessment. The two areas examined specifically were the crawler transporter loads and on-pad loads. With respect to the closure of the crawler transporter loads, the evaluation of actual environments showed no conditions that violated design and operational limits. All PRs written during crawler transporter operations show no indication of loads violations. This block was close in May by the MEICT. Significant drivers on the loads on pad are winds or significant mass properties shifts. All of the mass properties were within specified limits. Evaluations of the actual environments show no conditions that violate design and operational limits. The on-pad loads fault block was also closed in May. Mr. Purtle discussed the integrated vehicle ascent environment faults related to wing overload and thermal protection system (TPS) malfunction leading to burn-through. He reviewed the closure rationale for the integrated ascent loads fault. Detailed postflight loads reconstructions showed no instances of exceeding of element load limits. Assessment of the STS-107 trajectory shows the vehicle was within the certified alpha/beta/Qbar envelopes. Flight data confirms that the vehicle was within certified integrated environments. The block was closed in May by the MEICT. Mr. Purtle showed the location of orbiter wing load indicators that were evaluated and provided to Orbiter Structures. He also showed a graphic of the measured and reconstructed wing loads. The loads were within limits. MGen Barry noted that the bipod came off at 2.47 mach. Around 2.25 mach, the graph indicates that we start to have the minimum margin. In response to a question, Mr. Purtle indicated that there isn't any significance to this and that the presentation would address the ET attach loads that are more indicative of the loading in that area. In response to another question from MGen Barry, Mr. Purtle noted that A20 (the indicator with a value closest to the limit) is on the right side, the trailing edge of the wing. MGen Barry stated that the basic question is why the foam came off. The Board is trying to find a common thread. It is of interest that a second before the bipod came off, there is a minimum margin between the reconstructed wing load indicator (A20L) and the redline limit. Mr. Lambert Austin noted that every profile will look like this at mach 2.2. The general angle of attack shape is the driver. He added that the real red line for the wing is a flat line at the 1.3 mach value. The red line at mach 2.25 reflects a limit to honor on the day of launch, rather than the capability of the wing. MGen Barry indicated that he would address this further off line.

Mr. Purtle reviewed the ET load assessment. The ET loads are computed at interfaces with other elements and at all ET defined indicator locations. ET forward attach loads were provided to the ET project and were within certification. The STS-107 reconstructed orbiter/ET attach loads include the integrated effects of trajectory and wind environment. Wind shear at 57 seconds (mach 1.27) and beta at 60 seconds (mach 1.38) had small effect on ET loads relative to limits. In response to a question from MGen Barry, Mr. Purtle indicated that the side load is not a concern. Admiral Gehman added that the limits of the attachment points are around 60,000 pounds; however, this is not the limit of the foam. The Board is concerned about movement and stress around the attachment point. There were some stresses induced about 20 seconds before the bipod ramp let go. MGen Barry asked if there is any way to measure what kind of left/right

movement would have been inside the foam and whether the stress values can be translated to actual movement. In other words, how much is the orbiter moving laterally with respect to a stationary line through the tank? Mr. Purtle stated that this is a stiffness matrix calculation, and that value could be derived. MGen Barry observed that the 60-second deflection might have cracked the bipod ramp. Would that have contributed to the issue of the bipod coming off? What side loads would have been generated against the bipod foam for the 7 sheddings? He stated that he would like the answer to this question. Stone observed that this is a good question. He stated that KSC would look at the lateral loads on the bipod foam and his team would coordinate the answer to that question. Admiral Gehman added that regardless of whether it is an orbiter or tank problem, it is an integration issue.

Mr. Purtle continued with his review of the interface loads. The ET slosh dynamics are included in the ET interface loads. The aft ET/SRB attach loads were within limits. MGen Barry asked if the oscillation would contribute to the issue of breaking the bipod off if there was a crack at the 60 second wind shear. Mr. Purtle replied that it is still an oscillation load, and it was provided to the ET project. This feeds into the analysis of the foam. Mr. Randy Stone indicated that this was passed to the ET; however, his team could get this data and see if it could be a contributor. They could do this for STS-107, but they don't have all of the history data for all of the relevant flights. Mr. Purtle indicated that fluid is involved in sloshing in the top 20% of the tank. What drives slosh is the vehicle's alpha profile and the wind effect. MGen Barry commented that he is still puzzled about the coincidences with the Y side load—at almost exactly the same time the bipod falls off, we get a constant oscillation. Mr. Purtle referred the Board to the backup package on flight control, wind shear, and beta events (page 70). STS-107 experienced more than typical 0.6 Hz frequency content in SRB tilt actuators and moderate content in rock actuators. The STS-107 0.6 Hz frequency content was highly correlated to out of plane winds. The primary contributors are the commanded vehicle attitude transients, wind dynamics, and the rigid body mode at 0.2 Hz. The main concern is in the flight control area. Too much delay in the flight control response can lead to instability. The ET liquid oxygen (LOX) slosh mode is phase stabilized. A number of flights had similar magnitudes of 0.6 Hz oscillations in tilt actuators on both SRBs. Frequency content has been evaluated using shock response spectra (SRS) technique. STS-107 right tilt actuator experienced more than typical 0.6 Hz content. Admiral Gehman noted that the fact that this data is available means that we can look for other common experiences among the 7 flights in which there have been bipod shedding.

Mr. Purtle discussed the assessment of the air loads acting on the bipod ramp. He showed the ET forward bipod design air loads. The STS-107 reconstructed ET forward bipod attach point air loads were below design. At the point where the TPS came off, the aerodynamic loading was fairly benign. In summary, the integrated effects of ascent events have been assessed through flexible body loads. Orbiter wing loads were within limits and were provided to Orbiter. All external tank loads were provided to the ET project. ET has assessed the bipod air loads. ET has determined that ascent loads are a non-contributor to foam loss. MGen Barry felt that closing this out as a contributor would be a little premature. He indicated that he would work with Dr.

Paul Munafo on this. Admiral Gehman noted that in other fault trees, the basic argument in a closure is that there is proof that it didn't contribute to the accident. In this case, we don't demonstrate or prove that these things didn't cause the accident. The Board is struggling with eliminating things that it is not convinced (or has seen proof) that are not contributory. Mr. Austin agreed that the combination of the environments with something else (e.g., an aspect of the material) caused the foam to come off. Admiral Gehman agreed that the "and" is important. It is the Board's function to figure out how the things connect. It feels that what we have is a complex system that failed in a complex way—there were a series of "ands." If we close out all of the "and" items as being non-contributing, we will end up with nothing. We don't want to completely close out the environments (wind shear, vibration, air loads, etc.).

Mr. Purtle discussed the air loads fault and the closure rationale. Analysis of MADS pressure sensor data comparison showed good agreement with the aero database and prior missions. As part of the overall fault tree, the dynamic event at POGO was included. No POGO-type signatures were observed in pressure and acceleration measurements. The flight data was reviewed and showed that the acoustic environment was within the certified limits. The dynamic pressure is the key parameter driving acoustics, and it was in the middle of the flight envelope. The vibration fault was closed. There were no unusual vibration signatures. Mr. Purtle showed examples of plots of the vibration gauges. Sensor data was consistent with previous flights. Thermal sensor data showed no adverse temperature conditions that could be identified as sources that could have caused structural failure during ascent. Postflight reconstructed ascent aero-heating and plume heating environments were within the performance enhancements certification peak heat rate and total heat load limits. Mr. Purtle showed a summary comparing with other flights. There were no significant departures or trends.

Mr. Mike Elsperman led the technical discussion on contact with vehicle or launch pad. Detailed post flight trajectory reconstructions showed positive clearance between the orbiter and the elements. Flight data showed no expected signatures of an impact event between the orbiter and SRB or ET. Photographic evidence showed no orbiter re-contact with the SRB. No observable bird strike was seen in the photo review, but the block remains open as possible, but unlikely. Post launch inspections and flight trajectory assessment indicated no re-contact with the launch pad. A launch pad clearance reconstruction to quantify clearance margins has been completed and was approved outside of board. Data will be added to the closure forms. Ground wind was very light and was within cert limit. Mr. Elsperman showed some examples of the flight data that were reviewed. No impact signature was seen in the frequency domain at SRB separation. Accelerometer data at ET separation and ET separation dynamic responses are comparable to prior missions. Mr. Elsperman reviewed the in-flight impacts. Photographic/video review showed no evidence of an umbilical fire at liftoff. A debris transport mechanism does not exist for debris strikes forward of the point of origin. This is also part of the closure rationale for SSME debris striking orbiter during ascent. SSME debris during entry was closed based on the fact that the SSMEs are not operating during the entry phase. No transport mechanism exists for debris to impact the wing leading edge or lower wing surface. There are viable transport

mechanisms for debris from the ET, SRB, and orbiter. This block remains open. Mr. Elsperman showed the predicted bipod foam TPS impacts on the orbiter lower surface. The bolt-catcher trajectory was examined when released at 3 different BSM times. This is ongoing work and part of the return to flight activity.

In summary, ground processing induced loads were shown to be non-contributors. STS-107 ascent flight phase was within integrated vehicle design certification limits as well as element design capability. The orbiter had no re-contact with any flight elements. Debris sources and transport mechanisms have been evaluated and the debris blocks with viable transport mechanisms remain open.

Mr. Elsperman summarized the open System Integration Multi-Element fault blocks. Open CAI faults include: 9 Prelaunch Unidentified Impacts on Launch Pad (pending OVEWG/NAIT and dispositioned as PPO by the CAI Orbiter Team); 9 Liftoff (Pad Debris) impacts (PPO – unlikely); and 9 Orbiter Bird strike on Ascent (PPO – unlikely). There are 9 open integration faults associated with the Transport Mechanism (PPO – unlikely). There are 84 open Multi-Element Transfer Gates; of these, 79 are ET faults (PPO – unlikely) and 5 are SRB faults associated with the bolt catcher (open). Except for the open actions identified today, there is no further ongoing work with respect to reconstruction.

Mr. Stone indicated that he would meet with Mr. Munafo to discuss the bipod loads. Admiral Gehman indicated that the Board would give Mr. Frank Buzzard a request for information (RFI) for what it wants (**Action Item**). However, this doesn't change the status of the Fault Tree closeout. Admiral Gehman thanked Mr. Austin and his team for one of the most challenging of the Fault Trees. He concurred with the close out/open block summary as noted in the presentation. He observed that there is a straightforward comment on page 115 of the briefing charts that there are viable transport mechanisms to transport debris to the wing. He noted that he is glad to see this statement in the presentation; it is a good contribution.

This meeting was adjourned at 1430 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 26, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

At the ANSER facilities in Shrilington, VA

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-3229
MGen John Barry	CAIB	703-416-3570
MGen Ken Hess	CAIB	703-416-8481
MGen John Barry	CAIB	703-416-3570
Steve Schmidt	CAIB	703-416-8488
Dave Lengyel	CAIB	703-416-3516
Tim Bair	CAIB	703-416-8484
Chuck Babbish	CAIB	703-416-8492
Frank Buzzard	CTF	202-358-1401

On videocon at the Johnson Space Center, Houston, TX

NAME	ORG.	PHONE
Frank Delgado	NASA/ER	281-483-9077
Cathy Shaun	NASA/EV4	281-483-0124
Elizabeth Fountain	CTF	281-483-5257
Roger Tetrault	CAIB	941-505-9615
David Bowers	USA/PI	281-280-3769
Jim Kaminsky	Boeing/PI	281-226-5534
Sheila Widnall	CAIB	617-253-3594
Michael Elsperman	Boeing/PI	281-226-5533
Richard Schmidgall	JSC/MS	281-483-1972
James Hallock	CAIB	703-416-3272
Larry Purtle	Boeing/PI	281-226-5975
Reynaldo Gomez	NASA/EG3	281-483-6108
Bob Ess	NASA/MS2	281-483-0180
Steve Munday	NASA/EG4	281-483-6623
Kathryn Packard	NASA/MS3	281-244-5378
Curtis E. Larsen	NASA/MS2	281-483-8401
George James	NASA/ES2	281-483-5550
Henry Kunkel	Boeing/PI	281-226-5513
Randy Stone	NASA/AB	281-483-2465
Steve Poulos	NASA/EC	281-483-9108
Rodney Wallace	NASA/MS2	281-483-3904
Lambert Austin	NASA/MS	281-483-0969
Rodney Rocha	NASA/ES	281-483-8889

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
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NAME	ORG.	PHONE
Stephen Derry	NASA/JSC	281-483-6613
Frank Benz	NASA/JSC	281-483-3155
Robin Taylos	Boeing	281-483-5779
Philip Peterson	Boeing	281-226-5781
Doug Cooke	CAIB	202-329-8844
Donald Prevett	NASA/EP4	281-483-9036
John Shannon	CTF	281-483-0716
David Bawcom	CAIB	281-283-7838
Steve Bauder	USA/PI	

On videocon at the Kennedy Space Center, FL

NAME	ORG.	PHONE
Tim Wilson	JSC	

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 26, 2003
These Minutes Contain No Sensitive Data

Purpose: RCC Nose Cap NDE Presentation to CAIB

Date: June 30, 2003 **Time:** 1600 – 1745 EST

This meeting was conducted via videoconference at the ANSER facilities in Arlington, VA (Suite 700, Room 7052), the Johnson Space Center (Building 1, Room 945), and individuals via teleconferencing.

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the DOJ CDS database.

There were no action items generated from this meeting.

Mr. Brock "Randy" Stone was not able to attend this briefing due to his involvement in the working group on fault tree closure. Mr. Steve Poulos indicated that he was "standing in" for Mr. Stone.

Mr. Mike Gordon, Subsystem Manager for Orbiter Leading Edge Structural Subsystem (LESS), gave the presentation. He reviewed the vendor Nondestructive evaluation (NDE) methods: immersion ultrasonic through transmission (UT), radiography, and eddy current. UT is used to detect voids and delaminations in acreage areas. Radiography is used where UT is not usable (corners, short radius bends, tee intersections). Eddy current is used to measure silicon carbide (SiC) coating thickness prior to Type A processing. Admiral Gehman asked about vendor methods—Are these are only done in Dallas and not done by NASA or Space Flight Operations Contract (SFOC)? Mr. Gordon indicated that this is correct; these have already been baselined in Dallas. One of the key assumptions is that it is unlikely to have a gross oxidative void in areas that are rich in Type A sealant protection. Flaws detected in radiography include inclusions and tubular voids. Inclusions are typically fiberglass thread, metallic slivers from cutting, and thermocouple remnants that can survive processing until SiC coating. Many are eliminated during the processing. Corners typically contain filler plies and ply terminators as the material is tailored to form short radius corners that naturally leave voids during lay up. Voids are typically filled with phenolic resin or TetraEthyl OrthoSilane (TEOS). Mr. Gordon reviewed the fabrication acceptability criteria. One of the key items for tubular voids are internal regions outside of critical areas (defined by the spec). Analysis for some of the tubular voids was reviewed. Some of the criteria in this area will be revised. In response to a question, Mr. Gordon noted that radiography is performed at the reinforced carbon-carbon –3 (RCC-3) position. This is where the evaluation is done. There is no need to have every single void filled. It is not verified after TEOS application because it is not a load-bearing member. RCC-3 is

considered fully densified carbon laminate. It can be analyzed for maximum strength for flight at this stage. If there is a tubular void in the laminate, it would be detected prior to SiC coating.

Mr. Gordon discussed the results from the Orbital Vehicle – 103 (OV-103) Nose Cap NDE. No unacceptable defects were noted in ultrasonic inspection. One defect was noted during radiographic inspection—a tubular void that was not detected at manufacture. The defect is acceptable based on analysis. With respect to eddy current measurements, as-fabricated readings are suspect as comparisons to current thickness measurements which suggest a SiC thickness reduction. This trend is not possible from a thermodynamic standpoint. Admiral Gehman noted that this statement catches the Board's attention. Mr. Gordon added that nothing has mechanically or thermally happened to the coating that would reduce the thickness of the material. However, there is a plausible scenario (discussed later in the presentation). MGen John Barry commented that the issue regarding the SiC is around the corners—there is less thickness there. Mr. Gordon stated that the process is intended for acreage areas. For those reasons, thickness is accepted based on test data. The coating can be as little as 0.005 inch and still provide acceptable coating for the substrate. MGen Barry noted that this goes to the issue of specification. Are there any measurements outside the specs? Mr. Gordon indicated that coating exceedences have been accepted. The material review process itself is a concept derived from the WWII salvage boards. It was adapted by the military and has transcended into the NASA culture—acceptance of the part for a given environment. Board members have to be certified for the Material Request (MR) process, and there is an acceptance rationale for the given component. On the thin side, it is accepted based on acceptable oxidation for the substrate. MR's are common throughout the orbiter program.

In radiography, one tubular void was discovered on the upper left expansion seal corner. The defect was not previously documented. The void was evaluated and its overall length was confirmed at being 6.5 inches in length, which exceeds the allowable. The thread-like defect itself is right at the threshold of being detected by radiography. A combination of film and real-time x-ray had to be taken. In response to a comment from Admiral Gehman, Mr. Gordon noted that this was a new radiography. After 1988, there was a significant improvement in data recording. Admiral Gehman observed that in the case of Columbia, ~~44~~ 47 of the panels were original equipment, and we don't know if they have ever been NDE'd since they were built. Mr. Gordon agreed that he was correct. Admiral Gehman noted that a couple of panels were sent back to Dallas for vendor refurbishment; they may have been NDE's. The change of process in 1988 is not relevant to Columbia. Mr. Gordon stated that none of the panels on 103 failed a tactile test. The x-ray views for a particular defect were available to the Material Review Board (MRB), but there was a lack of discipline in recording this in the documentation. HWG

Mr. Gordon discussed the 3 scenarios of defect origin in OV-103: (1) the defect was present at the RCC-3 condition prior to coating and was not detected; or (2) the defect grew after coating and was not detected on account of there being no radiographic inspection after coating or TEOS; or (3) the defect was initially within allowable limits and grew during flight. Analyses

performed by the vendor show significant margins of safety that do not support void growth. Had this defect been identified during manufacture, it would have been accepted by the MRB action. This region has a high margin of safety and its potential for growth with repeated flight exposure is remote. The potential for undetermined void growth following coating on the load-bearing flat surfaces is not a concern. These locations undergo a full ultrasonic inspection after coating as well as in the RCC-3 condition. In response to a question from MGen Barry, Mr. Gordon indicated that it would have been acceptable to the MRB if they had been able to detect the 6.5-inch x 0.025-inch void. If a tubular void ran all the way through, the concern would be whether the void would be exposed at the edges of the part. The area with the largest moment (the worst case) would be analyzed. Where the void is relative to the load-bearing material would be of significance. The concern is about voids that affect the load-bearing corner (to withstand compressive or tensile loads). Location and diameter of the void, not the length, affect the part. Admiral Gehman noted that he couldn't determine whether the conclusion was right or not, but what is of interest to the Board is the program office waiving a technical specification. An independent agency (that had nothing to do with the program) should look at this before the specification is waived. This is another example where the owner of the technical requirements is the same person with responsibility for schedule and budget. Mr. Gordon stated that in addition to the engineering functions, there is a quality representative that is not subject to the schedule pressures as much as manufacturing is. Admiral Gehman commented that the Board is looking for more of that.

Mr. Gordon continued with the presentation. It is the technical position of the LESS Prevention/Resolution Team (PRT) that the noted defect on the OV-103 nose cap expansion seal was present at manufacture and was never detected due to the small diameter of the void (scenario #1). The majority of the defect is at or below the detectability threshold. The corner moment analysis shows that growth of voids is remote.

Eddy current measurements utilized a template to match inspection point locations. Data was compared with measurements from fabrication. Thickness variations were expected on account of sealant migration and glass formation. Interfacial oxidation would manifest itself as unexplained coating thickness increases (Type A sealant migration) over 0.005 inches. Inspection results showed an average delta thickness of -0.0036 inches. Thickness reduction is not possible, so the original measurements are suspect. It is likely that the complex curvature of the large dome caused the probe to rock, giving higher readings. At the time of manufacture, the thicker coating was analyzed and shown to be acceptable. Thick SiC analysis is over conservative. Data shows that thin SiC (down to 0.005) is acceptable. Admiral Gehman expressed concern about using an average delta thickness—in an examination of measurements like this, it is a dangerous term. Also, using PowerPoint to describe technical analyses is troublesome. Over a number of readings (22), there was an average loss of SiC, but the program is attributing this to operator error (rocking of the instrument). The SiC coating is a very important piece of the thermal protection system—it is the barrier that prevents the heat caused by catalytic action. Even if there were only two or three of the reading where the coating was

dangerously low, it would be significant and should be analyzed carefully. In response to a question regarding how many readings were too thin, Mr. Gordon noted that this would be covered on a subsequent chart. He explained that if an operator applies the probe completely perpendicular to the surface, with pressure, this would be the lowest point. Anything else would be an increase.

Mr. Don Curry referred to the plots in the chart package. The minimum coating thickness is well within the allowables. The coating thickness is sufficient to protect the basic RCC substrate. He agreed that it is dangerous to use an average thickness. In general, the coating thickness was always greater than the design limit, and the primary interest is in the reduction of strength allowable. In response to a question from Admiral Gehman, Mr. Curry indicated that the eddy current template was based on the original manufacturer. Gordon added that the template is considered special test equipment and is controlled as a tool. Before, there was a lot of variability in the readings. Today, the inspector makes sure that he is exactly perpendicular in each of his measurements. Admiral Gehman commented that there is no reason to believe that the reading taken today is any more valid than the reading taken some time ago. He drew attention to the deviation from the best-fit line and observed that there was very little variability in the red line. What the Board is after is whether NASA knows the condition of its flight equipment. This is the real question. Until this testing was done, the answer was "no." In response to a question from Col Larry Butkus regarding how many readings were taken by the operator at each location, Mr. Gordon indicated that there was one. The operator "dials in" the value to make sure he is at the closet point. The tool has markings on it that ensure its proper placement.

The problems with the eddy current as-fabricated measurements were assessed. The program is looking for gross voids, and the technique for detecting gross voids is ultrasound and radiography. The eddy current measurement that is performed in the absence of ultrasound cannot be used. The assessment that was performed at the time of manufacture that still showed positive margins of safety show that over conservatism exists for thicker SiC measurements. Thin coating measurements are not a concern since the test data supports coatings as thin as 0.005 inch to provide acceptable protection and values below 0.015 inch are very rare. In response to a question from Admiral Gehman, Mr. Gordon agreed that if there is an area in the nose cap or wing leading edge where there is a thin SiC coating, then that area is thin forever. Once you get out of the coating furnace, nothing more can be done. Admiral Gehman observed that although the areas below 0.015 are very rare, all you need is one. This is a concern. What happens if there is an area of thin coating that gets dinged by debris? Mr. Gordon responded that in this case, you would oxidize the surface beneath and you would see widespread damage on a post-flight inspection. This is type of damage is progressive and you would be able to see it. Mr. Curry added that wherever there have been very thin coatings in a "hot" area, they have been rejected. It is very important that we ensure that we do not have thin coatings in these areas.

Mr. Gordon discussed the OV-104 nose cap NDE results. No unacceptable defects were noted during ultrasonic inspection. No defects were on the dome or upper expansion seals during radiographic inspection. Other parts had tubular voids that were accepted via vendor MRB; however, no dimensional detail has been retained (this was corrected in 1988). There were no issues during eddy current measurements. SiC exceedences from the 0.010 – 0.040 criterion were already accepted by vendor MRA during fabrication. Previously undetected fabrication tubular void has prompted review of fabrication records for OV-104, OV-105, and spares. From the fabrication records, ultrasonic and eddy current showed no problems as-fabricated. Radiography indicated tubular voids at manufacture. MRA's were written and dispositioned by the vendor. Vender MR acceptance was performed based on x-ray views that were available at the time. The nose cap was delivered to the design center with a signed certificate of compliance. The eddy current inspection of the nose cap at Kennedy Space Center (KSC) after 26 flights indicated good agreement with as-fabricated measurements. Mr. Gordon discussed the nose cap radiographic inspection. There were undetected tubular voids on the upper left expansion seal on OV-103. This was explained earlier. Since 1988, NDE inspections have been performed in the Shook Building in Dallas and dimensional records have been retained. The largest nose cap tubular voids recorded were 0.035 x 12.5 (longest) and 0.075 x 5.8 (widest). Eddy current measurements were done on OV-104. There was a similar type of layout. The average delta thickness was +.0017 inch. The increase was consistent with the application of Type A sealant. The results indicate very good agreement with the as-fabricated measurements. The hottest location on the nose cap is the lower part of the nose cap. Sealant migrates from this area. Readings are very close to the as-fabricated readings. The area that shows the thickest increase is above the nose cap apex.

Mr. Gordon continued with the Wing Leading Edge (WLE) NDE results. This included infrared thermography, computed tomography, and vendor NDE. For infrared thermography, there has been no inferred (IR) thermography performed to date on OV-103. On OV-104, the left hand panels 1-7 are in work. On OV-105, panel 7 right is complete (no defects noted); and on spares, panels 6L, 8L, 9L, and 10L was or will be performed for the test article. On computed tomography, LH panels 6 & 8 for test articles was done on OV-103. On OV-104, no computed tomography was performed to date. On OV-105, RH panel 7 was done (no defects noted). On spares, panel 9L was complete for test article assessment (no defected noted). With respect to NDE, there has been no vendor NDE to date on OV-103. On OV-104, evaluation of the WLE is in work. On OV-105, there has been no vendor NDE to date. On spares, panel 8L was evaluated for test article assessment (no defects noted). The presentation back-up data contained more discussion on corner moments and void.

Admiral Gehman thanked Mr. Gordon for the presentation and indicated that this was what the Board wanted to hear. He expressed appreciation for the tenacity and detail with which NASA is approaching this issue. Through this process, we hope to learn a lot about our flight hardware. It is helpful to the Board for a number of reasons. It gives the board a first hand knowledge on how something that is out of spec gets through the system. When we finish, we will have

characterized the flight hardware in a way that hasn't been done since it came from the factory. In response to a question regarding how propagation of the void can be ruled out without dimensional data, Mr. Gordon indicated that as long as the highest stress riser did not exceed the material limits, the void will not grow. Mr. Curry added that critical locations are identified during manufacturing. Loads across the critical locations are different. These are put together in the analysis for each flight. Mr. Steve Poulos observed that the Board is struggling with the certification process. The approach is to define the minimum limit; if it is exceeded, analysis is done to determine whether there is sufficient strength to be able to say that the part is acceptable through the MR process. In response to a question regarding when the decision will be made on the OV-104 nose cone, Mr. Poulos stated that OV-104 will go to the Program Requirements Control Board (PRCB) this week. NASA intends to pull the OV-105 nose cap and fully characterize it. NDE is being done on the WLE components. The team is intends to look at worst case voids, inclusions, etc. for all NDE techniques, and through analysis to look at worst location to determine if there is sufficient structural margin to fly with OV-104. The final decision rests with Mr. Bill Parsons and Mr. Jim Halsell, in collaboration with the Strategic Leadership Council. Col Butkus commented that the strategy is to do the characterization on OV-105, and based on that, make the decision on OV-104. Mr. Poulos added that if the decision cannot be made that OV-104 is safe, then OV-103 will come out of Orbiter Major Modification (OMM) in the June time frame and it will be the first orbiter for flight.

This meeting was adjourned at 1745 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
June 26, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

At the ANSER facilities in Shrilington, VA

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-3229
BGen Duane Deal	CAIB	703-416-3349
Steve Schmidt	CAIB	703-416-8488
Dave Lengyel	CAIB	703-416-3516
Col Dave Nakayama	CAIB	703-416-8484
Col Larry Butkus	CAIB	703-416-8492

On telecon via the Johnson Space Center, Houston, TX

NAME	ORG.	PHONE
MGen John Barry	CAIB	703-416-3570
Col Richard Covey	RTF TG	

On videocon at the Kennedy Space Center, FL

NAME	ORG.	PHONE
Frank Delgado	JSC/ER	281-483-9077
Michael Gordon	Boeing	321-537-9691
Don Curry	JSC/ES	281-483-8865
Stu McClung	JSC/MV	281-483-3015
John Shannon	JSC/DA8	281-483-0716
Steve Poulos	JSC/EC	281-483-9108
Fred Ouellette	JSC/MV	281-483-0770

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 8, 2003
These Minutes Contain No Sensitive Data

Purpose: Briefing to Board: Determination of Debris Risk Due to the Columbia Breakup During Reentry – Dr. Jon Collins, ACTA Inc.

Date: July 8, 2003 **Time:** 1500 – 1640 EST

This meeting was conducted via teleconference from the ANSER facilities in Arlington, VA (Suite 800, Collbolm Room) and the Regents Park III facilities in Houston, TX.

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the DOJ CDS database.

There were no action items generated from this meeting.

Before beginning his presentation, Dr. Jon Collins noted that most of the work on the debris risk was performed by Mr. Mark Lynn, and Mr. Eric Larson. There were 4 steps in the methodology: (1) creation of a mathematical model of the breakup debris, (2) development of a "population library," (3) simulation of the debris cloud, and (4) an estimation of the risks to aircraft in the vicinity of the debris cloud. From the analysis, the ground debris risk results lie within the range of 0.22 (22 casualties in a 100 accidents) assuming that the recovered fragments are the only debris that survived, and 0.56 assuming that the entire mass of the orbiter and the payload survived. The probability of being hit by debris from an aircraft was 0.005 for commercial aircraft and 0.025 for general aviation (for the debris field only). The number of debris strikes for aircraft was approximated from another study. It was an order-or-magnitude estimate. Dr. Paul Wilde indicated that the Federal Aviation Administration (FAA) intends to pursue this aspect further. Dr. Collins noted that the risk in this study was measured in terms of the expected number of casualties. Casualty, rather than fatality, was chosen as the measure because it is the measure currently used by the USAF and by the FAA (for regulation of commercial launches). A casualty represents any person that has an injury from debris that is "serious"—Level 3 on the Abbreviated Injury Scale, which is defined as reversible injuries, hospitalization required—or greater. In response to a comment, Dr. Collins noted that this definition is becoming a standard. The probabilistic term is "casualty expectation," or E_c. Its measure is the average number of casualties, not the probability of a casualty. Dr. Collins described the mechanics of debris fall. Everything is done according to the ballistic coefficient (β). If the β is very high, the $W/(C_D A)$ is also very high. The high β is less affected by the wind; a low β is more affected by the wind.

Dr. Collins explained the contributions to debris impact dispersions. The data analyzed included the raw information of 84,000 pieces of debris, 75,000 of which had impact coordinates. With respect to mass, the study team was given only the total recovered weight of 84,900 lbs. (38% of orbiter and payload weight). For 15,470 records, at least two dimensions were provided. Material descriptions were used to categorize debris into categories. Dr. Collins showed the

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impact pattern that was given to the study team—the main impact region, two "streaks," and scatter. The team developed some rules for the data reduction process. Debris was assigned to different β ranges. All the data that didn't have dimensions were represented by the data that did have dimensions. Dr. Collins showed the logic diagram that was used to decide how what piece belonged to what class. The next step was to develop a histogram of the number of fragments in each ballistic range as a function of impact range. He showed the distribution in the different ballistic categories. The hard part was the lack of information about trajectory. An assumption had to be made in terms of what was happening during breakup. The study assumed a β of 200. NASA came up with 220 for the reference trajectory. The team developed relationships between the impact range for each β and breakup time on the reference trajectory. Dr. Collins showed a graph representing some of the relationships that were developed. The team developed state vectors at one-second intervals along the reference trajectory, numbers of fragments in each β category for each of the state vectors, and used the Common Real-Time Footprint (CRTF) program to compute the impact dispersions for each of the β groups for each of the times. Dr. Collins showed the breakup state vectors over 120 seconds. The team modeled all of the debris by 4 modes. Dr. Wilde noted that one of the valuable things would be to take the debris and study it to a larger extent, e.g., with dimensions for all of the pieces. This would provide a better understanding of how the Shuttle broke up and how other similar vehicles might break up. Dr. Wilde summarized that there were impact locations for all of the debris. The team worked backward, postulating the breakup based upon the impact locations.

The CRTF program was used to compute impact dispersions. ACTA Inc. has been doing risk analysis for the Air Force. They do the risks in the launch area before every launch and use the CRTF program. The software has been validated and tested. NASA is provided with a casualty expectation for each Shuttle launch. In this study, the CRTF computed the impact distribution for each debris category (12) for each state vector (120) for each mode (4). Each impact dispersion was modeled by a bivariate normal distribution. Dr. Collins showed the computational flow of the CRTF program. Mode 1 was to model the impact center. Mode 2 was to model one of the streaks. Mode 3 was the second streak. Mode 4 was the wide scatter. Dr. Collins discussed the comparison of the model dispersion with the actual gathered debris dispersion. In the model, wind uncertainty was used to force the cross-range dispersion; however, the real cause was probably lift and the current CRTF model underestimated the effect.

The next part was casualty models. There are two categories: one for people in the open and one for people sheltered. There are two aspects: the degree of injury due to the location of the hit on the body and the weight and velocity of the fragment, and the impact area wherein a hit can be defined. Dr. Collins described the injury severity scale (AIS levels 0 – 6). Penetration, blunt trauma, and crushing injuries are in the model. Dr. Collins discussed the general logic for computing the casualty area for people in the open—direct impact, rebound, and splatter. For this study, most of the casualty area was direct impact. Dr. Collins showed the distribution of total hazard (piece hitting, but not injuring), casualty, and fatality for people in the open among the Columbia debris classes. He also showed the roof penetration models used for determining

the vulnerability of sheltered people and an example of the casualty areas for very high-density debris hitting a roof.

A population library including sheltering was developed for the region affected by the debris. The information was derived from US Census 2000 data. The population library separated people into categories of being outside and being inside different types of structures. This model was set up for a weekend morning in the winter. It produced an estimate that 28% of the people were outside. Dr. Collins showed the debris field against the population model. The average population density in the debris area was 85 people/nm^2. A sensitivity analysis could be done on this, but the team did not have the time to do this under the current study. Day-of-event wind data was obtained and it was determined that the wind did not have a big effect.

As noted earlier, the risk analysis was performed by the CRTF program. Dr. Collins showed the methodology for simple impact probability and casualty computation and the fundamental risk equation. The process continues over all state vectors. The highest risk group was in mode 1. Based on the number of fragments, the E_c was 0.22; if 60% of the total weight survived, the E_c would be 0.35. In response to a question, Dr. Wilde noted that NASA has tools that the FAA has used to estimate what fraction of a vehicle will survive reentry. If the debris field is shifted over a high population area (e.g., downtown Dallas), the E_c goes up; however, if the breakup had occurred earlier, there would have been a different dispersion on the ground. This analysis shows that even if the Columbia had broken up over a major city, there would have been only a few people in the hospital, not hundreds as had been speculated. Dr. Collins showed the aircraft risk, based upon information from another study. The worst-case impact probability for any plane was 0.08 for commercial flights and 0.0037 for general aviation. Dr. Wilde noted that the FAA would want to follow up on this aspect of the study. Collins indicated that the model is keeping track of all of the state vectors for the entire length of time and 3D footprints can be obtained.

To test the results, a simple analysis was performed using the total casualty area impacting on an average population density of 85 people/nm^2. For the simple model, the E_c was 0.13; the risk analysis was 0.22. The simple model showed that the majority of the people who would be casualties would be fatalities. The hazard area (strike with little or no injury) was 4-5 times the casualty area. The computed E_c shifts up and down directly proportional to the percentage of the debris that survives; however, shifting the numbers of fragments to higher β categories while holding the total weight constant actually reduced the risk. Finally, the whole footprint was moved back 50 seconds (over Dallas). This increased the risk by 36%.

Conclusions:
The results of the risk analysis indicate that the lack of casualties was the expected event, but there was a reasonable probability (less than 0.5 but greater than 0.1) that casualties could have occurred. A preliminary evaluation of aircraft risk indicates that there was a lower likelihood of debris impact on airborne commercial or general aviation aircraft than to people on the ground,

although the probability levels are such that normal operations would most likely never be allowed under the circumstances.

Dr. Collins noted that the study was based on a relatively crude debris list. He recommended that the study be revisited after the fragment data have been fully processed. In addition, a more detailed aircraft risk analysis should be performed using the actual records of aircraft activity at the time of the accident.

Dr. Wilde noted that the study contract was only $25,000 and the government got its money's worth. However, the government had already invested a large amount into this type of analysis and this previous investment was of great value to the study team. In response to a comment, Collins added that the expected result was that no one would be a casualty, but it was "close."

Mr. Steve Wallace indicated that Dr. Wilde has drafted a recommendation that is being circulated among the Board members for comment. The Board is leaning in the direction of making a recommendation. Dr. Wilde commented that the current plan is to include the results of this study as an appendix in the final report. Mr. Wallace noted that the next CAIB meeting, the Board would discuss Dr. Wilde's recommendation and how to handle the study results in the CAIB report.

This meeting was adjourned at 1640 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 8, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

At the ANSER facilities in Shrilington, VA

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-3229
Roger Tetrualt	CAIB	703-416-3591
Dr. Jim Hallock	CAIB	703-416-3272
BGen Duane Deal	CAIB	703-416-3349
Dr. Doug Osheroff	CAIB	703-416-3490
RAdm Steve Turcotte	CAIB	703-416-3015
Dr. John Logsdon	CAIB	703-416-3057
Steve Wallace	CAIB	703-416-8405
Scott Hubbard	CAIB	703-416-3109
MGen Ken Hess	CAIB	703-416-8481
Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-283-7809
Doug Cooke	CAIB	281-283-7576
Dennis Jenkins	CAIB	703-416-3373
Paul Wilde	CAIB	703-416-3367
Dwayne Day	CAIB	703-416-3491
Frank Buzzard	CAIB	202-358-1401
Kevin Mabie	CAIB	703-416-4469
Mike Miller	CAIB	703-416-4469

On telecon via the Regents Park III, Houston, TX

NAME	ORG.	PHONE
Dave Lengyel	CAIB	281-283-7581
Joe Engle	RTF TG	281-483-3655
Ned Mueller	CTF (LM)	281-483-1495
Mike Thiessen	SAIC	281-483-3656

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 9, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Discussions

Date: July 9, 2003 **Time:** 0900 – 1145 EST

This meeting was conducted via teleconference from the ANSER facilities in Arlington, VA (Suite 800, Collbolm Room).

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the DOJ CDS database.

There was two action items generated from this meeting that is list in the main body of the minutes.

Board Discussions

Admiral Gehman raised the issue of the AP story about a previous wing burn through on the Space Shuttle Atlantis. This was not true—there was no "burn through." RAdm Steve Turcotte noted that they looked at every single intrusion on every orbiter. Throughout the Shuttle history, there have been several orbiters that have landed without tiles and insulating parts. Occasionally, there have been some gases that have intruded around these areas. In this particular instance, a bent insulator panel allowed some hot gas into the internal cavity behind the reinforced carbon-carbon (RCC) and in front of the spar and insulation. It was not a big event. There was no damage to any metal part, although some of the metal parts were discolored due to the heat. There was no hole. This did get to the Program Review Control Board (PRCB) and was on the in-flight anomaly (IFA) list. It was attributed to improper maintenance. This incident was not overlooked by the CAIB.

Schedule Discussion

July 23, 2003 was the rollout goal of Volume I of the Final Report – this will be missed by a couple of weeks (Congress has been informed and has no problem with the delay). The pressure is still on. The Board discussed when to reconvene. The issue was whether the Board could review the text remotely. Substantial portions are not yet available. There should be a complete second draft of the report during the week of July 21, 2003. The Board should plan to reconvene July 23-25, 2003 for final touches on the second draft. Dr. John Logsdon observed that at some point, the Board will have to review the final text. Mr. Dennis Jenkins indicated that the final text would be available August 6-8, 2003. Admiral Gehman indicated that rollout should be a week or two after that. Admiral Gehman is schedule to brief the Stafford/Covey Return to Flight Task Group (RTF TG) on August 5 at KSC. Dr. Doug Osheroff suggested that the editing staff put in low-resolution images for the remote review.

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Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 9, 2003
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The Board agreed to meet on July 22-25, 2003 to review Draft 2 of the report and the recommendations and findings. The Final Review (Draft 3 with recommendations and findings) will be August 6-8, 2003. The words in the report will be locked in by August 8, 2003. Mr. Jenkins indicated that layouts would be sent out section by section. "Rollout" will be August 26, 2003 and will include a press conference. There will be a limited number of paper copies of Volume I as well as a CD. Volume I will be posted on the Web site. Everyone should continue to be civil servants through the day of rollout. The only other press conference before roll out will be July 11. Mr. Scott Hubbard asked Mr. Steve Schmidt to find one or two unoccupied offices in which small groups of Board members could privately discuss issues. **Action: Mr. Schmidt to find conference rooms.**

Summary

July 23-25, 2003: Review of draft 2 of the report and all of the findings and recommendations
The writing team and Mr. Jenkins will put a smooth, final report together.
August 6-8, 2003: Final Board review of the report (Text will be frozen by August 8, 2003)
Two weeks are required for layout/graphics, etc.

Discussion on Outline of Report

The report is divided into three parts:

Part 1: What happened.

There are no changes to Chapters 1 and 2. Admiral Gehman noted that the details of the flight had been moved to Chapter 3. Chapter 2 is still the chronology of the flight. The details that the Board wanted to analyze have been moved to Chapter 3 (with the analysis). Chapter 3 is the analysis of the destruction. The other non-causal things have been moved out of Chapter 3 into Chapter 4. Chapter 3 contains the analysis and facts that support the foam story.

Part 2: Why the Accident occurred (or why NASA allowed this to happen).

Chapter 5 is the more modern history of the Shuttle and Shuttle program, including the budget pressures. This will include a discussion of Rogers Commission recommendations (on agenda to be discussed later today). Chapter 6 is the decision-making at NASA. Chapter 7 is where MGen Ken Hess's piece on high-reliability organizations goes. (The authors need to turn in their raw materials for review.) Admiral Gehman noted that the trade-off between high reliability and payload is not in the report yet. There is a chapter where the Board can editorialize, and that subject should be addressed there. Dr. Diane Vaughan is writing Chapter 8. If this chapter is not compelling, the Board will not put it in the report. Dr. John Logsdon indicated that he had sent her his Chapter 5. She will draw from it, but will not overlap the contents.

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Part 3: A Look Ahead

Chapter 9 is the short term RTF, the long term/future of the program, and the Board's views on replacing the Shuttle. The Board can editorialize in this chapter or in Chapter 10 (Other Significant Observations). Chapter 11 is a summary of Findings and Recommendations

There will be 3 appendices. Mr. Jenkins asked for Board feedback on Volumes II and III (collection of documents). The Volumes can be rearranged and can come in any order. The Board agreed that Volume II should contain things that the report references (currently outlined in Volume IV). Only Volume I will be distributed on August 21, 2003. Mr. Hubbard noted that all of the referenced reports must be delivered by the final review (August 6).

Action: Identify these reports and tell NASA they are needed by August 6, 2003.

When the second draft is posted it will follow revision 8 of the outline.

Jenkins raised questions about the following:

Topics to ensure are covered in the report, and topics that need a "home"

- Pad cameras—will figure out the best place for these to go
- Tuft's analysis of MMT charts – do we use him as a reference? The Board agreed to reference Tuft.
- Comment on term "in-family" – editorial comment, will be worked.
- Dr. Pate-Cornell's work (she was charged with updating it) – Widnall indicated that the work has been submitted. Will be reviewed and referenced.
- Duct tape – covered in report
- HQ disengagement – covered in report
- Documentation of minority engineering (and safety) views – covered in report
- Risk and Safety Scholarship in NASA – nicely covered
- The role of NASA's advisory councils – not yet covered (noted by Admiral Gehman). Dr. Logsdon indicated that he had cited comments made by Aerospace Safety Advisory Panel (ASAP) and NASA Advisory Council (NAC) in Chapter 5. Dr. Sheila Widnall noted that Dr. Nancy Leveson had some comments about the process for choosing candidates for membership in these councils. Admiral Gehman indicated that the Board could add some

comments in Chapter 10 about the ASAP; however, the Board has not reviewed the NAC and should not make comments without interviews or more work. Mr. Roger Tetrault indicated that the NAC acts in an advisory role, e.g., like a Board of Directors. Agendas are set by NASA. It gets reports from all of its Committees. The NAC is the advisory committee for the NASA Administrator. Dr. Logsdon observed that during his tenure, the NAC had been focused on the International Space Station (ISS). The Board decided not to discuss the NAC. Admiral Gehman noted that he has reviewed the ASAP recommendations for the last 5 years. Every year, one of the recommendations is on infrastructure. The ASAP members talk about what they are interested in. They stay in their "lanes." Dr. Logsdon added that there are also standing (external to NASA) advisory groups. Admiral Gehman commented that the Board was not particularly impressed with the ASAP. This can be included as one of the editorial comments. One of the headline findings that should be emphasized is that NASA does not learn. A learning organization is one of the attributes of a high reliability organization. One of the most compelling rationales is that NASA has been told over and over again about communication issues and management issues. For example, the Board has reviewed scores of reports from outside panels and committees, and this subject comes up over and over again. MGen Hess commented that it would be useful to have a list of the top ten themes in the report. Admiral Gehman stated that by the next review, the Board should come to agreement on the list. One of the top ten items is that foam can damage an orbiter.

With respect to format, Mr. Steve Wallace noted that the accident really starts with chapter 2. Chapter 1 could be "the space shuttle program: history and context".

Discussion on Rogers Commission Recommendations

1) Design - no comments

2) Independent oversight – no comments

3) Shuttle management structure – NASA implemented this. The CAIB is not recommending splitting apart any of the operational aspects of the Program Manager's authority. Dr. Logsdon noted that management was moved to NASA HQ with the authority that Rogers recommended. It was moved back to the Johnson Space Center (JSC) in 1996. Mr. Bill Aldridge was a product of the JSC culture and had good visibility into it. The structure was working fairly well through 1996 and there was good visibility at the Program Manager level. It was changed due to Goldin's decision to move all program management to the field Centers. Admiral Gehman commented that the CAIB recommendation is that there should be an independent technical authority that owns the technical requirements and safety requirements that the Program Manager cannot waive. This does not violate any of the Rogers recommendations. MGen John Barry noted that the change in 1986 did not get into movement of the balance of power. Admiral Gehman observed that there was an unintended consequence of consolidating management and giving the Program Manager more authority and responsibility. A follow-on

step was to cost all of the support services under the operational arm. This is where you start to lose the system safety aspect. The CAIB learned from Challenger and the Rogers Commission how to fix the institutional challenges. NASA needs to go down to the next level of management/institutional recommendations. Merely swinging the pendulum from one extreme to another doesn't do the job—checks and balances are needed. Also, NASA didn't differentiate between the two different enterprises: operational and developmental. Dr. Osheroff felt that the Board needs to make a recommendation that NASA has to do research to understand the nature of failure modes of essential systems.

4) Improved communications – this gets to "stovepipes". This is still true today. MGen Barry noted that Mr. Bill Parsons intends to address this issue through the Integration Office. This is a very positive step. Admiral Gehman opined that having this advice at the senior level may not do any good. Even the Administrator may not be able to overcome the isolation and cultural differences among Centers. In some cases, you need drastic action. To rely solely on this office to achieve this goal will not work. Mr. Hubbard added that to really achieve "one NASA", a forcing function (e.g., budgets) must be involved. Admiral Gehman summarized that in this particular case, NASA has not changed since the Rogers report. It is a monumental problem that the Administrator must address. [still outstanding]

5) Astronauts in Management – astronauts are moved into management, but they are not trained for this role. Mr. Hubbard noted that NASA is starting to address this and be more rigorous about management experience in its selection criteria. Dr. Osheroff observed that NASA is not grooming engineers for management. Dr. Logsdon noted that the intent of the recommendation was to inject a safety consciousness into the program. Admiral Gehman added that it appears that NASA has taken this seriously and the Board doesn't have much to comment upon. Astronauts in management is not necessarily a "fix." The idea of the astronauts bringing their safety perspective to management is good, but implementation has not included management training. There needs to be a process for grooming managers. Dr. Logsdon observed that NASA has had trouble attracting people to work for the organization except for one area—the astronauts. NASA should take this talent pool and nurture it. Admiral Gehman made a note of this to see where it might fit into the report. He acknowledged that Mr. Sean O'Keefe has a Human Capital plan that the Board got a briefing; however, the Board should not get into the detail, e.g., bonuses, etc.

6) Shuttle Safety Panel – this was created in 1986 and disappeared relatively quickly. No comment.

7) Criticality Review and Hazard Analysis – this has gone in the wrong direction. It is now unmanageable and incomprehensible. For example, thermal protection system (TPS) is a Crit 1 item. It is routinely being damaged on every flight, but alarm bells are not going off. There are hundreds of waivers on thousands of crit 1 items. This is an unmanageable system. Hess

commented that NASA has an ineffective was of buying back risk. MGen Barry added that NASA is just now starting to advance the probability risk assessment process.

8) Safety Organization – NASA paid lip service to this. The implementation of this recommendation was lacking. The current office does not have direct authority over safety and flight assurance, only policy authority.

9) Landing Safety – no comment

10) Launch Abort and Crew Escape – NASA did what it could within the time frame of the joint repair. It was "best efforts" implementation.

11) Flight Rate – Admiral Gehman noted that 17 years later we still have a single capability for human flight and very large satellites. MGen Barry commented that this recommendation suggested that NASA build an expendable launch vehicle (ELV) capability, which they did for space and earth science. There is a section in the report (9.3) where the Board will write an opinion about the urgency for Shuttle replacement. During its interview process, the Board did still detect schedule pressure in the Program (driven by Node 2).

12) Maintenance Safeguards – NASA has not done a good job in implementing this recommendation.

Mr. Tetrault noted that one of the issues is insufficient technical analysis on the current Shuttle. The question is, if NASA doesn't understand the technology today, is it ready to build a follow-on? It is interesting to note that the people involved in the Orbital Space Plane (OSP) program are the same people that were involved in the canceled X-33 program. Mr. Hubbard observed that in the briefings on prospective programs, there is not any indication that NASA has learned from the Shuttle or X-33 program.

This meeting was adjourned at 1145 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
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Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-283-7809
Dennis Jenkins	CAIB	703-416-3373
Dwayne Day	CAIB	703-416-3491
Robert Cobb	NASA IG	202-358-1220
Laura Brown	CAIB	703-416-3532
Tyrone Woodyard	CAIB	703-416-3532

On telecon via California

NAME	ORG.	PHONE
Dr. Sheila Widnall	CAIB	703-416-3445

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 23, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Session

Date: July 23, 2003 **Time:** 0900 – 1145 EST

This meeting was conducted at the ANSER facilities in Arlington, VA (Suite 700, Collaboration Room 7048E).

The list of attendees is appended to the end of this report.

There were no action items generated from this meeting.

The Board viewed a film on the Bureau Enquêtes-Accidents (BEA) investigation of the crash of Air France/Concorde in July 2000.

Items discussed during the Board Session:

- Request for Information (RFI's):

  There are about 15 open RFI's. Group 1 has 7 open; Group 2 has 3 open; Group 3 has 4 open. Admiral Gehman will have a member of the support staff check on each of these. It would be preferable to close all of these closed out before the Board disbands. Any still left open will be examined on a case-by-case basis.

- ANSER Bullpen changeover:

  On August 8, 2003, the text in the report will be approved and turned over to the production team. The Board concurred that it did not need to approve the layout. It was understood that none of the figures would be changed or modified in the layout process. Admiral Gehman suggested that government employment (of the "outside" Board members who were brought in as Civil Service employees) should terminate on August 8, 2003. Expenses would continue to be paid to the Board members for the report rollout, testimony, etc. Dr. Sheila Widnall requested that for liability and indemnification purposes, government employment should continue until rollout (August 26). Admiral Gehman agreed to this request. He noted that the Board will not be disbanded until after August 26, 2003 rollout of the report. Appendices need to be produced, work on archiving needs to be done, etc. Admiral Gehman estimated that this work should be completed by September 30, 2003. While most of this work is documentation production and archiving, there will be some decision-making—a few of the Appendices are Board produced documents, e.g., the report on the email, the reinforced carbon-carbon (RCC) story, the matrix. A small group of people will read through these and look for cases of contradictory statements. The bullpen will be closed, starting

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August 9, 2003. However, the Board will still be a resource. Dr. Widnall requested an out briefing from a government lawyer regarding potential exposure of Board members. Admiral Gehman indicated that he would have the lawyers produce a briefing and a paper to give the Board members covering this topic. It is his understanding that if the Board is sued, the government will defend the members, either as individuals or as a group. However, there is a limit to this. The government will substitute itself as a defendant as long as the Board is operating within its charter. Admiral Gehman advised the Board members to be careful about private opinions or stepping outside of the Board charter or the deliberations. With respect to personal finances, members can recoup the mandatory contributions to the retirement fund. Dr. John Logsdon commented that post-employment restrictions should be part of the briefing. After September 30, 2003 (or shortly thereafter), the members will receive formal notification that the CAIB is disbanded. The House has indicated that the first hearing will be Thursday, September 4, 2004. Admiral Gehman stated that he did not have a specific plan for rollout. With respect to the five constituencies, this will be worked.

Admiral Gehman discussed the issue of what to do with recommendations that are not return to flight (RTF) recommendations. The subject of an annual review by the CAIB has been suggested. Mr. Tom Young indicated that the International Space Station (ISS) Management and Cost Evaluation (IMCE) Task Force did a one-year review and gave a report to the NASA Advisory Committee (NAC). Some members of Congress have indicated that they are looking for something like this. Whatever is done should be public. The RTF items could be reviewed at the same time. Admiral Gehman indicated the he was scheduled to meet with the majority of the House Science Committee tomorrow (July 24, 2003). The Board agreed that he should discuss the topic of future CAIB activity at that meeting. In response to a question, Admiral Gehman noted that the Board would have to do more than just get briefings from NASA; it would have to do independent checks at the Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), etc.

- Issues:

The Board reviewed the list of issues drafted by Gehman.

1. Is "exceeds" is too strong a term for the sentence in the first chapter? The sentence talks about the risk associated with the shuttle under the present NASA management structure. As currently organized, the safety issues are beyond NASA's capabilities. If the organization changes, the shuttle could be safely managed. The philosophy of the report (Part II) is that the Board has found organizations that refuse to accept failure. The expectation of the shuttle program should be no failures. With this philosophy, the organization and management systems would be different. The problems are both organizational and cultural. NASA can organize its way out of an organizational problem; it cannot organize its way out of a cultural problem. Strong leadership is needed to lead NASA to cultural changes. The third issue is technical

competence. Dr. Logsdon stated that if the sentence at issue is taken out of context, it could be condemning NASA as of August 26, 2003. The report should be clear that the statement was made as of the time of the accident. Is the organization now one that meets the template and is able to manage risk and technology? Admiral Gehman took a vote on whether to use "exceeded" or "challenged". "Exceeded" passed.

2. Use of emphasis editorially in the report: The Board agreed that this is OK.

3. Chapter II needs more details of the final flight (some reviewers have commented that this chapter has become too brief/bland). The Board agreed that Chapters 2 and 3 needs to be re-balanced.

4. Case for schedule pressure: this is not very well brought out in the report. Because of the delay in the Orbiter Major Modification (OMM) for Discovery, Columbia was needed for a Station flight later in October. It then became critical to meet the launch date. Mr. Mike Bloomfield noted that there was a definite perception at JSC that there was schedule pressure. BGen Duane Deal observed that about 80% of the interviewees talked about schedule pressure. Admiral Gehman indicated that this aspect of the report will be fixed.

5. Signatures on the Flight Readiness Review/ Certification for Flight Readiness (FRR/CoFR): What do they mean? Is this relevant to the process condemnation? The signature process seems to be key to how the shuttle is certified to fly. It appears to be open to personal interpretation. The reason for a FRR is so that the collective wisdom can detect problems. Does the signature mean that the person doesn't hear anything at the FRR that is a safety issue or question? Is this process helpful or inadvertently disguising a problem? Admiral Gehman indicated that this would be looked into further.

6. STS-107 heavy rain exposure: there is not much documentation about this, but there is some "late-breaking" news from Palo Alto, CA. Dr. Doug Osheroff noted that water vapor will diffuse through the foam in six hours, both in and out. If one side is cold and one is warm, water will start condensing. A piece of foam 9 in^2 will absorb a gram of water. However the presence of water doesn't appear to compromise the material.

7. Purpose of N_2 in the inter-tank void: two different reasons appear in the report. Conclusion: the purpose is for both reasons. This will be fixed in the report.

8. 5 vs. 7 statistic of bipod foam on Columbia: BGen Deal noted that there have been extensive briefings, but there are some statistical abnormalities. This is one of the

unanswered questions. The statistical trend is unlikely to be attributed to coincidence. This should have alerted someone. The flaw is lack of curiosity.

9. Foam debris cloud over the wing: This is recent evidence by one reporting agency (National Imagery and Mapping Agency - NIMA). This would mean that the strike was closer to the apex, and the force would have been worse. BGen Deal noted that the statements that no debris went over the wing have been deleted.

10. The statement regarding risk and expense of human space travel. The Board basically agreed with statement as an underlying theme. Dr. Widnall added that not only is budget squeezed but the technological promises exceed what can reasonably be done. Dr. Logsdon observed that the statement tries to draw a direct causal link between limited budgets and fatal accidents. There is a difference between robotic and human missions. Admiral Gehman noted that the point is that accepting these risks for robotic missions is one thing, but is something entirely different for human missions.

11. Comments from January 12, 2003 Mission Management Team (MMT) meeting: there were things that were not followed up on. This is a condemnation of the inquisitiveness and the professionalism of the MMT. MGen Ken Hess noted that there was a shared opinion at the MMT that this orbiter was not in trouble.

12. How much to make of the PowerPoint issue: The status/credibility of emails is covered in the report. PowerPoint is covered—is it important? Admiral Gehman observed that this is a symptom of a lack of technical proficiency or documentation. Mr. Scott Hubbard noted that it is another aspect of schedule pressure. It is also a marketing tool. Dr. Osheroff added that the idea that images/impressions are very important in NASA seems to be part of the problem. PowerPoint doesn't provide a complete archive of how decisions are made. Admiral Gehman noted that PowerPoint is a management tool—it allows top-level managers to think they have visibility into a project. As a management tool, it may work. However, this doesn't work as an engineering tool. For engineering, there must be technical, detailed analysis. In conclusion, the PowerPoint issue is more than trivial and should be covered in the report.

13. Is the Shuttle a heavy lift or medium lift system?: It is a heavy lift system.

Remaining questions (14 – 16) deferred to Board session the following day.

Two more questions added:

14. Is Linda Hamm's handling of 3 separate roles/jobs a significant matter?

15. Technical qualifications of the work force?

This meeting was adjourned at 1145 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 23, 2003
These Minutes Contain No Sensitive Data

Attendees at the meeting are as follows:

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-3229
Roger Tetrualt	CAIB	703-416-3591
Dr. Sheila WIdnall	CAIB	703-416-3445
BGen Duane Deal	CAIB	703-416-3349
Dr. Doug Osheroff	CAIB	703-416-3490
RAdm Steve Turcotte	CAIB	703-416-3015
Dr. John Logsdon	CAIB	703-416-3057
Steve Wallace	CAIB	703-416-8405
Scott Hubbard	CAIB	703-416-3109
MGen Ken Hess	CAIB	703-416-8481
Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-283-7809
Dennis Jenkins	CAIB	703-416-3373

CMM012-0006

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 23, 2003
These Minutes Contain No Sensitive Data

Purpose: Outbriefing for RFI 256. Michael Conley (Introduction), Pam Madera (Process), Joe Caram (Aerothermal), Don Curry (RCC Subsystem Manager)

Date: July 23, 2003 **Time:** 1400 – 1640 EST

This meeting was conducted via videoconference from the ANSER facilities in Arlington, VA (Suite 700, Room 7052) and the Johnson Space Center (Building 1, Room 945), Houston, TX.

The list of attendees is appended to the end of this report.

Presentation materials used at this meeting can be found on the DOJ CDS database.

There was one action item generated from this meeting.

Mr. Michael Conley reviewed the discussion outline and the major objectives of the leading edge structural subsystem/reinforced carbon-carbon (LESS/RCC). The models and the model verification were developed jointly with NASA and the contractor team during space transportation system design, development, test, and evaluation (STS DDT&E). Models were (and are) updated as a result of testing and flight experience. Currently, NASA is not significantly involved in flight-to-flight predictions/reconstruction and RCC flight certifications. NASA is notified in case of anomalies. Prior to RTF, the process will be modified to insert NASA into the flight-to-flight activity.

Ms. Pam Madera discussed the flight-to-flight RCC analysis process. RCC margins and life are generically certified. Pre-flight planning and real time processes ensure that the planned mission specific thermal environments are within generic certification. The Mission Operations Directorate with a tool—the Thermal/Structural Enveloping Program (TSEP), performs pre-flight and real time trajectory screening. TSEP violations are reported to the Johnson Space Center (JSC) Orbiter Element to request a detailed thermal/structural assessment. Boeing Orbiter performs a certification rigor aeroheating, thermal, and stress analysis for the flagged mission specific condition. The process for addressing TSEP violations is defined in the forward of the Shuttle Operations Data Book (SODB). The current baseline is in hard copy; Madera indicated that the relevant pages could be sent to the Board. Ms. Madera showed a flow chart of the process. There has never been a negative margin condition. If there were, it would be taken to the program level for a redesign of the missions, e.g., taking off secondaries. Ms. Madera described the TSEP tool. It is an entry trajectory evaluation tool that allows mission planners to determine if trajectories are within the Orbiter certified entry thermal/structural envelope. The program was developed based on a thermal evaluation at 35 orbiter locations.

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RCC/LESS is a unique design combining thermal protection and structure. It is limited by material temperature and a maximum thermal gradient at the flange area. TSEP covers this requirement by evaluating six body points with corresponding thermal math models of RCC components including nose cap, wing leading edge panels, and chin panel. The worst RCC panel (#9) is monitored. TSEP is under configuration control by NASA Orbiter Element. In the last 10 years, there have been three changes. In response to a question regarding TSEP variables, Ms. Madera indicated that the major drivers are inclination and weight; secondary drivers are cg, cross range, altitude, approach and direction, and season. Ms. Madera gave a top-level summary of mass loss. RCC mission life is limited by mass loss. Mass loss rate is determined as a function of temperature and pressure. RCC life analysis is based on a mission mix of design and reference trajectories compiled to represent the projected manifest. The annual Space Shuttle Life Tracking Report documents a high level evaluation performed to ensure that certification assumptions are still valid. Projections are made into the future with current mission manifest trends to foresee impending mass loss concerns. Concerns are raised at the Orbiter Element Vehicle Engineering Control Board (VECB). A particular mission is evaluated with the TSEP tool. This was done before and during the STS-107 mission. The tool produces an indicator (pass/fail) for each trigger. An out-of-family condition is sent to the DCE. DCE decides whether or not to submit it to Mr. Don Curry. Mr. Curry is matrixed to Orbiter Element for RCC. There have been many exceedances of one or two degrees. There have never been any large exceedances. There is a formal process for disposition; adjacent system areas communicate verbally. Ms. Madera presented an example of the Life Tracking Report. The "actual flights to date" table is updated on an annual basis.

Maximum temperatures for past missions were derived from the TSEP. The ISS/MIR mission history was assessed. There were 26 missions (STS-63 to STS-113). The average RCC wing leading edge temperature was 2895 degrees; the maximum RCC wing leading edge temperature was 2950 degrees. Ms. Madera discussed the recommended process improvement: implementation of detailed post-flight mass loss calculations. Best estimated trajectory and atmosphere would be evaluated with high fidelity aeroheating, thermal, and stress tools to define mass loss limits. Mr. Chuck Babish posed the question: What is the benefit of this particular task? Ms. Madera replied that this would be a more detailed health check and produce a more refined understanding of the mass loss on trajectories that have been flown. Mr. Curry stated that sufficient analytical work has been done to have a high confidence in the mission life limits that have been published. The mission life should not change significantly. Mission life is also affected by other aspects, e.g., the refurbishment schedule. Mr. Conley added that within the project and the engineering directorate, NASA has been talking about how to improve the process. With respect to oversight, NASA plans to bring in a one-to-one counterpart for each of the system managers (another 80 people).

Mr. Jose Caram provided an overview of the development of the pre-Orbiter Flight Tests (OFT) orbiter body point heating methodology, the wing leading edge (WLE) heating environment, correlation to flight test, heating uncertainties, and the effect of dispersions on heating. Pre-STS-

Pre-STS-1, development of the heating database relied heavily on wind tunnel data with advanced analytically and computational methods used as verification. WLE was represented by body points. Each body point has a specific math model. The model was last updated in the late 80's/early 90's. Mr. Caram stated that this is a very good model with the set of body points existing today. The WLE heating is dominated by the shock interaction zone. The shock interaction zone was treated with specific emphasis due to the increased heating that resulted from the interaction of the bow shock with the wing shock. Overall, the WLE heating was generally modeled by using swept cylinder heating correlated with wind tunnel data except in the double shock region. Heating in this region was modeled using the ratio of wind tunnel test (WTT) data to reference sphere heating. Heating is a function of angle of attack. The shock interaction location on the wind is a function of Mach number. Prior to STS-1, the uncertainty in the location of the interaction during the period of high heating ranged from 47% to 55% semi-span. The 47% semi-span was used to model the peaking heating due to an analysis of the effects that high temperature gas has on shock stand off distances. Prior to STS-1, WTT data was applied directly to the flight for the WLE heating (no scaling for WLE environments). Mr. Caram discussed the uncertainty definition prior to STS-1. There was an uncertainty assessment prior to the mission. For WLE, wind tunnel test scatter and flow interference (double shock) were the relevant uncertainty considerations. The data collected from STS-1 through 4 and STS-5 were used for the verification of the heating models. When necessary, flight derived correlations were developed. For the WLE, radiometer data was obtained for panels 4, 9, 16, and 22. Data showed that models over-predicted for panels 4 and 22, accurately predicted for panel 16, and under-predicted for panel 9. A factor of 1.34 was needed to correlate the panel 9 flight data to the model. Mr. Caram showed the graph that depicted the panel 9 flight data to the model. MGen John Barry repeated a question raised by the Board. Dr. James Hallock brought in a chart that showed heating at 2900. How does this affect the mass loss model? Mr. Curry indicated that he would address this later in the presentation. Mr. Caram discussed the WLE peak heating prediction uncertainty of the flight-correlated model. The data from the flight was compared with the high fidelity model to assess the uncertainties. Only one flight out of the 13 predictions under-predicted the measurement. Based upon all of the data available, the heating predictions can under-predict by 28 degrees and over-predict by 88 degrees. Mr. Caram discussed the effect of dispersions on the algorithms. A worst on worst 100 case Monte Carlo was performed to assess the affect of dispersions on peak WLE heating. The case included ISS inclination, heavy weight, forward cg, winter atmosphere, and hotter trajectory design. The peak heating for this case was 2950 degrees, 10 degrees below the multi-use limit. The peak temperature (local spike, not a constant bias) can vary by 150 degrees up and down. Mr. Caram showed an example of the trajectories from the Monte Carlo.

Mr. Curry discussed RCC design certification. RCC is certified by analysis, which is a mission life limited analysis. An extensive test program is used to verify analytical techniques. There has been full-scale hardware and integrated testing. All of the design allowables work was done by the Lockheed Martin Missiles and Fire Control operation. The allowables are statistically determined. Mr. Curry presented data on room temperature strength, strength at temperature,

and RCC conditioned design allowables. He showed cross-section images of the coating interface. Curry noted the two different types of mass loss—interior and exterior. Subsurface degradation was first observed from arc jet tests at Ames Research Center (ARC) and JSC in 1973. In February 1978, the tetraethyl orthosilicate (TEOS) mass loss database was established. The mass loss rate is greater in a convective environment than a radiative environment. An improved coating system was developed and baselined for orbital vehicle 102 (OV-102) and subs in March 1976. Type A coating enhancement was developed to seal the surface porosity. It was baselined for all vehicles in March 1980. Radiant mass loss correlations were developed and based on steady state and mission profile test conditions. Mass loss was similar between the steady state and transient profiles. Mr. Curry showed the actual correlations for radiant mass loss. Equations were developed for two regimes to fit data—reaction rate controlled and modified diffusion controlled. The convective mass loss data is based on testing at JSC. About 140 specimens were tested. Data from all test conditions (varying temperature and pressure) are used to develop a convective mass loss correlation. Mr. Curry showed the actual correlations for convective mass loss. MGen Barry observed that at higher temperatures, the mass loss rate for TEOS and Type A is comparable. Mr. Curry noted that more sealant is lost at the lower temperatures due to the way the vaporization works with the glasses.

Mr. Curry discussed mission life analysis. The design goal is 100 missions. Calculation of discrete mission life for each part is based on exceeding zero margin of safety and mass loss cutoff. There are two types of mass loss cutoff—radiant mass loss limit of 0.10 psf and convective mass loss limit of 0.03 psf. At 100 missions, there are positive safety margins. Mass loss cutoffs are not exceeded. Accumulated mass loss indicates 100 missions or better. Temperature and pressure environments are utilized in the Mass Loss Correlation Program to predict RCC mass loss for orbiter past and future missions (mission mix). Mass loss histories for critical RCC locations are transmitted to the Stress Team for further analysis to assess RCC mission life. About 7 years ago, the correlations were transferred from Vought to Rockwell. Personnel were taught how to use the correlations. Correlation changes are now the responsibility of Boeing. Independent of the correlations developed by Vought, JSC developed its correlations and has done crosschecks to compare correlation data. However, in mission life correlations, the Vought correlations were used. Both correlations use the same database. Mr. Curry showed the temperature predictions versus flight data for STS-5, WLE panel 9. He also showed the RCC panel 9 temperatures for all of the 103 flights. Panel 9 on 103 has been performing fairly accurately. In response to a question, Mr. Curry indicated that on the last flight the TMM indicated a temperature of 2914 degrees. Normally, the thermal protection system (TSP) model runs hotter than the thermal math model (TMM). The WLE RCC components are certified based on structural analyses with positive margins. The analysis process is the same for all vehicles. The structural analysis for the RCC WLE Panel/T-seal utilizes NASA structural analysis program (NASTRAN) finite element analysis method and process. The same models used for flight were the same models used in testing. All of the models are under configuration control and cannot be changed without review and approval by NASA. Mr. Curry showed how the thermal analysis and structural analysis are put together to determine a positive margin of

safety for the longest possible mission life. Mission life analysis results have been correlated with destructive evaluation of flown panels with pinholes. Data was consistent with the degraded allowables and pinholes. Mr. Curry noted that data he has been recently given indicates that on panel 8, the flexure strength was on the order of 14,000-15,000 psi. This would indicate very little degradation or aging of the RCC panel. Data on panel 6 (cracked) indicates a stress level of 7000 psi. This means that after 30 missions, there was not much degradation and it was within the allowable properties. The project will take a panel after 30 missions and test it in detail to obtain better data. Mr. Curry emphasized that this is preliminary data and could change. If the preliminary numbers turn out to be accurate, this would indicate that panels have been performing close to the typical properties and significantly above the A value.

Mr. Curry showed the mission life for all of the panels for OV-102, WLE. For OV-102, RCC panel 9 is in the 50-mission life point; RCC panel 8 is slightly above 60.

MGen Barry asked if Mr. Curry discovered something tangible regarding RCC that he didn't know before. Mr. Curry noted that additional insights have come from impact testing. Mr. Caram indicated that we have a significantly better idea of what the fluid dynamics would be when assessing penetration. Ms. Madera indicated that from a process standpoint, it would be healthy to go ahead and pursue the post-flight inspections. MGen Barry posed the question: If there is a maximum temperature of 3220 degrees, how do we explain a 1.4 flight safety factor? Mr. Curry explained that the 1.4 safety factor is on structure at the end of mission life, based on allowables. He referred to the chart on the RCC shell tests. Mr. Curry stated that there is no factor of safety on thermal (temperature); it is 1.0. Mr. Babish clarified that for the structure, the thermal loads and air loads factor is 1.4. Mr. Curry agreed. For the thermal analysis (temperature), there is no factor. MGen Barry asked: Regarding the impact of a dent, would it be prudent to have a safety factor of 1.4? Mr. Curry stated that the program always tries to maintain the 260-degree delta; this allows a transatlantic abort case. Flight rules say that you cannot design a trajectory that goes beyond 3220. However, under particular conditions (e.g., abort) there is a triangle in time (40 seconds at 3320) where that is allowed. MGen Barry posed the question: What kind of a hit on the RCC could be taken that would disrupt the boundary layer but would not allow the temperature to go above 3220? Mr. Conley indicated that the test program is in development right now. There is a maximum allowable forward facing step of ~~30,000.~~ .0030 The criteria is in the 23 spec.

HWJ

MGen Barry acknowledged all of the hard work that was done for this RFI. He indicated that the Board may wish to include this presentation as an appendix in the report.

Action: The program will provide a copy of the 107 SODB (it will include the change history) to the Board.

MGen Barry indicated that this presentation would close out the RFI.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 23, 2003
These Minutes Contain No Sensitive Data

This meeting was adjourned at 1640 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 23, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

At the ANSER facilities in Shrilington, VA

NAME	ORG.	PHONE
MGen John Barry	CAIB	703-416-3570
RAdm Steve Turcotte	CAIB	703-416-3015
Steve Schmidt	CAIB	703-416-8488
Dave Pye	CAIB	281-283-7549
Paul Wilde	CAIB	703-416-3367

On video conference via JSC at Houston, TX

NAME	ORG.	PHONE
Michael Conley	NASA	281-483-6511
Pamela Madera	USA	281-282-4453
Jose Caram	NASA	281-483-5365
Don Curry	NASA	281-483-8865

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 24, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Session

Date: July 24, 2003 **Time:** 0930 – 1540 EST

This meeting was conducted in the ANSER facilities in Arlington, VA (Suite 700, Collaboration Room 7048E).

The list of attendees is appended to the end of this report.

There was one action items generated from this meeting.

Discussion on Probable Cause Statement:

Mr. Steve Wallace presented his suggested changes to the statement. "The physical cause"... This is physically what happened. "Physical" is better than "direct." Admiral Gehman observed that "probable" should not be mixed with "mechanical/physical." "Probable" is a different discussion. The Board agreed on "physical."

The Board agreed on "breach was caused" with no qualifiers.

"Gases" can be misinterpreted; the Board agreed on "air."

Admiral Gehman noted that the breach in the reinforced carbon-carbon (RCC) allowed a second breach to occur. "Thermal protection system" is misleading. It was the insulation protecting the aluminum structure. Most of the Board felt that the statement needed to address the destruction of the insulation. There are two different activities: the hole in the RCC which allowed superheated air to get in; and the hot air that did additional damage.

The Board discussed use of "burn," and "penetrate," and whether failure of the wing or loss of control came first. Except for the word "penetrate," the Board agreed on the following text: "During re-entry this breach allowed superheated air to *[penetrate]* the thermal protection system and then through the insulation and aluminum structure of the left wing, resulting in a progressive loss of strength until increasing aerodynamic forces caused failure of the wing, loss of control, and breakup of the Orbiter." **Mr. Wallace took the action to come up with a word for "penetrate" and get unanimous consent on it.**

Issues to be Discussed (continuation of the Board session on July 23, 2003):

14. How much of Dr. Bagian's material to include: Mr. Wallace has written a piece on the crew module and crew escape. In Chapter 2, there is a gap between loss of signal and debris.

RAdm Steve Turcotte proposed inserting the piece written by Mr. Wallace (minus the part on crew escape) here. This makes it read like a real accident report. The Board agreed that the sequence of the break-up, the crew module, and the method of death would go in Chapter 2. Admiral Gehman indicated that this write-up would be circulated separately for review and comment.

15. Hardening of the Orbiter: There is not a good discussion of this yet. Should this be recommended? Mr. Wallace suggested that the Board not launch a major effort on Orbiter hardening. He felt that it didn't rise to the level of a separate recommendation. Mr. Scott Hubbard observed that hardening of the Orbiter has been mentioned. MGen John Barry noted that there is a new section on the tiles that he will be submitting for review. Admiral Gehman added that there are no plans for making tougher RCC. MGen Barry noted that they are going through more testing to find the threshold. The Board agreed to write a couple of paragraphs expressing the Board's concern that there are no research, plans, etc. for tougher RCC. This will be submitted off-line for review and comment. It will go into Chapter 3.

16. Order of appendices: this is a mechanical issue—guidance is needed. Volume II will be the CAIB/ internal documents that are referenced in Volume I; Volume III will be other documents that are referenced in Volume I. They will be numbered the way they appear in the report. Volume IV is source material that the CAIB was given or briefed on but is not referred to in the report. Copyrighted material will not be put in the appendices—it will be referenced only. Public hearing transcripts go in the "all others" volume. Admiral Gehman noted that the Department of Justice (DOJ) will be giving guidance on what goes in the archive. Anything that the members want in the archive should be given to Mr. Dennis Jenkins. The lawyers will be talking about personal notes, etc.

17. Is Ms. Linda Ham handling 3 separate roles/jobs an issue? MGen Ken Hess felt that this is not germane to the argument. Admiral Gehman noted that one of the problems is that if there is a blind spot, it can get carried through the whole system. The Board agreed to not emphasize this as an issue. It should be noted, describe what it means, and not draw any conclusions.

18. Technical qualifications of the workforce? The Board did not find big holes. Admiral Gehman noted that off-line, this has come up again and again as an issue (in emails and letters). The real expertise has gravitated over to the contractors. MGen Hess felt that an interesting point to raise is the influence of the Space Flight Operations Contract (SFOC) contract on the culture. One of the issues is a very senior NASA person who is hired by the contractor and continues to have a relationship with civil servants that he mentored. Even when the person moves over to the contractor, a very subtle mentor/mentoree relationship remains. Dr. John Logsdon noted that Mr. Sean O'Keefe's workforce initiative is aimed at addressing the workforce issues. Mr. Hubbard observed that when looking at the distribution

of quality of workforce in 1969 and 2003, the best are still as good, but there is not the crop of best and brightest that there was 30 years ago. The whole questioning attitude that comes out of failures has changed. There is more "box checking." Admiral Gehman noted that the Board can get at this issue through review of literature—e.g., "previous studies have found ..."

Discussion of Part I

Admiral Gehman requested that the discussion be focused on things that are factually wrong, contradictions, or wrong conclusions.

Board Statement: (will be modified as discussed earlier)

Executive Summary: Admiral Gehman stated that this was just created over the weekend and has not been edited. Dr. Logsdon felt that the report should be precise about its boundaries (page 1). A conscious decision was made to not get into policy. Page 5 - The signals that something was wrong were not strong signals; however, there were people who were very concerned that something was wrong. The paragraph (page 5) was not phrased in accordance with the way the Board felt. Admiral Gehman agreed to make a modification to reflect the consensus of the Board. The paragraph on page 6 will be changed in accordance with earlier discussions. MGen Hess raised the following point: Is there going to be a second causal statement in Chapter 2? The Board felt that there should be one. Chapter 6, 7, 8 – the paragraph is a "melding" of Board statements that have been made around the table. Page 8 (cultural issues) -- cultural problems can only be fixed by leadership. The Board felt that something about the need for extraordinary leadership should be added.

Chapter 1: This chapter has been reviewed twice. Dr. Sheila Widnall noted that Section 3.6 has big errors. Admiral Gehman indicated that each of the groups has been asked to appoint someone to help run the facts down. Editorially, there will be only one decimal point. Dr. Widnall observed that there is a constant misunderstanding about the radiation. She offered to prepare a sentence. Dr. James Hallock raised a question about whether NASA would be ready for return to flight. Admiral Gehman referred to the statement about chapter 9 in the executive summary.

Chapter 2: Admiral Gehman noted that the structure would be fixed. A timeline and more facts will be added. RAdm Turcotte felt that this chapter needs to talk about the orbiter preparation process (insert after payload preparation, page 2-5). He submitted a write-up for consideration. MGen Hess's write-up about what a signature means will be added. De-orbit burn and entry events will be added as discussed earlier. The Board agreed to leave in the 2.4 timeline. It could be shortened. The title of 2.5 will be modified. There should be a sidebar or chart on how the elements are related to each other. There are still a lot of editorial comments in 2.6 that need to be incorporated. It needs an introduction. In many places throughout the report, transitional

sentences are needed. Page 31 – Mr. Hubbard noted that the evidence from debris did not force people to re-examine the photo evidence. Admiral Gehman agreed that this is misleading. There was a question about whether to cite Web sites.

Chapter 3: Probable Cause Statement (worked in morning session) will be inserted in this chapter. In the sidebar, the graphic can come out, along with a lot of the detail. When the thrust panels are discussed later on, they will have to be described. There are two "3.2s" – this will be fixed. The discussion of VX 250 and VX 265 is very confusing – it needs editing and fact-checking. The external tank on Columbia had 250. The issue regarding Freon/blowing agent needs to be factually correct. One of the figures cited in the text is missing – this will be fixed. The discussion regarding two groups of design is too vague. Page 15 – the issue of 5 vs. 7 was discussed the previous day. Mr. Wallace felt that this might require a footnote discussion. Admiral Gehman indicated that the 5 out of 7 will be noted in a sidebar.

Findings: check out whether "closeout" has been defined. The Board discussed whether it needed another finding about the foam. RCC section: needs fact checking on foot-pounds. Add a drawing or picture of a wing with panels numbered (for clarity). The substrate is converted, not grown. Editors will look at this. There are no good close-up images of Columbia's leading edge—this should be footnoted. Pages 19, 20 – which panels are taken off and reused changes through the story; the fact-checkers are working on this. Page 21 – use temperature, define double A type sealant. This will be fact-checked.

Findings: Finding #3 leads to a recommendation that has already been issued. Admiral Gehman will check to see wording of previous interim finding. Words should be lifted verbatim if possible. He noted that there can be findings with no recommendations. For reference purposes, there will be a numbering system on all of the findings and recommendations.

3.4 Analysis of impact: amplify "plate-like" description. Use "force" instead of "impulse" in last line of third paragraph. Page 26 – last two bullets, there appears to be an equivocation between the two types of debris. This needs to be explained better. The first refers to what the cloud looked like; the latter refers to what the large piece of debris looked like. There needs to be a fact-checking action on what "away from the wing" means. Page 27, Modeling and Testing: First sentence, use ~ 3000 lbs. Page 28: Dr. Widnall noted that a pressure differential in psi cannot be compared to a stress in psi. In the report, it looks like a comparison and these are completely different things. Both of these stresses were negligible. This needs to be clarified to remove confusion. Page 30 – this is a poor description of Enterprise. Page 32 – It is not clear what the meaning of "reference" is in the third column of the chart. This needs to be clarified. In third paragraph, use "11.5 inch edge" instead of "longer edge." Mr. Hubbard noted that the first couple of tests are not addressed. On page 31, add a paragraph about this and reference the test report. Page 33: the RCC panel 8 text was just submitted and will replace the placeholder text. The crack was through the rib. Page 34, findings and recommendations: the wording needs to be consistent with recommendations already released. Mr. Hubbard to provide the right

numbers for the size of the foam for the Board's finding. Page 34, instead of "conclusion," this should be a transition statement before findings and recommendations (as in other sections).

3.5 On-Orbit Debris Separation: the figure on page 38 is not understandable. The Board agreed to take it out. Dr. Widnall indicated that she would continue to try to shorten this section. Page 40, findings, second bullet: use "relationship" or "association" rather than "contribution."

3.6 De-Orbit/Re-Entry: This section contains only the "whats" and not the "whys". Dr. Widnall is working with Ltc Pat Goodman to get some analysis into this section. The significant events will be added to the timeline in Chapter 2. Page 41, last paragraph, the editors have arbitrarily decided to call these "sensor 1, sensor 2", etc.

Page 52, findings: change "profile" to "flight path" and add "until just prior to loss of signal." Insert "abnormal" at beginning of third bullet. The third bullet should be broken into two findings. Last bullet has awkward wording—it should be "debris analysis supports the location of the wing breach…" The recommendation is too murky. On the remaining orbiters, the modular auxiliary data system (MADS) records payload data, not the sensors in the wing. A new recommendation is needed. The Board discussed whether to recommend adding sensors or a telemetered "flight data recorder" to the other orbiters. Admiral Gehman indicated that a new recommendation would be drafted.

Chapter 4: Dr. Widnall felt that a couple of sentences linking the two approaches (the fault tree process and the scenario-based investigation) should be added. The Board agreed to add some transition sentences. Page 3 – title of second column of chart should be "number of elements" (delete "open"). 4.3: The report doesn't explain very well why these alternate factors were selected for detailed discussion. An introductory sentence is needed. The figures need some work. Page 6 findings: it should be clear that this is a negative finding. This is based on a technical report. (Look at this again.) Mr. Hubbard suggested putting in a recommendation to use something better than Crater. Admiral Gehman indicated that this would go in chapter 6. Page 8 – Dr. Widnall suggested adding a statement that the Air Force has taken Kapton wiring out of its aircraft. Remove one of the figures (lower right one). Page 9 finding: This finding is not very well justified; it needs to be fixed. Page 10 recommendation: the two recommendations on maintenance at the Kennedy Space Center (KSC) should be brought into alignment (use the same words). This is a candidate for elimination if it is adequately covered in chapter 3. Page 41 – Change beginning of first sentence to "Based on public input…" Page 12 – a modification is needed to the second paragraph. Mr. Mike Bloomfield will work on the right words. A separate security report was done that should be referenced on page 14. All of the recommendations should end the same way. Page 45, first paragraph – the recommendation on final closeouts is included in another section and should be taken out of this section. Micrometeoroids and orbital debris: There is a sidebar that shows how the orbiter is tracked and kept away from known debris. Admiral Gehman suggested saying that the Board doesn't understand why there is a lower standard for the Shuttle than for the International Space Station

(ISS). This section will be rewritten. The Board agreed that Orbiter Major Maintenance (OMM) should be moved to Other Significant Observations (Chapter 6). There is a finding in the second paragraph; this should be pulled out as a finding.

This meeting was adjourned at 1540 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 25, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Session – Review of Parts II and III of the Final Report

Date: July 25, 2003 **Time:** 0900 – 1220 EST

This meeting was conducted via teleconference in the ANSER facilities in Arlington, VA (Suite 700, Collaboration Room 7048E) with Dr. Sally Ride located in California.

The list of attendees is appended to the end of this report.

There was one action item generated from this meeting.

Dr. Sally Ride made some general comments about Part I of the Final Report. The Executive Summary, it appears to be more of an introduction rather than an executive summary. An executive summary should stand-alone. Re tone, the Board seemed to be a little too central in the Executive Summary.

Dr. Sheila Widnall raised a technical point—the issue of the figures. Twenty-nine figures are planned for Chapter 3 of the document—this is too many. It breaks up the text. Also, there has to be a way to put the figures in a Portable Document Format (PDF) file so that they can be seen within the context of the narrative. Mr. Scott Hubbard agreed. There should be an editorial policy regarding the correct balance. For example, all of the radar data on the second day event should go in an appendix. Admiral Gehman noted that he and the editorial staff are aware these problems. There is unevenness among the drafting styles. In some cases, the authors put all of their math and physics in the report; in other cases the authors put the bottom line in the report and the detail data in an appendix. There should be a considerable amount of logic and rationale in the report, just enough to lead the reader to the conclusion. For any additional detail, the reader should be directed to the appendix. Mr. Dennis Jenkins indicated that in the next draft, there will be a PDF file with drawings. Photos can easily be eliminated. The goal of the Board is to make NASA a safer organization. Mr. Roger Tetrault noted that Chapter 3 seems to have a lot of data without a story that tells how all of the data lines up. There should be such a story—either in the front or as a conclusion—it doesn't have to be long. Admiral Gehman agreed that this could be done. There needs to be "connecting tissue." Dr. Ride added that this is a good philosophy for all of the chapters.

Admiral Gehman discussed the process for finishing the editing. Revision 2 is out now; Chapters 1-4 are in revision 3. The best way to close out the document is the following: after edits of Part I, there will be revision 4. Figures for revision 4 will be posted as a PDF. Captions will be in the text. Final comments on Revision 3, Part I are due Monday. Misspelling errors/typos can be taken anytime up to August 22; however, comments/edits on Rev 3, Part I (Chapters 1-4) are cut off after Monday. The Final draft revision (rev. 5) will be in column form with layout (PDF file). Next week will be detailed review of Chapters 5 – 8. By next weekend

(August 2-3), the editorial staff will go to work on Chapters 5-8 and publish it. The next meeting on August 6-8 will be the collective Board review of Chapters 5-8. There will be a cabinet in Techdoc labeled Rev 4 and a cabinet labeled "Final." ANSER will print a Technicolor document, with figures and lines, to be handed out on August 26, 2003.

Chapter 10 (Significant other observations) will be reviewed today, along with Chapters 5-8.

Admiral Gehman noted that Chapter 9 is the only tricky part. Pieces of it have been turned in. He will finish this and post it on Monday. The first part will be return to flight; the second part will be the mid-term recommendations (next 3 – 15 years); the third part will be an editorial comment regarding a replacement vehicle. It will stop short of designing the replacement vehicle. Philosophically, the suggestion will be to separate cargo from crew and have a vehicle optimized for humans. First, decide what the operations requirement is (i.e., taxi cab to/from Low Earth Orbit (LEO), or more). Mr. Tetrault observed that NASA has been criticized for not having "vision;" however, NASA can't have any vision as long as it is tied to chemical propulsion. Until a technological leap beyond chemical propulsion is made, NASA can't do what most people want it to do in space. Mr. Sean O'Keefe has said that NASA needs to develop nuclear technology. Does the Board what to take a position on this? Admiral Gehman noted that the Board has not researched this subject in enough depth to pursue it. The vision thing is an interesting question. Is the lack of a vision causing any problems to the space program? Mr. Hubbard suggested looking at the strategic plan. Admiral Gehman observed that the problem with the Shuttle program is that Congress wanted a $5 billion vision. The question is not whether NASA has a vision, but whether the nation (and the Administration) has a vision. The nation (through its elected representatives) has not embraced human exploration beyond LEO. Admiral Gehman stated that no matter what the vision is, it starts in LEO—we must perfect humans going to and from LEO. Dr. Doug Osheroff observed that this must be done with the existing technology. Mr. Hubbard opined that the Board could do a great service by saying that the nation should embrace a vision. The vision must be established by the country or the White House. The lack of a vision is also a decision—a decision that has profound implications. The Board agreed with these comments. Admiral Gehman indicated that he would draft the third part of chapter 9 per this guidance. The report will not suggest a particular vision, but will make a statement regarding the need for a vision and what the consequences are without such a vision. It will also make the statement about the need to perfect humans going to and from LEO.

With respect to the tone of the Executive Summary, Dr. Widnall noted that the Nuclear Regulatory Commission (NRC) derives its credibility from the peer review process; the CAIB's credibility derives from the Board itself. The Executive Summary should not look like an executive summary in an NRC report. However, the Board agreed that a true executive summary should be a "condensation" or summary of the report. Admiral Gehman noted that perhaps what the CAIB has is not an executive summary. Mr. Steve Wallace agreed that the CAIB's executive summary is more of an introduction to the report. Dr. Ride suggested putting the "story" at the beginning of each chapter. People could read this and the findings and

recommendations and get a good sense of the report. The Board agreed that this could be done. The Board discussed whether to create another "thing" as a real executive summary. Admiral Gehman noted that the original plan was that the CAIB report would be a technical report and the chapters need to be read in their entirety. Dr. Ride observed that if the CAIB does not write an executive summary, the press will do it for them. After discussion, the Board decided to prepare a two page Executive Summary and **Mr. Wallace took the action to draft this**. He requested input from Board members. The present executive summary will be changed to an "Overview."

Dr. Osheroff brought up the issue of a NASA not being a "learning organization" in Chapter 8. He suggested that this is one of the key findings.

For Dr. Ride's benefit, Admiral Gehman raised the multiple function issue of Ms. Linda Ham and asked if she had a view. Dr. Ride stated that all of Ms. Ham's "hats" related to STS-107 and that the Board shouldn't make a big deal out of this. However, she was doing other things as well—she was working on STS-114 during the mission. They had discussions related to getting people talking about the foam loss in preparation of STS-114. If any issue is made over Ms. Ham's multiple jobs, it should be made regarding things in addition to STS-107.

The Board collectively discussed Chapters 5 – 8 in general terms. Part II is laid out the same way as Part I is (history lesson, factual recounting, and analysis). Chapter 5 is the post-Challenger history of the Shuttle program. MGen Ken Hess drew the Board's attention to his draft language on the introduction to Part II (Chapters 5 – 8). Chapter 5 has 3 or 4 historical vignettes, which satisfy the intent to put the accident in context. Chapter 6 is a factual narrative of several interesting things—emails, foam audit, and other safety things. The next two chapters analyze this. Chapter 5 is rather long (like Chapter 1 used to be). Mr. Hubbard noted that the intellectual flow makes good sense. Chapter 5 is an historical tome. The question is: Does it all contribute to the point of Chapter 5, or could it be compressed? Dr. Diane Vaughn has been working off-line to see if something that is analyzed or concluded in Chapters 7-8 is noted in Chapter 5. One of the criteria for compression will be whether the material contributes to the mosaic. MGen Hess noted that Chapter 5 does a very clear job of explaining external involvement. One of the themes of the report is that not only is the NASA management scheme not appropriate for a high risk program, the Agency has been told this a number of times. In terms of editing/condensation, Admiral Gehman suggested erring on the side of completeness. Chapter 5 has a budgetary point, a cultural point, etc. The rewrite that Dr. John Logsdon has done is much better than the one that was posted, but it is equally as long. Dr. Ride added that Dr. Logsdon was aiming for completeness and getting the tone right, keying up all of the issues; however, it could be about half the length that it is and still include all of the issues. The focus should be on making sure that it makes all of the points that the Board wants to make, but a little crisper. It has the appropriate tone. Admiral Gehman observed that Dr. Logsdon comes with a point of view; the CAIB must be careful to ensure that Chapter 5 reflects the Board's collective view and not personal views.

Chapter 6 is a factual recounting of some events—the email story, the foam audit. Section 6.1 refers to the emails and picture taking. Mr. Dan Diggins did a complete report with charts and graphs, which will be made an appendix. The story was condensed for the report itself. Dr. James Hallock noted that the personal email address should be deleted from the report. Mr. Jenkins stated that this would be redacted. Chapter 6 contains a discussion/context along with the verbatim quotes—this is approach is very compelling. The analysis and the words are there—there is a little bit of judgmental aspect. Admiral Gehman suggested that the Board indicate whether or not they felt that this was too much or not. Mr. Hubbard indicated that this section will get a lot of interest—it is contradictory to Ms. Ham's press conference. In response to a question, Admiral Gehman noted that the audiotape of the Mission Management Team (MMT) and mission control should be included on the delta velocity display (DVD). Admiral Gehman requested that the Board members check to see if this chapter has been properly balanced with the written statements. In response to a comment, Admiral Gehman noted that NASA really believed that the foam couldn't damage the wing and that there was no transport mechanism. The Board was satisfied with the tone and style of Section 6.1. Admiral Gehman added that it cannot be shorted very much. MGen Hess noted that the Program Review Control Board (PRCB) decided to continue flying after the foam hit the skirt of STS-112. Ms. Ham inherited this decision. Mr. Wallace added that this is an important point and is included in the "foam story." Dr. Vaughn added that the flight readiness rationale for STS-113 should be stated. The Board agreed to put the PRCB decision story in 6.1. The flight decision on 113 makes the story more compelling editorially. This sets things up sequentially. Section 6.2 begins with what foam is and what an external tank is. This is extensively discussed in Chapter 3; it could be referenced. Dr. Osheroff observed that the way the management structure is set up, the managers make the decisions—they are sometimes ill equipped to make these decisions because of schedule and budget pressures. Admiral Gehman noted that decisions have to be rolled up to get to the go/no go decision. The philosophy of the Board is that if there is a complex hierarchical system (separated by geography, function, culture, etc.) the process must be rather elegant and it is not. The Board discussed some ways that communication between different layers in the organization could be effective. MGen Hess observed that the MMT, as a body, needs to be trained to build the right techniques and abilities in the matrix group. Mr. Tetrault added that the philosophical criteria should be: prove that it is right, not prove that it is wrong. Admiral Gehman translated this into the practical challenge—if this were the philosophy, there would be 600 or 700 things that would come up as "wrong." However, a good program would have a healthy testing and research program to work through these things. NASA does not—this is an indictment of NASA as a human flight center of excellence. It has given up a lot of testing and research in order to meet schedule and budget pressures. Because NASA does not have the research and test program, there is not a system of checks and balances. Dr. Osheroff indicated that he had put in a recommendation that when "out of family" behavior is seen over and over again, it must be continually tracked in order to eliminate it. MGen Hess noted that Ms. Lisa Reid is writing the section on schedule influence/pressure. It addresses Mr. Sean O'Keefe's charter when coming to NASA from the Office of Management and Budget (OMB). Mr. Hubbard suggested that somewhere the CAIB should crystallize the management part with some

kind of figure, like Mr. Tom Young did with risk in the International Space Station (ISS) Management and Cost Evaluation (IMCE) Task Force report.

Section 6.3 is about eroding safety margins—anecdotes about various corrective actions that have been taken. Dr. Hallock felt that this detracted from 6.2. Admiral Gehman agreed that it is less than compelling. The idea was that whatever safety margins there were, by not fixing them they are being chipped away. It is not the author's fault—there is not much story there. Dr. Osheroff suggested a summary of this content. Admiral Gehman asked the rest of the Board to weigh in with their opinions. MGen Hess noted that there are some instances where NASA took aggressive action. NASA has not failed in every safety issue—when problems are obvious, the organization responds magnificently. The Board will take a critical look at this section and decide whether reduce it or move it.

Chapter 7 uses the lessons from Dr. Logsdon piece and the evidence from Chapter ~~7~~ 6 to compare NASA with other organizations that deal with high-risk technology where performance is measured with great public scrutiny. This talks some about the negative aspects of the organizational structure and communications across the complex structure. It looks at the safety and mission assurance organization. This organization is dependent in its entirety upon the program. The Safety and Mission Assurance (S&MA) organization never truly met the vision of the Rogers commission. In time, this organization became the currency of exchange as pressures increased. Chapter 7 summarizes key points and describes the "blind spot" in the organization that allows this to happen. The essence of the conclusion and recommendations is that NASA should create a separate technical authority that is a control mechanism. The Shuttle program should operate to standards that are maintained by another organization. Admiral Gehman observed that Chapter 7 starts off with a rather extensive tutorial on what the Board learned about reliability and what things about high-risk organizations made an impression upon it. After this tutorial, there should be a discussion of compelling attributes, with a comparison to NASA. The present organizational system (rigid hierarchy, signatures, extent of program manager authority, etc.) is a good system when you want to know whom to fire; however, it doesn't make it safe. At the tactical level, the Board examined whether anyone erred, and there were some errors. However, who is responsible for operating, running, feeding, and abetting an unsatisfactory and dangerous organization? --Headquarters. Should the Board bring this out? If the Board comes to the conclusion that the organization is incapable for running the operation safely, who should take the blame for that? --The people at the top. The Board felt that this falls from the recommendation. Editorially, the report will try to come to a conclusion about this. Admiral Gehman commented that if there is an organizational problem, it could be solved by reorganizing. However, a cultural problem cannot be solved by reorganization alone; it must be driven out by leadership. The Board agreed with this view. This puts an imperative on the top people of NASA to get personally involved. Also, leaders must have good tools (resources, a good set of rules, etc.) to work with in order to control outcomes. BGen Duane Deal raised the issue of whether the recommendations on NASA would have unintended consequences at all of the field centers. Dr. Osheroff noted that the report should be clear that their recommendations are focused on human space flight and the Shuttle program in particular. MGen Hess requested

that any "pet" ideas be sent to him today or tomorrow and he would try to weave these into the chapter. Admiral Gehman added that this is the place where all of the personal vignettes, theories, Board observations, etc., go.

As an aside, Admiral Gehman noted that there is a section on rescue and survivability. Something should be stated about CO_2 regeneration.

The purpose of Chapter 8 is to pull together all of the separate chapters in Part II. The point is to show the connections. It recounts the historical decisions by political leaders and how this is connected to the historical decisions about the foam problem. The comparison about Challenger and Columbia is to show that the problem is systemic. Dr. Vaughn noted that the editorial team is working on beginnings and endings to Chapters 5-8. Admiral Gehman observed that Chapters 5 and 6 are "what." Chapter 7 is an analysis. Chapter 8 is "why." Dr. Ride noted that the latest version of Chapter 8 could be cut down, similar to Chapter 5, keeping the tone and conclusions. One of Dr. Ride's concerns was whether Chapter 8 really does tie everything from Chapters 5, 6, and 7 together. There may be some findings necessary in Chapter 6. The Board agreed. Admiral Gehman indicated that the appropriate number of summary and connecting statements will be inserted into the chapters. Dr. Vaughn commented that Chapter 8 will refer to management theories, previous studies and conclusions, etc., that appear in Chapters 5, 6, and 7. The Board recognized that the story is layered—Chapter 7 is a layer above Chapter 6, and Chapter 8 is a layer above Chapter 8; a step cannot be skipped. The reader must understand what is presented in Chapter 7 in order to understand Chapter 8. Admiral Gehman indicated that he would draft the "organization as a cause" statement and send it to all members. The Board agreed that a case has been made for "history as a cause" and felt that it is important to include it in the report. Admiral Gehman noted that Chapter 5 reviewed the history of the safety organization between Apollo 1 and Challenger (19 years) and between Challenger and Columbia (17 years). It would be worth pointing out that if the organization is left to itself, the same evolution could happen again, due to budgetary and schedule pressures. Unless some serious cultural and managerial changes are made, it could be expected that safety would atrophy again over time. Admiral Gehman made a note to go back to Chapter 5 and see if some statement needs to be drawn there.

Admiral Gehman noted that the Board does not comment on the Aerospace Safety Advisory Panel (ASAP). (One reference was made in the crew escape part.) With respect to the issues about the safety organization, what about ASAP? Dr. Widnall noted that ASAP recommended crew escape, but the ASAP's primary agenda is to get more money for NASA and they are careful about how they criticize the Agency. They have "pet rocks." and are not really effective. NASA ignores most of the recommendations. Mr. Hubbard noted that ASAP has little influence over the human space flight part of NASA. Admiral Gehman suggested writing something up in the "other significant observations" section. Dr. Ride added that the problem is larger than ASAP. Congress could be stimulated to take a stronger hand and put some real safety people on ASAP.

Gehman reviewed the current collection of draft interim recommendations:

- Get a better Crater model
- MMT training
- Better closeout photos and engineering drawings
- Standardization of foreign object damage (FOD) characterization
- Public safety of overhead crash
- Understanding the foam and stopping it from coming off
- The quality program

This meeting was adjourned at 1220 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
July 25, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

At the ANSER facilities in Shrilington, VA

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-3229
Roger Tetrualt	CAIB	703-416-3591
Dr. Jim Hallock	CAIB	703-416-3272
BGen Duane Deal	CAIB	703-416-3349
Dr. Doug Osheroff	CAIB	703-416-3490
RAdm Steve Turcotte	CAIB	703-416-3015
Steve Wallace	CAIB	703-416-8405
Scott Hubbard	CAIB	703-416-3109
MGen Ken Hess	CAIB	703-416-8481
Dr. Sheila Widnall	CAIB	703-416-3445
Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-283-7809
Ltc Don White	CAIB	703-416-3235
Dennis Jenkins	CAIB	703-416-3373
Dan Diggins	CAIB	703-416-3054
Les Reingold	CAIB	703-416-3551
Chris Kirchhoff	CAIB	703-416-3121
Dwayne Day	CAIB	703-416-3491
Dr. Diane Vaughan	CAIB	

On telecon via California

NAME	ORG.	PHONE
Dr. Sally Ride	CAIB	703-416-8497

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 6, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Discussion on Liability, Refund of Retirement Contributions, and Schedule

Date: August 6, 2003 **Time:** 0900 – 1000 EST

This meeting was conducted via teleconference in the ANSER facilities in Arlington, VA (Suite 700, Collaboration Room 7048E) with Dr. Sally Ride located in California.

The list of attendees is appended to the end of this report.

There were no action items generated from this meeting.

Admiral Gehman reported on his briefing to the Return to Flight Task Group (RTF TG) the previous day (8/5/03) at the Kennedy Space Center (KSC). The CAIB was given high marks on its effort. The RTF Task Group was particularly interested in why some of the organizational changes were not RTF issues. Admiral Gehman suggested that as the Board goes through its review of Part II of the final report, it could reconsider this aspect. Other issues were the mid-term operation of the Shuttle and the subject of the future—replacing the vehicle and getting people back to low earth orbit (LEO).

Admiral Gehman covered some administrative matters as well as the week's agenda. The goal is to get through Chapter 5 today, Chapter 6-7 on Thursday, and Chapters 8-11 on Friday. Admiral Gehman indicated that he would like to meet with a subgroup on Chapter 3 in the afternoon.

Mr. Bill Sikora discussed personal liability for temporary, paid government employees. With respect to potential personal liability, if the member is acting within the scope of the group's charter and is sued, the U.S. Government is substituted as the defending party would defend the suit. The key is coverage for actions within the course and scope of employment. Bottom line: as long as the members stay within the scope of what the Board has found, liabilities are covered, even for former employees. Mr. Roger Tetrault asked about the statute of limitations, e.g., something that occurs in the future that the Board did not find. Mr. Sikora indicated that this depends on the state in which action is brought. There is a statute of limitations, normally around 3 years. It is a latency issue, and you get into state law. The Board's decision on what should be investigated within the scope of its charter is discretionary. The fact the something was not investigated does not incur any liability. Admiral Gehman asked about the case where the families sue Boeing—can members be called as witnesses? Mr. Sikora indicated that in this case, there is the possibility for subpoenas. Under those circumstances, the member subpoenaed would have representation from the Justice Department. More likely, the requirement would be for deposition. If members are contacted by any attorneys, first contact the NASA General Counsel's office (Mr. Sikora). The member can only respond with factual information, not answer any personal opinion questions. The factual information includes the judgments and

conclusions in the report. To go beyond that is out of bounds. It is important to have the government attorney involved; he or she will make sure that the limitations are adhered to. Regarding anything the interviewed witnesses said—this is privileged information, and the government attorney would object to that. Mr. Sikora emphasized that it is important to contact NASA before talking to anyone.

The other issue is post employment limitation. For those going back into the private sector, the only realistic limitation is the restriction on Senior Executive Service (SES) level 5 (18 USC 207). Basically, there is a one-year "cooling off" period before the person can come back and represent another party in an advocacy role to NASA. However, you can come back and work for the government. You cannot personally advocate to NASA. The lifetime bar only applies to "particular matters;" this investigation is not a particular matter in that sense. Advocacy is the key with respect to where the restrictions lie. For example, if a member is asked to speak at a NASA training program, and the member is paid through a contract, this is okay. If the person is a principle investigator (PI) on a NASA proposal, it is okay as long as the person does not "advocate." Just signing the proposal is not "advocacy", as long as the person is not personally representing the proposal entity to NASA. However, if there is "pre-review" where the PI is asked to support the proposal, this would be problematic. Mr. Sikora recommended that a person not engage in this type of advocacy for one year. He recommended having an associate handle the proposal process, review, and interaction with NASA. This does not restrict a person from working for the government, e.g., the NASA Advisory Council (NAC). The limitation only applies after the member leaves CAIB employment (8/26/03). Admiral Gehman noted that if a member does submit a proposal and the PI is called or has a review, it is legal to inform NASA about the one year restriction and offer an associate to engage directly with the government. No one can use his or her official position on the CAIB to influence action for any third party (university, company, etc.). Re ongoing contractual relationships that predate appointment to the Board—there is no restriction in terms of performing anything, only advocacy. Also, the restriction on advocacy only applies to the agency that the person worked for. It does not apply for other government agencies. Mr. Sikora invited members to contact him regarding any questions related to specific circumstances.

Mr. Steve Schmidt discussed the subject of refund of mandatory contributions to the SES retirement fund. NASA is putting together a package for the members for their government departure. This should be available by Friday. Dr. Sheila Widnall noted that she was a fully vested Federal employee and requested that NASA facilitate her retirement from Federal service. Dr. John Logsdon requested that all of the members get a copy of their SF 278's that are on record.

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 6, 2003
These Minutes Contain No Sensitive Data

Schedule:

Plenary meetings this week will be 0900-1200. There will be an extra activity at Champps on Thursday, August 7, 2003 at 1830.

After all of the editing activity this week, Admiral Gehman and the editors will compare various edits on Saturday morning. Editors will start preparing another copy of Chapters 5, 6, etc. on Monday. Meanwhile, Chapters 1-4 are now being laid out and these will be posted as soon as they are ready. More work will be done on Chapter 3 this week and it may be posted by Friday. There will be one more opportunity on Chapters 5 – 8, then it will be sent to the printers. Emails will be sent out when final versions are posted. Admiral Gehman will be in and out of the office throughout this period. Roll-out is still scheduled for 8/26/03. The House and Senate are adjourned. Admiral Gehman may be hand delivering a copy to Mr. Sean O'Keefe at NASA. Three or four people will be going to Houston, TX. The first hearing will be around 9/3/03, and it will primarily consist of reading the report into the record. The following hearings will be more interactive. There will be a press conference on 8/26/03, but it is not necessary for the full Board to be present. The formal presentation materials will be available around the first week of September 2003. [A version is available now.] The Chamber of Commerce briefing does not contain all of the management/organizational material. Admiral Gehman emphasized that the report will not be given out to anyone before rollout. There will not be a big family gathering in Houston, TX—the family members have a previous commitment in Guam and have been asked to not change their plans.

Dr. Jim Hallock commented on the appendices—he will start looking at these next week. He strongly recommended the need for quality control and volunteered to help. The first appendix should be out quickly. Admiral Gehman noted that documents that have been prepared by somebody else are their responsibility. CAIB documents must be checked. This includes things that have been prepared by others that have the CAIB name on them (i.e., chartered by the CAIB). Admiral Gehman and others will be working on this during September 2003. A deadline has not yet been established for the final versions of the appendices. There is a lot of editorial discretion for Volumes IV and V. Admiral Gehman indicated that he is most concerned about the viewgraphs of presentations and the references to them. Volumes II, III, IV, and V should all be finished by the end of September 2003. The facility will be open as a resource during September 2003. There is additional schedule and quality pressure on Volume II because these are the references contained in Volume I.

Board adjourn to Executive Session at 1000.

This meeting was adjourned at 1000 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 6, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

At the ANSER facilities in Shrilington, VA

NAME	ORG	PHONE
Admiral Gehman	CAIB	703-416-3229
Roger Tetrualt	CAIB	703-416-3591
Dr. Jim Hallock	CAIB	703-416-3272
MGen Ken Hess	CAIB	703-416-8481
BGen Duane Deal	CAIB	703-416-3349
Dr. John Logsdon	CAIB	703-416-3057
RAdm Steve Turcotte	CAIB	703-416-3015
MGen John Barry	CAIB	703-416-3570
Steve Wallace	CAIB	703-416-8405
Scott Hubbard	CAIB	703-416-3109
MGen Ken Hess	CAIB	703-416-8481
Dr. Sheila Widnall	CAIB	703-416-3445
Steve Schmidt	CAIB	703-416-8488
Bill Sikora	CAIB	281-283-3363
Paul Cromier	CAIB	281-283-3262
Mike Bloomfield	CAIB	281-283-7809
Paul Wilde	CAIB	703-416-3367
Lt. Chuck Ensinger	CAIB	703-416-3229
Les Reingold	CAIB	703-416-3551
Chris Kirchhoff	CAIB	703-416-3121
Dwayne Day	CAIB	703-416-3491
Dr. Diane Vaughan	CAIB	
Pat Trenner	CAIB	703-416-3256
Laura Brown	CAIB	703-416-3532
Tom Carter	CAIB	703-416-3461

On telecon via California

NAME	ORG	PHONE
Dr. Sally Ride	CAIB	703-416-8497

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
Aug 6, 2003
These Minutes Contain No Sensitive Data

Purpose: CAIB Executive Session

Date: Aug 6, 2003 **Time:** 1015 – 1240 EST

This meeting was conducted via teleconference in the ANSER facilities in Arlington, VA (Suite 700, Collaboration Room 7048E) with Dr. Sally Ride located in California.

The list of attendees is appended to the end of this report.

There were no action items generated from this meeting.

Board Discussion of Issues

Admiral Gehman and MGen John Barry discussed their "on the record" interview with Mr. Sean O'Keefe. He was very forthcoming, sincere, and professional. A transcript is being prepared and will be available. Mr. O'Keefe referred to some of the things that the Board has accepted as fact (e.g., budget pressures, freeze on Shuttle upgrades), as "folklore" or "urban legend." This is disturbing and indicates a different "mental plot" from the Board.

> **Decision: The Board agreed that the report is a little unbalanced (not enough positive things about NASA); this has been noted for editing. The discrepancy (Mr. O'Keefe statement vs. report) re the request for relief on the February 2004 date needs to be fact-checked.**

Recent Email invitation from Mr. Sean O'Keefe: Mr. O'Keefe would like to bring the top NASA Administrators and the Board together for an informal "farewell dinner" the week of the release.

> **Decision: Make a counteroffer--<u>After</u> release of the report, the Board would like to have an interactive meeting with Mr. O'Keefe and the top administrators at NASA Headquarters in the PRC, with dinner afterwards (either at NASA or elsewhere).**

Issues from Chapters 5-8:

1. Proposed statement: "NASA thinks it is OK to fly the orbiter through a shower of debris (ice, foam, etc.) on every flight." Is this the right expression? **No—too harsh.**

> **Acceptable statement: State factually. NASA "tolerates"... etc.**

2. Why did we have 2 out of 3 flights lose bipod foam after 10 years? Do we need to answer this question?

   Answer: We don't need to answer this in a technical sense, but address it in a process sense. This is adequately covered in the report.

3. The transition to SFOC was not causal… agree or disagree?

   Answer: It added risk (more complexity), but it was not causal.

4. Broad generalization: "One can look at repeated debris strikes only one of two ways:

   1. Repeated success proves there is no safety of flight issue, or

   2. Repeated violation of requirement not to hit the thermal protection system (TPS) can only go on for so long until it causes something bad to happen."

Question: Did Mr. Feyman tell NASA what the correct way to look at this issue was? Was his interpretation clear? [was NASA given the answer?]

Answer: This is oversimplification. There was evidence; NASA never did the testing necessary. Focus on the testing. Checks and balances should answer the problem.

5. Address the issue presented by the quotes in Chapter 6, page 47 re Ms. Linda Ham's email: Is Ms. Ham expressing some doubt about the "urban legend" (that foam can't hurt the orbiter)? Is she looking for reassurance?

Answer: She is looking for reassurance. She is answered by Mr. Ralph Roe. Later, Mr. Calvin Schomburg makes statement.

Question: Do these emails demonstrate that these three people had doubts about or were aware that if a strike was of sufficient size and speed, it could damage the orbiter?

Answer: They knew that the conventional wisdom that foam cannot hurt the orbiter was incorrect. The question of "how big" was being run through analysis; they would have the answer the next morning.

The Board reviewed the words in the sequence of emails and the transcript of the meeting.

Answer: Go back and verify exact words in emails, transcript. The Board has established the right policy—not make personal performance judgments, but lay out the facts. [no changes to present text]

6. Are we sure the bipod ramp foam did it?

   Answer: Yes

7. 7 MCC members needing recertifications was not causal…Agree or disagree?

   Answer: agree. This is indicator of the bigger issue of "rule-following"—Admiral Gehman to check to make sure that this issue is covered in report.

8. Discuss pages 9, 10, and 11, Chapter 10: crew survival.

The Board reviewed the draft text.

Conclusions: Under Failure of Crew Module section--Change wording in second sentence re combustion source. Correct errors in chart. Clear up XO 576, etc. Re window of destruction of crew module—go back over temperature reference (can be misleading).

Upon initial review, draft text is professional, careful, sensitive, and is appropriate. Board agreed to move the facts up to Chapter 2. Findings, etc. will stay where they are.

Other issues:

1. Others have raised the question: "Who is in charge?" **This is in the report under organizational issues.**

2. Reports/viewgraphs versus actual prose? **This is addressed in the report.**

3. Push back on what the Board is going to say about the Safety organization owning the requirements vs. the Program Manager owning the requirements. **Report will be clear about need for checks and balances.**

4. Insularity and not reaching out to where the expertise is.

5. Mr. O'Keefe's Return to Flight (RTF) speech is focused on debris recovery. Does not mention other four lines of inquiry. **Emphasizing seriousness of Board's feelings on managerial and engineering failures is important.**

6. NASA's tendency to focus on the "trees" and spotty on looking at the "forest" (systems engineering). **May need more words on this in report.**

This meeting was adjourned at 1240 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

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Dr. Diane Vaughan	CAIB	

On telecon via California

NAME	ORG.	PHONE
Dr. Sally Ride	CAIB	703-416-8497

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 6, 2003
These Minutes Contain No Sensitive Data

Purpose: Editorial Review of Chapter 5

Date: August 6, 2003 **Time:** 1345 – 1730 EST

This meeting was conducted via teleconference in the ANSER facilities in Arlington, VA (Suite 700, Collaboration Room 7048E) with Dr. Sally Ride located in California.

The list of attendees is appended to the end of this report.

There was one action item generated from this meeting.

Admiral Gehman reminded everyone that Part I follows a pattern: Chapter 1 is a history lesson; Chapter 2 is a recitation of facts; Chapters 3 and 4 are analysis. Part II follows the same pattern. The purpose of Chapter 5 is to give the historical background of the post-Challenger Shuttle program.

Dr. John Logsdon noted that there are some tonal questions with the Chapter. Dr. Sheila Widnall observed that the Chapter sounds like NASA was having things "done to it." This tone is not valid. NASA was also an active participant. For example, NASA put forward an ambitious space program and sold it. She felt that the Board should not signal that it was endorsing the Orbital Space Plane (OSP). Mr. Steve Wallace commented that there are too many budget charts. Dr. Logsdon felt that the Story of Chapter 5 should be: NASA, having promised the country an ambitious program, was not provided adequate resources, was managed by a person that was driven to reduce resources, and was following a philosophy that the Shuttle was a mature system that could be operated on a routine basis by a single contractor. Because of this judgment, there was not the desire to invest in a long term Shuttle program. Mr. Scott Hubbard added that the Board should make sure that the report includes all of the "co-conspirators." The editing has de-personalized NASA during the 1990's. The question is: How much does the Board want to personalize (i.e., Mr. Dan Goldin and Mr. George Abbey) on how this part of the agency was run?

Admiral Gehman noted that if the report is going to be critical of the Office of Management and Budget (OMB) and Congress (and it is), it needs to be complete. It is difficult to make this Chapter shorter. The public policy issues cannot be discussed in much less space.

Dr. Sally Ride had several comments. She observed that the section was long and there is a lot of stuff that has the potential to detract from the significant points; however, if the Board wants to set the context, there must have a balanced story. In the editing, the tone has changed in some places. With only the one section that describes Mr. Goldin left in, it gives the impression that he was a good reformer. The Board should make sure that it reads like an investigation report,

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not a public policy monograph or academic review. There are a couple of sections that tend that way. MGen John Barry noted that the section about Challenger (i.e., the Rogers report) is repetitive with Chapter 8. Admiral Gehman noted that it should be stated here; analyzed later. Dr. Ride agreed; she felt that it sets up the material in Chapters 6 & 7. With respect to names, the people mentioned are the key players.

Page 1:

Second paragraph, next to last sentence—this is fairly inflammatory and judgmental. Dr. Ride felt that if the Board says this, then the organizational changes must be made before return to flight. Admiral Gehman noted that the report makes the argument that the first few flights will be carried with enough zeal. Mr. Roger Tetrault felt that it should read, "As the agency was operated at the time of STS-107." Admiral Gehman noted that the basic premise of the report is that not only is the problem with the way that it is operated, but with the way that it is organized (checks and balances). Organization alone is not sufficient. The Board decided that the parenthetical should read, "As the agency is currently operated and organized."

There is a philosophical issue—whether fixing the organizational problem is a return to flight issue. Dr. Logsdon suggested that the sentence be removed—it shows the conclusion before the case is organized. Mr. Steve Wallace also suggested removing the last sentence of the paragraph (regarding internal culture). Other changes: take "even" out of the sentence about privatizing; take "in many ways" out (referring to the Shuttle as a developmental vehicle); remove quotes from around "privatize." With respect to use of the terms "White House" and "OMB," Admiral Gehman noted that the Board was not able to differentiate between these and with respect to budget, they are synonymous.

Page 2:

Third paragraph: Change "incident" to "accident". Change "burned through O ring" to "blew past the O ring and burned through the joint." Change "disintegrated" to "broke apart." Usually, the order of the astronaut list is commander, pilot, mission specialist, payload specialist. Dr. Ride suggested highlighting two more things. Add lack of engineering analysis and lack of testing (in second paragraph from bottom)—"neither tested that joint or developed a solution." Last paragraph, these flaws affected more than the launch decision. The report focused on the whole organizational and communications problems, and how they affected problems over the years.

Page 3:

In the first paragraph, use the words "created schedule pressure" rather than "brought difficulties."

Summary sidebar: recognize the importance of testing. Dr. Ride will look at the wording of the recommendation and try to pull something out.

Page 4:

Third paragraph, last sentence—reference is from the 90 day study on the moon and Mars; it was not something that the Space Shuttle program was planning. The Board agreed to take the third paragraph out.

Page 5:

Some of the statements need to be linked to other places in the report. There should be a consistent definition of what the Board means by "culture." In some places culture is good, in some places it is bad. It can be both. Admiral Gehman suggested a sidebar with the Board's definition.

Page 6:

Third paragraph, first sentence—this sentence is judgmental and sounds like a finding or conclusion. However, the report is going to prove this in the following chapters. The Board agreed to leave this sentence in. There is a terminology shift between "NASA" and "NASA Human Space Flight." It should be clear what the Board means. The Board's investigation has been into the human space flight program. When the report means the Space Shuttle Program (SSP), it will use "SSP." Fourth paragraph—this is true, but it could be moved into Chapter 7 (referring back to Chapter 5) if it is not already there. This paragraph could belong in the introduction to Part II. MGen John Barry suggested emphasizing a "reusable vehicle."

Page 7:

Add "too" before little in title. There are a number of other minor edits. First paragraph, last sentence, change to "program that was already overcommitted." Second paragraph, "in less than two years, there were a series of problems…" This part is broader than the human space flight and the use of "NASA" is correct. There have been multiple reviews by respectable bodies to try to characterize the risk. Congress has asked the Board to clearly state a way to characterize risk. Although it is redundant, it is helpful. Put an introductory sentence in the sidebar to the effect that Mr. Norman Augustine's committee was not the only one. Put the footnote reference in the sidebar (it must be stand alone).

Page 8:

Add something to change the tone per Dr. Widnall's earlier suggestion, e.g., "neither the White House or Congress were interested... but NASA continued to propose one." Put the source underneath each of figures and tables. Add units wherever possible.

Page 9:

No comments

Page 10:

Second paragraph, there is a conclusion. The Board was satisfied with it here. Stennis and Goddard are also space flight centers; the Board is only talking about Marshall Space Flight Center (MSFC), Johnson Space Center (JSC), and the Kennedy Space Center (KSC) (add to parenthetical—such as a "human" space flight center).

Page 11, 12, 13:

The chart (Figure 3) could come out. Table 2 shows the difference between what the White House did versus the Congress. Align decimal points. Take out figure 4.

Page 14:

Third paragraph, there is a judgmental statement. It is implied that budgets had something to do with not flying the Shuttle safely. Does the Board really think this? The body of the report does not blame it on money. The report suggests that the money issue instituted a series of outcomes—it created a culture of effectiveness and efficiency. It is not clear that more money would have fixed the program; however, the lack of money precluded any chance of having good safety and engineering departments. Lack of money set in motion a false set of priorities. Add the following: Budget is a secondary contributor in the following ways: making the Shuttle a "cash cow" for other programs sends a signal about priorities and that it is an operational program; it had an effect on the workforce (removal of personnel and layer of oversight), and it precluded a good program of testing and analysis. It also sent a signal about what is important to Headquarters (cost and schedule).

Page 15:

Sum table at the bottom rather than top.

Page 16:

What about the one report (Dr. Christopher C. Kraft) that is different than the others? Is there is a direct connection between the NASA decision on Space Flight Operations Contract (SFOC) and the Kraft report? [Yes, this is in an interview.] Does the Board want to make a big deal out of this? This report confirmed Mr. Dan Goldin's predilection for privatization. Moving in the direction of SFOC made sense if the assumptions were valid. The first assumption (Shuttle a mature and reliable system) was not. The Board decided to leave the facts about the Kraft report here and comment about it in Chapter 7. Move "Goldin's vision" (page 18) to a position just before the paragraph about the Kraft report; this puts it in context.

Page 18:

Move the second paragraph back to page 16. This chapter goes through the chronology several times, but for a different purpose each time. Mr. Goldin (Section 5.5) should come before Kraft. Goldin could be introduced at any time, perhaps as far back as 5.3. Combining the two sections would be a major rewrite. The Board agreed that Goldin should be introduced sooner. Dr. Logsdon will work with editors to get enough about Goldin in earlier (e.g., take the first 7 paragraphs in 5.5 and move them up; swap the order of paragraphs 2 and 3).

Page 32 (schedule pressure):

What more should be here from material Dr. Ride has developed? Dr. Ride noted that Ms. Lisa Reed's paper had many parts to it. One was a historical discussion with some good quotes from testimony; the rest laid out the environment leading up to STS-107, and what was coming after STS-107. Dr. Ride took out Lisa's historical part, assuming a better place for it would be here. Some of that should be woven in here [editors have already started to do this, and will coordinate with Logsdon and Ride].

Page 31:

Last paragraph, there is a subjective, judgmental budget statement. The report doesn't tie a knot around the budget any other place than this Chapter. However, the concluding budget statement should be neutral—i.e., these programs cost more than the money available. **Action: Take all of the judgmental statements in this chapter and summarize them at the end.**

Page 34:

Last paragraph re the Integrated Space Transportation Plan (ISTP)—the Board does not want to express an opinion about this [remove].

Page 20:

It is proposed that the Foster & Olsen report to the CAIB be put in the appendix. It is acceptable as a source document. The Board did not want to draw conclusions about the SFOC contract.

Page 18:

Define what "insight" means. Include sidebar here.

Page 19:

Re editor's comments on what SFOC meant for people on the ground—No, not here.
It is not only MSFC that has resisted transfers. It should read MSFC and others [to be editorialized].

Last paragraph, there is a finding [move to end]. What point is being made? Is the transition of NASA oversight to the scheme of "insight" increasing risk? This is subjective. Contract consolidation can be very effective. However, along with contract consolidation, NASA moved from the philosophy of oversight to insight. Both were done at the same time. The SFOC in and of itself did not appear to increase risk. Changing the philosophy of oversight to insight did increase risk. A statement will be written and emailed to members separately for review.

Page 21:

Privatizing was part of the movement, it was considered, and it has faded. The Board doesn't draw anything out of this. It shows the mindset that thought the Shuttle was mature enough to be privatized. It also lays a foundation for what is in Chapter 7. The Board doesn't want to pursue the RAND study and other items noted in editorial comment any further.

Page 22:

This section moves forward as noted earlier. The Board debated how to express replacement of Truly. It agreed to simply state that in 1992, the White House replaced VAdm Richard Truly with Mr. Goldin. Admiral Gehman will discuss with the editors their style of using quotes around individual words.

Page 23:

No comments.

Page 24:

The two graphs could be combined into one. Use "employee" instead of full-time equivalent (FTE).

Page 25:

Another principle was that checks and balances were unnecessary. Show emphasis on this statement in the report. Third paragraph, put in date when Bridges threatened to resign. Admiral Gehman will figure out where introduction of Mr. Abby goes.

Page 26 & 27:

No comments.

Page 28:

Fact checks on X-33 and Space Launch initiative (SLI).

Page 29:

Figure out where the quote came from. Third paragraph, last sentence—reader is left hanging. Insert two or three sentences re top-level things from the report. Leave sidebar on upgrades in Chapter 7.

Page 30:

Re table--say the same thing in two sentences and delete the table.

Page 31:

Fourth paragraph, last sentence—this has been checked and is factual. Judgment sentences (the Board believes…) should move out of this section.

Page 32:

Testimony section to be added. Add, "See section 6.2 for full discussion of schedule pressure."

Page 33:

In the first paragraph under Trying to Fix the Problems—the Board agrees with the statement.

Footnotes:

Go back and explain references (both references and where to find them in the CAIB database).

This meeting was adjourned at 1730 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 6, 2003
These Minutes Contain No Sensitive Data

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Dr. Diane Vaughan	CAIB	

On telecon via California

NAME	ORG.	PHONE
Dr. Sally Ride	CAIB	703-416-8497

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 7, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Session – Review of Final Report
HWG 7
Date: August ~~6~~, 2003 **Time:** 0830 – 1645 EST

This meeting was conducted via teleconference in the ANSER facilities in Arlington, VA (Suite 700, Collaboration Room 7048E) with Dr. Sally Ride located in California.

The list of attendees is appended to the end of this report.

There were two action items generated from this meeting.

Organizational Cause Statement

There are many issues and influences that are not in the statement. The Board decided that the issue of operational versus developmental vehicle should be in the statement. Other changes were:

- First sentence, change to: "... the Space Shuttle program's history and culture, including ... schedule pressures, mischaracterization the Shuttle as operational rather than developmental, and lack of an agreed national vision."

- Second sentence, change to: "Cultural traits and organization practices detrimental...were allowed to develop, including relying on past successes as a substitute ... practices (such as testing...specifications), ineffective communications, lack of integrated management, stifling...opinion, and ...command and processes ... outside the organization's rules. "

The Board agreed to come back to the cause statement after going through Chapter 6.

Admiral Gehman reviewed some Chapter 4 questions:

- There is a statement that the crushed foam did not contribute..., etc. Dr. Doug Osheroff was concerned about evidence for this. He was not persuaded that it did not contribute to the loss of the bipod ramp. The Board felt that this could be taken out.

- There was another question about the numbers for micrometeorite debris (MMD). The International Space Station (ISS) has much higher criteria (even when normalized for time) and defines it differently. The ISS has a higher safety margin for MMD than the Shuttle. Why is the standard higher? It appears that NASA set the criteria for Shuttle based on what can be achieved. In the probability risk assessment (PRA) model, MMD is the largest

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element of risk. This issue is still open. The Board felt that it should make a finding and recommendation on this subject.

Chapter 6 Review

Admiral Gehman noted that the order of sections in this chapter have moved around. The Board approved of the present order.

Page 1:

- Second paragraph, middle: change "politically-motivated" goal to "management imposed" goal.

- Further in the paragraph: "management's recently reinforced belief" is too obscure. Change to "the STS-112 decision". Tone down schedule pressure on Node 2—e.g., influenced rather than encouraged.

Section 6.1

- Last paragraph: delete "such" from second sentence. At the end of paragraph, say something to the effect that statistics indicate that the number of hits remains flat.

Page 2:

- Original Design Requirements, first paragraph, insert year that spec was written

Page 3:

- First paragraph, 30 ft. should be 6 in.

- Discussion of Foam before the Rogers Commission:

    - Did Rogers investigation have any conclusion about foam? The Rogers commission did not perceive the danger about foam. Foam shedding was treated more seriously in the beginning of the program than later.

    - Need a sentence at the beginning and end of the paragraph to "walk" into this.

- Continuing Foam Loss: later, there are different numbers. Both are correct. The report should be consistent, rather than try to explain the difference in the two sets of numbers.

Page 4:

- First sentence of second paragraph is conclusion or judgment. It is true. Leave as is.
- Last sentence in second paragraph: these were never analyzed in any sort of engineering sense. Take analyzed out.
- Last paragraph—fact-check numbers.

Page 5:

- No to editor's note (not all, may put one in). Reference the detailed matrix in the appendix.
- Sidebar: should be "seven" rather than "five." The sidebar is a bad analysis. The beginning of the sidebar is OK. End the sidebar after the next to last sentence in the paragraph.

Page 6:

- First paragraph after sidebar: Is this a constraint to flight or not? At the Program Review Control Board (PRCB), something can be designated as an in flight anomaly, then separately designated as a constraint to flight. Quote exactly from the spec rather than the last sentence.
- Last paragraph, second sentence, change to "Columbia had a camera…"

Page 7:

- Second paragraph, there is a conversational, chatty tone. The tone of some of other chapters are more sober, academic, etc. Edit this to be consistent with tone of other chapters.
- In the second paragraph, there are a number of single words in quotes. If the quote is from a document, it should be footnoted. Quotation marks shouldn't be used a way of adding emphasis.
- Use a consistent and concise style among the paragraphs that talk about the foam loss incidents (pages 6 & 7).
- Need to document from the PCRB for the 4th and 5th loss events (**Action: RAdm Steve Turcotte to submit sidebar write-up**).
- There was never any thorough analysis of what could happen to the orbiter as a result of the foam loss. Expand the first sentence on page 7 to include this.

Page 8:

- Insert photo of the big ding (Rick has copy).
- Bottom of page, what is the process by which the Board has come to these opinions? Asking a question and answering it is a way to lead the reader to the next subject. Leave as is.
- Second paragraph: Was the decision made by the PRCB or the Flight Readiness Review (FRR)? The PRCB decided that it was not a constraint to the next flight. Leave as is.
- Last sentence of second paragraph: The ramification of the PRCB carried over to the FRR and the Mission Management Team (MMT). The Board agreed with the logic train, but decided to take out Ms. Linda Ham's name and fix the sentence.
- Third paragraph: change reversal to inconsistent.
- Emphasize (italics) last sentence of last paragraph.

Page 9:

- ISS schedule pressure may come up later; don't do it in both places. Put photos in order.

Page 10:

- The Board will criticize NASA later in the report for making the decision based on the rationale bullets shown on the chart. After "sleight of hand," insert a sentence about the Board noting a number of serious flaws with the decision-making.

Page 11:

- Next to last paragraph, fourth line, "stipulations" is not the right word. Change to "conditions."
- Last paragraph. Not all engineers; use "some" or "many." Change "NASA" to "SSP." Add sentence about this still being an open item (postponed until after STS-112). Technically, they were following their rules, but this is a case of bureaucracy taking precedence over good engineering practices. Board agreed to develop a sentence and insert here.

Page 12:

- Editor's note: Move section forward of the STS-113 FRR discussion. Outline and see how it fits together.

Page 13:

- Paragraph: There are two different points of view. The point is that on previous flights there were major debris events including the loss of a tile. Is NASA a learning organization? Editorialize out everything about who saw what on the ground.

- Last paragraph, first sentence, take out statement about Mr. R.L. "Hoot" Gibson.

- Take out photos except for STS-27 and STS-87.

Page 14:

- Fact-check: "burn through" was not in the report. The photo shows the missing tile and minor discoloration of the room-temperature vulcanizing silicone adhesive (RTV). The photo is not compelling. The lost tile was in a fairly cool area. This needs to be toned down.

- Last paragraph: need a footnote reference from the STS-27R investigation team.

- Second paragraph: "Program management" should be the "Shuttle Program management." Add in "photography or". Delete "astonishing" in last sentence.

Page 15:

- Board agreed that a short sidebar on timeline would be useful.

- Last paragraph: There is no evidence on what the man-made debris was. Take out speculative sentences. Consensus was to not mention the bolt catcher.

Page 16:

- Third paragraph, third sentence: we understand why this one anomalous event occurred, but this doesn't explain why foam comes off. Take out next to last sentence. Bipod ramps are still applied with Freon.

- Second paragraph: Make reference to thrust panels.

Page 17:

- Top paragraph, change to: based on NASA's "mistakenly held understanding"... The latter procedure has been shown to not address the fundamental cause.

- Second paragraph: in one place the report says 30; in another place it says 23—fact-check and make consistent. 21 versus 23 is not significant. This paragraph does not convey a lot of information. The point is the Space Shuttle Program (SSP) got the foam loss down to the point it was before, and then stopped. Another bad engineering rationale is to not address something because it is in the middle of a test program. The Board decided to delete the entire paragraph.

- Tighten up the way that the Dr. Elizabeth Pate-Cornell work is referred to.

Page 18:

- Impact Resistant Tile: there are tougher tiles, but whether they are tough enough is very subjective because there is no specification.

- Last sentence: The impact "capability" for ...There is a finding later on that builds on this.

- Conclusion: first paragraph, last sentence: "merging" in their minds—use different expression.

- Last sentence: Is there evidence for this? If not supported, don't say it. In the foam improvement initiative, they were allowed to complete the initiative over 8 flights. This suggests that the pressure to fly took precedence over the fixes. Text on page 16 and 17 talk about the incremental program. The Board decided to take the last sentence out.

Page 19:

- Third paragraph: Attribute "normalization of deviance" to its originator. Last sentence, change to: "...phenomena in the context of the Challenger accident."

Page 20:

- Findings:
    - #5: Add title of the document.
    - #6: Change ordered to directed or tasked.
    - #7: fact check statement

- Mr. Sean O'Keefe testimony will be put in Chapter 5.

Section 6.2

Page 21:

- Talk about schedule pressure without adequate relief. Did they have enough relief? How did the organization respond to it? Move up statement (from next page) about schedules not being bad.

- What impact did schedule pressure on the workforce have? What is the case that is being made here? How is it relevant to the accident? The focus should be the pressure on the managers and the decision-making process. The point is that there is schedule pressure on the system. High-level managers deny this. The only place to find evidence is at the lower level (the workforce). The story about three shifts, etc., is not causal, but it is the only evidence of schedule pressure and there must be some of this in here to refute the denials of the senior managers. Admiral Gehman asked for the story about the impact on the workforce to be shortened, but not lose the evidentiary part of it. Try to tie the MMT actions back to the evidence. The report may need to acknowledge the inferential connection between schedule pressure and management actions.

- Fourth paragraph: the documentation is critical to the story—need to get this. Depending on what is obtained, word accordingly.

Page 24:

- Last paragraph, use correct title of group: ISS Management and Cost Evaluation (IMCE) Task Force.

Page 30:

- Turn off the time/date on chart.

Section 6.2 needs modification—present evidence about schedule pressure without overdoing it. Make findings/conclusions format consistent among sections.

Section 6.3

Page 32:

- Second paragraph, third line: debris impact

Page 33:

- Second paragraph: there was never really a request to dispatch the crew on a space walk. Even the casual discussion never got up to a person who could do anything about it.

Page 34:

- Second paragraph: need to get Roe's job title correct.
- Add evidence in email from USA containing statement the foam couldn't do enough damage.
- Check reference on what Mr. John Disler notified the Mission Evaluation Room (MER) about.
- First paragraph: regarding the self-forming team of analysts—this is "mushy". State who initially chaired it, later chaired by Mr. Rodney Rocha, etc. Be clearer about this self-forming debris assessment team.

Page 35:

- Houston, TX vs. Huntington Beach, CA is discussed in Chapter 7. It is not pivotal here.

Page 36:

- Sidebar on Crater—needs to make a few points. It is currently being drafted. Should have by end of day or tomorrow morning for review.
- Issue: what did NASA know and when did they know it? NASA wasn't following its own rules. Make this an emphasis and commentary.

Page 37:

- Why didn't they think it was the reinforced carbon-carbon (RCC)? Some analysis was done on RCC. The algorithm for ice was transposed to foam. They computed that there was some possibility for penetration with a greater than 15 degree angle. Transport analysis shows a greater than 21 degree angle. The size used in the analysis was a six-inch diameter object. Use the insert from MGen John Barry as a substitute for the existing second paragraph.
- Imagery Request #2: This didn't really qualify as a request. Mr. Rocha did not put in a request; he asked if anyone had put in a request. However, it does constitute a "poke" at the system to see if it was awake or not. Put in the title of the manager. Mr. Rocha was not

asking for an extravehicular activity (EVA) (visual inspection was intended to mean looking out the window). Classify this as a "missed opportunity" rather than an imagery request.

Page 38:

- Last paragraph: what does "under consideration" mean? Clarify the wording.

Page 39:

- MMT is all verbal—there were no viewgraphs. Mr. Don McCormack was not a member of the debris team. He was briefed by them. No changes to transcript excerpts.

- There was an email exchange between Ms. Ham and Mr. Ron Dittemore regarding the flight rationale from STS-112 to STS-113 (bad then and bad now). This proves that Ms. Ham was in contact with Mr. Dittimore. There was no discussion about what it meant for STS-107. They were worried about the flight rationale. Ms. Ham was also the flight integration manager for STS-114. The Board agreed to insert the email between Ms. Ham and Mr. Dittemore.

Page 40:

- The crew took hand-held picture of the external tank (ET) separation. Why didn't the Program aggressively go after the crew to find out what they saw? There were two films by the crew. Mr. Disler (who trained the astronauts) indicated that he would expect 2 to 3 minutes of film. The Board decided to classify this as another missed opportunity. It would have been a chance to get another picture. This additional evidence may not have provided more data, but it might have been more dramatic and stimulated some action.

Page 42:

- Renumber the missed opportunity and imagery request.

Page 43:

- First paragraph: Not necessary to mention Lee's name. This implies that Austin did not know the right procedure for requesting imagery. Add a sentence to indicate this.

- Last paragraph: What is meaning of "lack of leadership" as used in this sentence? This is poorly stated. The report is really talking about lack of a formal charge or charter or lack of direction or guidance. Change to "lack of direction".

Page 44:

- Restructure the first sentence under Flight Day Seven so that is makes more sense in its location.

- Last paragraph, use title but not name.

Page 47:

- There is no way to prove that the space object identification (SOI) went to 4 star general.

- Emails suggest that Ms. Ham has a doubt in her mind about no safety of flight damage. Mr. Ralph Roe's email says that if big enough, it could be a safety of flight issue. Mr. Calvin Schomburg agrees that size can cause enough damage. These three people knew that a foam piece of large enough size could damage the orbiter. Define what is meant by "follow through," i.e., "follow through (such as ...) occurred. Put in the full quote from Mr. Schomburg's email. This proves that they knew that there could be damage to Columbia and that the party line (foam not a safety issue) was not true.

Page 49:

- Third paragraph, first sentence: not necessary.

- Last paragraph: pin down timeframe on Rocha's unsent email and indicate that although unsent, it was shown to colleagues.

Page 53:

- Email was written by a relatively junior person not at the Kennedy Space Center (KSC) or the Johnson Space Center (JSC). It doesn't represent a program position. Tone the editorial comment down. The email reflects the commonly held view, but not policy level decisions.

Page 54:

- Paragraph four, third sentence: change to "Unlike the earlier briefing in the morning..."

- Add statement from earlier email from Mr. Englehoff to Ms. Ham regarding email sent to crew.

Page 58:

- No one makes the point at any time that they are considering catastrophic loss (disintegration) of the orbiter upon re-entry.

Page 59:

- Take out email address.

Page 60:

- Summary Conclusion – use "Summary" only
- Include Mr. Bill Readdy's statement for the record.

Page 61:

- Summary is a little long.

Page 62:

- Second paragraph: Another lack of leadership phrase—use "lack of direction."
- Third paragraph: "bewildering points" – delete "bewildering."

Page 63:

- First paragraph, last sentence, it appears that text is missing.
- Fourth paragraph: As leaders, the managers should have been able to see the value of imagery and not relied on some engineer to tell them the value of it.
- Prior to section on Program Management's Low Level of Concern: add a sentence about how the total number of uncertainties in this situation should have led a good manager to go get more information.

Page 64:

- Second paragraph is not well worded. Take it out. Look at the next paragraph and see if a transition is needed when second paragraph is removed.
- Third paragraph: use "guidance" instead of "leadership".

Page 65:

- Second paragraph: What is Board trying to say? The paragraph refers to poor communications and leadership by saying that the decisions of the MMT were poorly characterized down and the concerns at the lower level were never communicated up. Collectively, the foam and email messages illustrate gaps in communications, etc. If the point is already made in the previous two paragraphs, does the report need the third paragraph? **Action: Editors and Admiral Gehman to see if this is covered adequately.**

Page 66:

- Failure of Safety's Role: This seems very brief given the Board's emphasis. Safety is discussed in Chapter 7; the Board is just making a note here. Need a sentence to make it less obscure—say that safety is thoroughly analyzed in Chapter 7. If last sentence was learned in privileged interview, take it out.

In conclusion:

- This is a very judgmental statement, but summarizes the situation perfectly. The Board debated whether this was too broad a brush. Some managers tried to make things right. In the third sentence, change "violated…" to "failed to fulfill…" Change to "Space Shuttle Program managers" to "Some Space Shuttle Program managers …".

- Vaughan's work: Use the first sentence, leave out the second through fourth sentences, then continue with "The Board's expanded…" Next to last sentence: need to re-work sentence to say that the influence of schedules and other things (name them) influence people's actions.

Other (Page 19):

At the FRR, Mr. Bryan O'Connor asked for a hazard analysis and the Program turned him down. This is in 6.1 (fact-check on this).

Section 6.4

- Change title to "Possibility of Rescue or Repair"

Page 67:

- First paragraph, sub-paragraph (2): use precise language regarding ditching payload.

- Dr. Osheroff's comments were not discussed or looked at (except baking cannisters), and were left out. Follow up with Dr. Osheroff.

Page 68:

- Insert artist's rendering of Space Shuttle Atlantis rescue.
- Last paragraph: Based on the assumptions that were given, this rescue was challenging but feasible. Put the assumptions in.

Page 69:

- These are the findings for the whole chapter. Make this Section 6.5
- The first sub-section of findings is missing a subtitle (Photo-Analysis)
- Second bullet: fact-check "one camera"
- Fifth bullet: reword
- Debris Assessment Team (DAT)
  [be consistent with where the findings are placed in Chapter 6]

Page 70:

- First bullet is not right; needs to be re-worded [Dan to provide] to agree with what was put in earlier.
- "The assumptions and the range of uncertainties were never presented…"
- Leave off Ms. Lisa Sayegh's suggested addition.

Page 71:

- Need something that says "regarding RCC" before bullet about RCC.

Space Shuttle Program Management.

- First bullet: change to "There were management lapses in leadership and communications that made it difficult…"
- Second bullet: Add something about "as had become accepted practice."

Page 72:

- MGen Barry comments should be findings in this section.

Communication:

- Be consistent about number of requests for imagery.
- Last bullet: This is introduced for the first time. The finding has not been substantiated. Delete.
- Second bullet: put as second bullet under management.
- Third bullet: this is redundant; delete.
- Sixth bullet: the whole regime of communications does not support the kinds of technical, life and death decisions that have to be made. Change to read "An overly informal communications scheme did not support effective decision-making."

Safety's Role:

- "safety" is used as a shorthand—use proper term, e.g., safety representative, etc.
- Delete last two bullets.

The organizational causal statement goes in Chapter 7 (highlight at beginning), as well as the Executive Summary.

Chapter 7 review

This chapter covers about 20 things; each thing is covered in about 3 pages. Content and points are good. The problem is the organization/layout of the chapter. The first section is very tutorial. Dr. Diane Vaughan is working to clean up the front and make it more evidentiary in its nature. The major recommendation (at the back) is the independent technical authority (a solid check and balance). The first section is important because it sets the foundation. It could be done in a lot fewer words. The Board debated whether a tutorial is really needed. It helps explain how the Board came to its findings and conclusions. A suggestion was made to go through the analysis of the organization, then look at how we understand this. Bring the theory in at the end; put the "authority" in the references. The report should be clear about the template that it is using. The two theories (High Reliability and Normal Accident) go in different

directions. The one thing that both agree on is the importance of the commitment of the leadership to a safety culture.

The characteristics of a High Reliability Organization (HRO) (page 4 and 5) are a good summary. The Board suggested scoping the tutorial section down—take the points and analyze them. The evidence that this chapter draws on is presented in Chapters 5 and 6. Insights from both theories can be used. High Reliability practitioners believe that they can prevent failure. Human space flight is a risky proposition. This is the root of the problem. NASA needs to move more in the direction of a HRO.

Board conclusion: Shorter is better. What is really needed is a roadmap for the chapter. The important thing is to build a logic tree that the reader can follow.

Chapter 7 is in process or re-organization/revision and will be available for plenary review first thing tomorrow morning.

Following day will be plenary review of Chapters 7, 8, 9, and 10.

This meeting was adjourned at 1645 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 7, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

At the ANSER facilities in Shrilington, VA

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-3229
Roger Tetrualt	CAIB	703-416-3591
Dr. Jim Hallock	CAIB	703-416-3272
MGen Ken Hess	CAIB	703-416-8481
BGen Duane Deal	CAIB	703-416-3349
Dr. John Logsdon	CAIB	703-416-3057
RAdm Steve Turcotte	CAIB	703-416-3015
MGen John Barry	CAIB	703-416-3570
Steve Wallace	CAIB	703-416-8405
Scott Hubbard	CAIB	703-416-3109
Dr. Sheila Widnall	CAIB	703-416-3445
Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-283-7809
Paul Wilde	CAIB	703-416-3367
Les Reingold	CAIB	703-416-3551
Chris Kirchhoff	CAIB	703-416-3121
Don White	CAIB	703-416-3235
Dan Diggins	CAIB	703-416-3054
Rick Burgess	CAIB	703-416-3292

On telecon via California

NAME	ORG.	PHONE
Dr. Sally Ride	CAIB	703-416-8497

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 8, 2003
These Minutes Contain No Sensitive Data

Purpose: Board Session – Review of Final Report

Date: August 8, 2003 **Time:** 0900 – 1700 EST

This meeting was conducted via teleconference in the ANSER facilities in Arlington, VA (Suite 700, Collaboration Room 7048E) with Dr. Sally Ride located in California.

The list of attendees is appended to the end of this report.

There were two action items generated from this meeting.

Agenda:

- Review Chapters 8 & 9; read the revised Chapter 7; review chapter 7; review the list of "Other Significant Observations"

Chapter 8 – History as Cause

- This Chapter is heavy on Challenger, but that doesn't appear to be a problem.
- One of the goals of this Chapter is to tie Chapters 5, 6, and 7 together. There are places where the Chapter could be made shorter.

Section 8.1

- Define what is meant by the word "history" in the first paragraph.
- The Board began its investigation with three questions (What happened? Why did it happen? Why did NASA allow it to happen again?). However, there were two questions about NASA decisions. Leave as is.
- Second sentence: It is OK to quote Sally Ride.
- Second paragraph: do not discount the technical cause—change to: "The foam debris hit was not the single cause…" Use "failure of the joint seal that permitted O-ring erosion" rather than "O-ring erosion" in this paragraph.
- Emphasize (with italics) the sentence that begins "History is not just a backdrop…"

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- Take out the word "historical" (use "previous"). Decisions were "budgetary," not "economic". Make these corrections universally.

- Take the two sentences in the middle of the second paragraph and start this Chapter with them—"NASA's history is not just a backdrop…".

Page 2:

- Top of third paragraph, change "eluciating" to "drawing".

- Delete "What this model does mean is that"

- Take the names out. Just use "Shuttle managers".

- Fourth sentence, organizational system includes the organizational structure, budgets, policy, and culture.

- Last sentence, put White House first; delete "historic", delete "and Challenger".

Section 8.2

- First sentence, statistics – use the right numbers. Foam loss occurred on all missions; bipod foam loss occurred on 9% of the flights on which we have visible evidence.

- Use first person ("we" rather than "it") when referring to the Board.

- Second sentence—this is fairly judgmental and emotional, but leave as is.

- Last sentence: "deteriorated" is not the best word. Is there a better one? If so, consider using it.

Page 3:

- First paragraph, ninth sentence: delete "mathematical". Last sentence -- as written, this implies that the tinkering broke it. Change to "tinkering with it …" (take out "until it broke.")

- Second paragraph: Move parenthetical before the period – (Ch. 6). Define "Crit 1" and "Crit 1R".

- Third paragraph: delete the phrase after the dash.

Page 4:

- Editor's note is correct. Strike the sentence referring to the Rogers Commission. Delete "Agreement was total." Delete name, leave in title.
- Last sentence, change "understanding" to "belief".
- Second paragraph: Consider deleting sentence "Signals that seemed strong…"
- Use "frequently" rather than "on almost every launch".
- Change the phrase in the sentence the begins "Finally …" to "like shutdown of the Shuttle main engines on the launch pad."

Page 5:

- First paragraph: On the October launch of STS-112, the bipod ramp foam hit the solid rocket booster (SRB) skirt, not the External Tank (ET). It has been 10 years since the last known bipod ramp foam event. Make these corrections.
- Last sentence: Engineering reaction to the two events were not comparable. Delete sentence.
- Second paragraph: NASA took no immediate action to bipod shedding (not no action). Correct.
- Delete last sentence. Add "bipod" in front of "foam" in next to last sentence.
- Last paragraph, first sentence, change to "Presidential Commission member…"
- "Normalization of deviance" needs to be defined.

Page 6:

- First sentence: Change to "The consequences of foam debris were viewed as not safety of flight issues, just maintenance issues—losing tiles, …"

Section 8.3

- Middle of first paragraph: delete "culture, with its ….contradictions". Change "gave permission" to "allowed."

- Last paragraph, second sentence, change to: "One of the results was that ..."

- Further down, the bargain was with the White House, not Congress. Correct this.

- Don't use "underfunded NASA" – change to "budget-constrained SSP". Change the sense of the sentence to indicated that the Shuttle Program has been squeezed, not NASA.

- First paragraph, in sentence that begins "as NASA leaders responded", use "organization." Make both cases (Challenger and Columbia) clear.

- Fourth sentence: after "key political players" change to "who put strict budget limits on NASA's ambitious goals."

- Bottom of page, third line from bottom: Delete last sentences on page, starting with "They were the downfall..." Check to make sure this reads okay.

Page 7:

- Last paragraph, second sentence: Before Challenger, there was a similar move to push things to contractors. Take the economizing/budgeting aspects out of sentence, but make the point about complexities, communication problems.

- First paragraph: take out "politically important," use "management imposed" in front of the February 2004 date. The date was arbitrary, but was not politically motivated.

- Seventh line regarding NASA cutting corners and launches proceeding without all of the engineering work complete: This statement is very sweeping; it implies that everything has to be perfect. Change this to "launches proceeded without all of the engineering work on these flaws completed."

- Second paragraph, fourth sentence: Change to read, "If they were in place at NASA, they weren't working."

- Last paragraph: "tinkering" is a trivialized word for major management shifts. Change "by subsequent tinkering" to "undone over time."

- Privatization is not the right word. Change last phrase in sentence to "transferred increased responsibilities to a single contractor."

Page 8:

- First paragraph, what is "it" at beginning of first sentence? Use another word.
- Delete the sentence starting with "Among the changes…"
- The FRR is a singular event. As used in this paragraph (the levels, structure, etc.) it is the flight readiness processes. Correct this.
- The process dilutes accountability. Make this clear.

Page 9:

- First paragraph, first line: Normally, the last line of defense in any defense should be the safety system. Take out the references to O-ring erosion and foam debris and fix sentence.
- First paragraph, next to last sentence, change to: "A disturbing finding was …"

Section 8.4

Page 9:

- First sentence: rephrase. Don't use "from higher up." "Structural" may be confusing; change to "organizational".

Page 10:

- Editor's note: do not work in the "perfect places" thesis from Chapter 5. It's OK to mention it, with "see Chapter 5." The Can-Do attitude affected the engineers and program planners. When taken too far, there is a reluctance to ever say something can't be done. Add something to the effect that the Can-Do attitude was found deep in the organization.
-
- Delete "with alarm".
- The sentences talking about rules, bureaucratic accountability, culture, seem like a contraction. Explain the this more clearly.

Section 8.5

- Challenger comparisons have been edited down.

Page 11:

- Is it necessary to have all of the comparisons between Challenger and Columbia? Some of the details could be taken out.

Section 8.6

Page 12:

- Use "Summary" for title.
- Take out asterisks. The idea of "operational" needs to go into the statement about goals.
- Use first paragraph after the italics statement; next two paragraphs are not required. Make sure nothing important is missing by doing this. Leave in material about Ham's multiple roles. Don't lose the point about "dual-hatting."

Page 13:

- First paragraph after italics: Delete rest of paragraph starting with "This discouraged…" Pick up with next paragraph. Make sure nothing is lost with this deletion.
- Last paragraph: delete phrase "as in Flight Readiness Review"

Page 14:

- Second sentence stays in. Delete rest of paragraph starting with "Their presentation went awry…". If there are any good, key lines, keep them in.
- Italics statement: change to "NASA organization structure and hierarchy blocked effective communications." You can't create missing signals.
- Last paragraph, delete starting with "No one in the other two locations…"

Page 15:

- Delete sentence: "The "No" percolated down …"
- Last paragraph, change to "This is an informal …"
- Delete Mr. Calvin Schomburg's name, use position title.

- Check to see if informal hierarchy among Centers was introduced in earlier Chapter. If not, this is not the place to introduce it. Is the material about the Langley Research Center (LaRC) needed?

- First paragraph, replace "hour long" with "formal briefing"

- Delete Mr. Schomburg's name; use title/position.

Page 16:

- Delete bracketed phrase.

- Delete paragraph starting with "The Board repeatedly came across…"

- Italics statement: use another word than privatization. The structure actually became less complex. Change to something like: "The transfer of NASA's roles and responsibilities which accompanied the Shuttle contract reduced in-house capability…" The Board conclusions are founded on the principle that the system is complex (not that it became more complex). Coupled with reducing in-house capabilities, increasing responsibilities to contractors increases the importance of good communications.

- The text under italics talks about dependence on contractors, not the importance of good communications.

- Are there two distinct communications issues: (1) NASA organization hierarchy blocking signals and (2) good communications skills and attributes?

Page 17:

- Delete starting with "The Boeing CRATER…" Pick up again with "Unfamiliar Crater…"

- Consider deleting reference to Dr. Elizabeth Pate-Cornell/Fischbeck study.

- Italics, change to read: "NASA's safety organization lacked sufficient critical resources, independence, …sufficient to bring …".

- Put "Silent Safety System" in quotes. Take out "true to its name".

Section 8.7

Page 19:

- First paragraph: There should be a better lead-in to the paragraph—state the principle. The leaders in Washington D.C. have a big piece of the problem. Top leaders are responsible for the culture and must fix it.

- Changes: reorder the list of national leaders (White House first); take Office of Budget and Management (OMB) out (it is part of the Administration); "measure of NASA success became cost reductions…". What is an "event-driven" process? Fly when ready. Say Headquarters when Headquarters is meant.

Discussion on Return to Flight organizational recommendations

- Issue: Whether or not and to what degree the Board should require an independent technical authority, an independent safety organization, an integration office, and a start on cultural fixes as return to flight (RTF) items?

- Admiral Gehman suggested that the Board could add a RTF recommendation: Completion of the plan on how to accomplish the first three (an independent technical authority, an independent safety organization, an integration office), before RTF. The longer-term issue is changing NASA's culture. At the annual budget review, NASA should report on progress on Plan.

- ***Proposal:*** ***Make the development and submission of a management plan an RTF item; the actual implementation will be judged by an annual review by Congress. The Board voted unanimously to do this.***

Continuation of Section 8.7

Page 18:

- First paragraph, turn first sentence around (use Diane's words). The Board found evidence to the contrary. Use NASA "managers" rather than "administrators". Delete "aging".

- Last paragraph, delete first sentence. Last sentence, change to: "The Board's analysis of organizational causes provides … ".

Page 19:

- Start each paragraph with principle. Put principle in bold, then Chapter and title.
- Order of paragraphs is top to bottom—okay as is.

Page 20:

- Delete "snakes"; rewrite sentence.

Chapter 9 – Implications for the Future of Human Spaceflight

Section 9.1

Page 1:

- Sidebar both quotes.
- First paragraph, last sentence:
- Second paragraph: change to "since the days ..."
- Last paragraph, first sentence, change to: "true for human space flight missions." This sentence shifts the reader to space flight in third paragraph. Delete "immutable."

Page 2:

- First full paragraph: add another "because" – the complication of using a reusable vehicle.

Section 9.2

- First sentence, the concept is that of several factors, the most important is safety. Change to "...with the overriding objective of safety."
- Last paragraph, delete "operational".
- The recommendations will be audited (every recommendation in the summary list should be in the report chapters where there is analysis—Chapters 3, 4, 7, 8). **Action: Admiral Gehman will send an email of the RTF recommendations to members.** The Board decided to put the summary of all of the recommendations in one place—in Chapter 11, not in section 9.2. Include the organizational RTF recommendation (the Plan).

Page 4:

Section 9.3

- The section includes the implementation of the organizational recommendations.
- "Separate Technical Authority and Safety" is two recommendations. Break this out.

Page 5:

- First paragraph: the technical authority needs to be independently funded—resources not under the control of the Program. One of the duties of this organization should be to develop and prescribe a regime of vehicle qualification to fly more than 20 years. This is not a RTF recommendation.
- Systems Integration: Make it clear what this section is talking about—the function, the professional skill. It is not talking about further contract integration.

Page 6:

- Bullets are already in Chapter 7—not needed here.
- Culture: Culture is defined in the front of Chapter 7. More "meat" is needed in this section. NASA needs more concrete direction—pull from previous chapters. Add the following: deference to technical expertise of engineers, having to prove that it is safe rather than having to prove that it is unsafe. Put in something about "safety culture." Don't mix in process or rules issues. Delete reference to differences between human space flight programs and non-human space flight programs (Board didn't look at this).

Page 7:

- First paragraph: turn around to make positive statement, e.g., reorganization is a good tool and the three recommended organizational actions are good first steps, but culture cannot be correction by these alone. Top leadership is needed.
- Where should the recommendation to establish program schedule consistent with resources go? Put this on page 19 (chapter 5)--Add in a sentence regarding matching the program to the resources provided. Mention schedule pressure as a bad habit in the first paragraph of 9.3. Making sure that the flight rate doesn't exceed resources involves a lot of trade-offs.

Forcing Function

- Include something about an annual implementation review at budget time.

Section 9.4

- Need different title: Long Term—The Next Steps
- Set the framework for the debate.
- First line, delete "naturally".

Page 8:

- Fill in blanks.
- A vision without resources is a dream.
- Commitment to a New System: a transition sentence is needed.
- First sentence: delete the first phrase about the Board being surprised.

Page 9:

- The Board statement in italics is a significant shift from focusing on dollars per pound to low earth orbit (LEO). Move next to last paragraph on page up to here. Change italicized statement to something like: The nation would be well served if the Space Shuttle as a transportation system for humans were replaced ..." Admiral Gehman to rewrite italics sentence.

Page 10:

- Last sentence: make positive statement, e.g., The US should continue with the human space flight system.

Agreed upon revision to:

Organizational Cause Statement

The organizational causes of the accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressure, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human space flight. Cultural traits and organizational practices detrimental to safety were allowed to develop, including: reliance on past successes as a

substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements); organizational barriers which prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules.

Chapter 7 – A Safety Failure: NASA Culture, Structure and Safety System

Page 35, Cultural Signals

- The first paragraph here is excellent and should be the first paragraph of the entire Chapter.
- **Action on Chapter 7: Pre-editing tonight. Post Chapter 7 tomorrow. Board members: This critical chapter must be reviewed this weekend!**
- Next week, Admiral Gehman, MGen John Barry, etc., will integrate comments.

Chapter 10 – Other Significant Observations [don't call these recommendations]

The Board voted "in" or "out" on each one. Content was not reviewed (to be reviewed later).

- Section One: Public Risk Assessment: In
- Section Two: Thematic Safety Concerns in the Shuttle Program
    - Crew Escape and Survival: In except for 10.2-3
    - Engineering Drawings: In
    - Industrial Safety and Quality Assurance: needs to be edited – abbreviate
    - Maintenance Documentation (WAD accuracy): In
    - Orbiter Maintenance Down Period/Major Modification: In
- Section Three: Physical Structure of the Shuttle System
    - Orbiter Service Life: Out; If there is some valuable stuff here, cite as appendix in body of report
    - Service Life Extension Program: In

- Exposure to the Elements: Out (covered in report)
- Orbiter Corrosion: In
- Tile Loss: Out (covered in report)
- Lower Carrier Panel Bolt Fractures: In
- Hold Down Post Cable Anomaly: In

- Section Four: Additional Findings and Observations
  - Solid Rocket Booster External Tank Attach Ring: In
  - RSRM Segments Shipping Security: In
  - "Two-Person Control": Out (recommendation already in Chapter 4)
  - Test Equipment Upgrades: In
  - Michoud Assembly Facility Security: not very compelling (question whether this should be left in)
  - Leadership/Managerial Training: In
  - Michoud Assembly Facility Quality Program Review: In (put this beside the one for KSC); drop out ** items
  - Astronaut Work Center Visits: Out (not significant)

Frontpiece

In Memoriam: lists names with NASA roles (OK as printed); take nickname (Buzz) off

Board Statement:

- Fourth paragraph: diminish the "elusiveness" aspect. The Board has nailed this.
- Fourth paragraph, right column: Has the Board actually framed the debate? Yes, Chapter 9 does this.

- Last Paragraph: correct mistake (27 missions); take helicopter departed out.

Executive Summary:

- Organizational causal factors—does approved statement lift into here? Check to make sure.
- No other changes

Synopsis (formerly called executive summary):

- This lays out the whole report, tells how it is organized. Call it "Synopsis of This Report"
- It is okay that it repeats some of the executive summary and board statement.
- Part I, Chapter 1: NASA never put a proposal before the Johnson administration—correct this.

This meeting was adjourned at 1700 EST.

These minutes are hereby submitted for the record.

Approved

Theron Bradley, Jr.
Executive Secretary
Columbia Accident Investigation Board

Approved

H.W. Admiral Gehman, Jr.
Admiral, U.S. Navy (Retired)
Chairman
Columbia Accident Investigation Board

Columbia Accident Investigation Board (CAIB)
Minutes of Meeting
August 8, 2003
These Minutes Contain No Sensitive Data

Attendees are as follows:

At the ANSER facilities in Shrilington, VA

NAME	ORG.	PHONE
Admiral Gehman	CAIB	703-416-3229
Roger Tetrualt	CAIB	703-416-3591
Dr. Jim Hallock	CAIB	703-416-3272
MGen Ken Hess	CAIB	703-416-8481
BGen Duane Deal	CAIB	703-416-3349
Dr. John Logsdon	CAIB	703-416-3057
RAdm Steve Turcotte	CAIB	703-416-3015
MGen John Barry	CAIB	703-416-3570
Steve Wallace	CAIB	703-416-8405
Scott Hubbard	CAIB	703-416-3109
Dr. Sheila Widnall	CAIB	703-416-3445
Steve Schmidt	CAIB	703-416-8488
Mike Bloomfield	CAIB	281-283-7809
Paul Wilde	CAIB	703-416-3367
Les Reingold	CAIB	703-416-3551
Chris Kirchhoff	CAIB	703-416-3121
Don White	CAIB	703-416-3235
Dan Diggins	CAIB	703-416-3054
Rick Burgess	CAIB	703-416-3292

On telecon via California

NAME	ORG.	PHONE
Dr. Sally Ride	CAIB	703-416-8497