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Features

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Oct. 22, 2010

RELEASE : 10-269

NASA Releases Report About Australia Balloon Mishap

WASHINGTON -- A NASA panel that investigated the unsuccessful April 28 launch of a scientific balloon from Alice Springs, Australia, has released its report.

NASA was attempting to launch the balloon carrying a gamma-ray telescope belonging to the University of California at Berkeley. The Nuclear Compton Telescope, which was partially destroyed in the accident, was designed to look for distant galaxies from a vantage point high in Earth's upper atmosphere.

The scientific payload inadvertently separated from a mobile crane being used for the launch, and it was dragged approximately 150 yards by the airborne balloon. Spectators narrowly escaped injury when the payload hit an airport fence and a car.

NASA's Mishap Investigation Board determined weather conditions were acceptable for launch, and there were no technical problems with the vehicle or the payload.

The board was led by Michael L. Weiss of NASA's Goddard Space Flight Center in Greenbelt, Md. The board's report listed 25 proximate, intermediate and root causes related to insufficient risk analysis, contingency planning, personnel training, technical knowledge, government oversight and public safety accommodations.

"There is no question in our minds that balloon launches are fragile processes," Weiss said. "The mishap board reviewed a large volume of information about the accident and conducted numerous interviews with eyewitnesses. But in the course of our investigation, we found surprisingly few documented procedures for balloon launches. No one considered the launch phase to be a potential hazard."

The purpose of the investigation was to discover what caused the mishap and provide recommendations to help prevent similar future mishaps. The board listed 44 recommendations regarding the need for better communication; more robust range and ground safety plans and procedures; and better understanding of potentially unsafe conditions that can lead to accidents.

Immediately after the accident in Australia, launch operations at all of NASA's balloon sites were suspended. NASA's Balloon Program Office will resume launches once it has implemented and verified new procedures to safeguard launch crews and the public.

"We have learned a lot from this incident, and we'll have a better balloon program because of it," said Rob Strain, Goddard Space Flight Center director.

The Columbia Scientific Balloon Facility in Palestine, Texas, conducts balloon launches for NASA under contract to the Balloon Program Office. The program office is based at NASA's Wallops Flight Facility in Virginia, which is managed by Goddard.

To download the report, visit:

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- end -

text-only version of this release

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

October 21, 2010

Reply to Attn of: 350

TO: Distribution

FROM: 100/Director

SUBJECT: Approval of the Nuclear Compton Telescope Balloon Launch Mishap Investigation Report

The Nuclear Compton Telescope Balloon Launch Mishap Investigation Board was established on May 12, 2010, in accordance with NPR 8621.1, "NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping." The Investigating Authority was appointed to obtain and analyze evidence and facts; conduct necessary testing; impound property, equipment, and records; identify the causal and contributing factors relating to the mishap; and to recommend appropriate actions to prevent a similar mishap from recurring.

The appropriate NASA officials have conducted all other reviews and endorsements of the investigation report. We will evaluate all endorsement comments and address those appropriately. As a result of the positive endorsements, including my own, the Nuclear Compton Telescope Balloon Launch Mishap Investigation Board report is hereby approved. The MIB has met all assigned requirements regarding this investigation and is released with my personal thanks for a job well done.

Should you have any questions concerning this matter, please contact Ms. Lisa Cutler, at 301-286-7409.

Robert Strain

Distribution:
100/Mr. Obenschain
100/Ms. Abell
300/Ms. Bruner
350/Mr. Lopez
350/Ms. Cutler
455/Mr. Weiss

cc:
HQ-GA000/Mr. O'Connor
HQ-KA000/Dr. Ryschkewitsch

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

October 14, 2010

Reply to Attn of: Safety and Assurance Requirements Division

TO: Goddard Space Flight Center
Attn: 100/Director

FROM: Chief, Safety and Mission Assurance

SUBJECT: Endorsement of the Nuclear Compton Telescope Balloon Launch in Alice Springs, Northern Territory, Australia High Visibility Type B Mishap Report, Case Number S-2010-119-00007

I have reviewed the mishap investigation report of the Nuclear Compton Telescope (NCT) Balloon Launch in Alice Springs, Northern Territory, Australia High Visibility Type B Mishap and endorse the report. I concur that the report has been prepared as directed by the appointment letter and meets the requirements specified in NPR 8621.1B, NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping.

This Mishap Investigation Board (MIB) provided a complete detailed description of both the nominal balloon launch process and the launch process the day of the mishap, allowing the reader to discern the anomalies that contributed to the incident. The MIB also did an excellent job including documents and evidence in the report such as, but not limited to, a detailed list of evidence collected and evaluated, a comprehensive description of the tests and analysis conducted with supporting results, a comprehensive Event and Causal Factor tree with supporting discussion, a log (including thumbnail images) of all the photographs of the mishap, the Civil Aviation Safety Authority (CASA) permits, and the NCT Flight Folder documents. The report included a comprehensive human factors engineering (HFE) analysis which described each error type, factors that led to that error, and recommendations that would prevent the error from occurring. Additionally, the HFE analysis included a detailed analysis of the human force required to pull the lanyard to launch the balloon, as compared with the maximum reasonable human capability, thereby demonstrating the launch attempt was unsuccessful given the required force exceeded a human's abilities. This section and related references were well done and serve as a model for future investigations.

I concur with the findings and recommendations in the report with the following exceptions and comments.

The MIB report refers to "WFF Safety Leadership" and "GSFC Safety Leadership," without providing definitions of the scope of this expression. I read this to refer to the WFF or GSFC

Director, the Division Director with responsibility for the balloon program, and the safety organization, at a minimum.

Similarly, Intermediate Cause I1 is stated as, "WFF safety office did not perform rigorous hazard analysis," and the associated recommendation is that the WFF Safety Office should perform such an analysis in accordance with NPR 8715.5 section 3.2. The cited NPR requirement is that the vehicle program, in coordination with a Center range safety organization or the NASA Range Safety Manager, ensure that such an analysis is performed. It is important to recognize that the responsibility for safety is much broader than the safety organization alone.

The MIB report correctly documents many areas where the Balloon Program's crane operations were not in compliance with NASA standards for lifting devices. The mobile crane was used in an unorthodox manner as a dynamic launch vehicle, accelerating, decelerating, and turning with a load. Mobile cranes are not designed to move or perform sudden acceleration or deceleration under load because this may cause the load to shift and swing into the crane cab or cause the crane to tip over; both which have the potential to result in employee fatalities. Additionally, mobile cranes are not to be side loaded or used to drag a load sideways because this action can result in excessive overturning moments, causing them to flip over. NASA has experienced a number of incidents in the last two years where heavy lift equipment and cranes have flipped over, damaging equipment, injuring personnel, and potentially causing fatalities.

Other significant safety findings in the report include that the crane operator left the crane cab during the launch process (a violation of Occupational Safety and Health Administration (OSHA) requirements). Per OSHA, a crane cabin should be occupied at all times when a load is suspended (thus allowing immediate response in the event of an emergency). Although OSHA requirements do not apply to Australia, they do apply to similar operations in the United States and are in existence to protect the health and safety of the employees and the people around mobile crane operations.

Prior to use of the mobile crane for balloon launches, the mobile crane rented by the Columbia Scientific Balloon Facility (CSBF) was modified with a platform and railings in front of the crane cab. This allowed the flight crew to stand in front of the cab during the launch operation. The platform is open on both sides and is not a safe enclosed structure to be used while the crane is moving, accelerating, or making sharp turns. In addition to allowing potential falls from the platform, the design places the employees in the balloon/equipment fall zone as well as in danger of being hit by a swinging or falling load. Other modifications were made to the crane to add swivel wheels to the outriggers, allowing the outriggers to be deployed during movement. This unconventional design modification was made to allow the crane some stability because it was being used in an unconventional manner. However, no engineering design analysis seems to have been conducted to evaluate the placement, size, and design of the outriggers to demonstrate they provide the desired balance and protection for all payload weights and sizes.

Overall, all of these findings, and others related to the mobile crane indicate that the mobile crane was not being used in a safe manner at the time of the mishap. NASA should not use mobile cranes outside their design limits, in violation of OSHA requirements, or in violation of NASA safety requirements. Consequently, I add the following recommendation: The Balloon Program Office (BPO) should re-evaluate its balloon launch method and determine a safe method to release the balloon without violating NASA and OSHA lifting requirements. The analysis should ensure that the public and all employees are a safe distance from the load, and that there are adequate emergency stop capabilities if the load sways and poses risk to people or hardware.

I do not concur on the MIB's Root Cause R5 "NASA Agency Range Safety Program failed to ensure corrective actions were accomplished from previous audits." The 2002 WFF Assessment was a NASA Range Safety Independent Assessment and not a formal audit. The purpose was to identify findings (non-compliances and observations) and to ensure closure of the findings via establishment of corrective action plans by the host organization. Ensuring that the corrective action plans are accomplished is the responsibility of the balloon program and the Center safety organization; i.e., not an Agency Range Safety Program function.

The Agency Range Safety Program did follow up on the findings from the 2002 WFF Assessment, and in particular finding #9 on the balloon program, to ensure corrective action plans were in place. The Agency Range Safety Program concurred with the WFF initial response in June 2002. The Agency Range Safety Program closed finding #9 in November 2002 based on procedure and process audits of the balloon contractor performed by the WFF safety and balloon program offices. During the next Range Safety Assessment of WFF in April 2005, the Agency Range Safety team verified that all 2002 findings were closed.

Modifications to the Agency Range Safety Program that are currently in affect address the MIB's Recommendations D-1 and D-2 regarding appropriate follow up on audit recommendations and placing range safety audits under NASA Safety Center responsibility. Per the updated policy in NPR 8715.5 Revision A, the Agency Range Safety Program now participates as an element of the NASA Headquarters Safety and Mission Assurance Audits, Reviews, and Assessments program defined by NPR 8705.6, which is managed by the NASA Safety Center. The Agency Range Safety Program also supports Inter-center Aircraft Operations Panel reviews as defined by NPR 7900.3, which are managed by the NASA Aviation Safety Office. Range safety related audit and review findings and corrective actions are now documented, followed up, and tracked using formally established Agency systems and processes.

I do not concur on the MIB's recommendation I8-1 "BPO should perform a cost, utility, and feasibility assessment for improving the terrain at Alice Springs Airport." This recommendation is based on the assumption that it is safe to use a mobile crane to launch balloons, which at this time has not been proven. Instead, I recommend that the BPO identify and use launch sites which are determined to be safe, allow an adequate range envelope to protect the public, and provide safe operation consistent to NASA's policies and procedures.

Please thank this MIB for their dedication, tireless service, and excellent work in completing this investigation and providing NASA with recommendations to improve public safety and ensure future safe and successful Balloon Program operations. In keeping with NASA policy, please attach this endorsement to the top of the mishap investigation report and publish/distribute it as a part of the report.

Bryan O'Connor

cc:
Chief Engineer/Dr. Ryschkewitsch
Chief Health and Medical Officer/Dr. Williams
Office of Safety and Mission Assurance/Dr. Stamatelatos
Mr. Schumann
Science Mission Directorate/Mr. Gay
Office of General Counsel/Mr. Thomas
Office of International and Interagency Relations/Mr. Besha
Office of Public Affairs/Ms. Dickey
Office of Legislative and Intergovernmental Affairs/Mr. Flaherty
Office of Procurement/Mr. Hodgdon
GSFC/Mr. Obenschain
Ms. Bruner
Ms. Cutler
Mr. Weiss
Ms. Hamilton
Mr. Leitner
Mr. Simpson
Mr. Farley
MSFC/Ms. French
KSC/Mr. Schumann
NSC/Mr. Phillips
Mr. O'Connor

National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001

October 7, 2010

Reply to Attn of: Office of the Chief Engineer

TO: Goddard Space Flight Center
100/Director

FROM: NASA Chief Engineer

SUBJECT: Endorsement of the Nuclear Compton Telescope Balloon Launch Mishap Investigation Report

The Office of the Chief Engineer has reviewed the subject Mishap Investigation Report (ref: IRIS Case Number: S-2010-119-00007) and endorses the very thorough report and its recommendations.

Per NASA Policy Requirements, please include this endorsement with the published MIB report.

Dr. Michael Ryschkewitsch

cc:
Associate Administrator/Mr. Scolese
Chief, Safety and Mission Assurance/Mr. O'Connor/ Ms. Chandler
Chief Health and Medical Officer/Dr. Williams
Office of the Chief Engineer/Mr. Ledbetter
Goddard Space Flight Center/300/Ms. Brunner/Ms. Cutler/Mr. Lopez

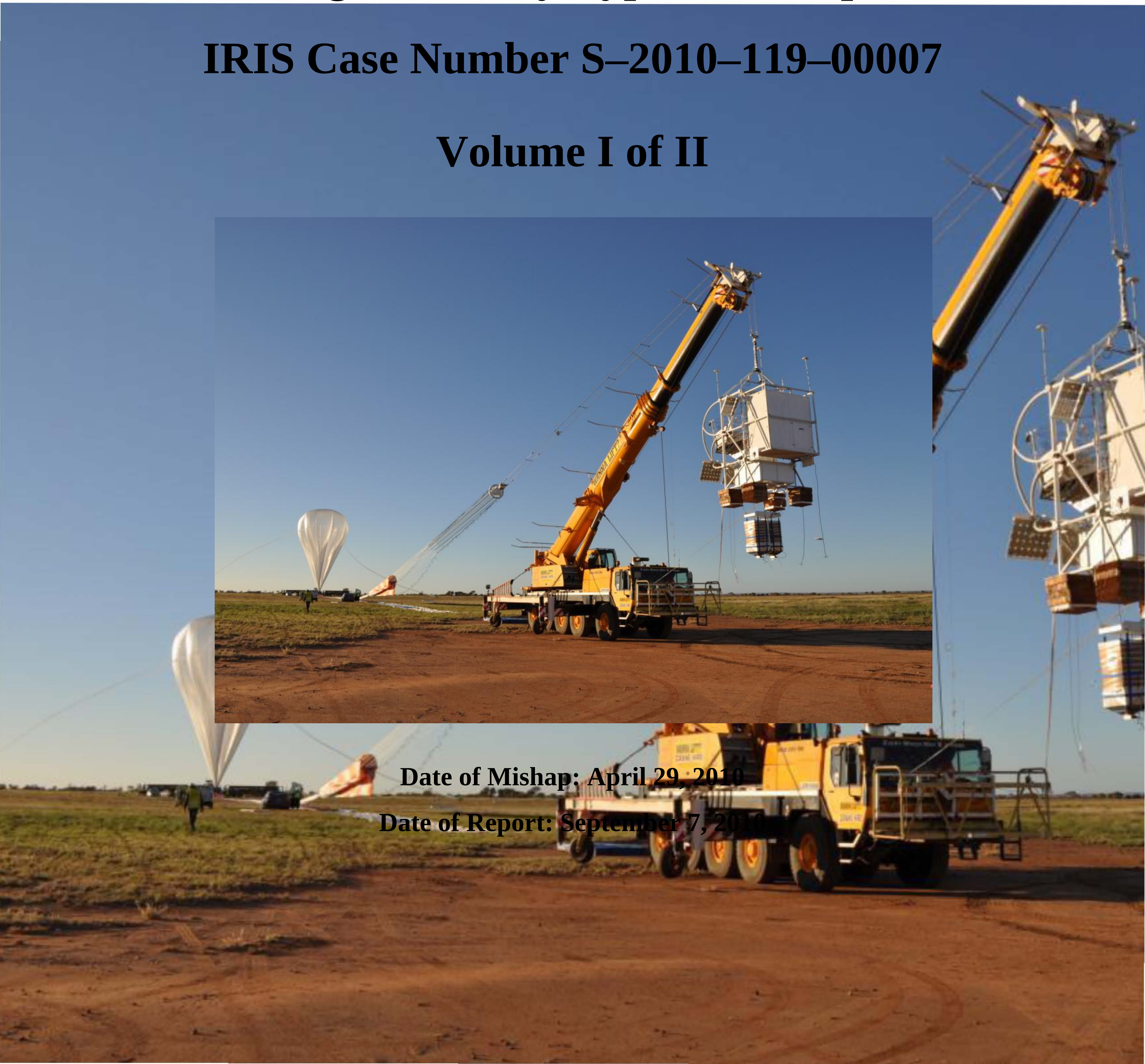
National Aeronautics and Space Administration

Nuclear Compton Telescope Balloon Launch in Alice Springs, Northern Territory, Australia

High Visibility Type B Mishap

IRIS Case Number S–2010–119–00007

Volume I of II



Date of Mishap: April 29, 2010

Date of Report: September 7, 2010

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Acknowledgments

The Nuclear Compton Telescope (NCT) Balloon Launch Mishap Investigation Board (MIB) acknowledges with appreciation the cooperation and contributions that were made by the Australian Commonwealth Scientific and Research Organization (CSIRO), the University of New South Wales, the Australia's Civil Aviation Safety Authority (CASA), the Balloon Program Office (BPO), and the Columbia Scientific Balloon Facility (CSBF) rigging crew while the MIB team was in Alice Springs, Australia. Their responsive support allowed valuable data gathering, interviews, and on-site field tests to be conducted effectively. The MIB would like to acknowledge the contributions of other individuals and organizations: Faith Chandler, NASA Office of Safety and Mission Assurance (OSMA), and Kristie French, NASA Safety Center (NSC), provided immeasurable assistance with the Root Cause Analysis Tool (RCAT) and the mishap investigation process. Lisa Cutler, Goddard Space Flight Center's Occupational Safety and Health Division (GSFC Code 350) provided timely and helpful assistance to the MIB. Dr. Steve Boggs (University of California at Berkeley) provided valuable assistance and NCT payload data. Sydney Cain and Janel Cassard (Arctic Slope Regional Corporation) were patient and skilled in providing administrative support. Dave Peters (GSFC, Code 547), Bill Hrybyk (TRAX International), Jay O'Leary (Arctic Slope Regional Corporation), and Walt Feimer and Chris Meaney (Honeywell) provided expert graphics and video support. Finally, the MIB wishes to acknowledge those others who helped to facilitate the board's tasks including personnel from the Outsourcing Desktop Initiative for NASA (ODIN) and Facility and Security at GSFC. The MIB would like to make one final acknowledgement to the U.S. Department of State and the Commonwealth of Australia for their efforts in enabling the board to travel immediately to the mishap site to start the investigative process.

Foreword

The Nuclear Compton Telescope Balloon Launch Mishap Investigation Board (MIB) was commissioned on May 12, 2010 to gather information, analyze facts, and identify the proximate cause(s), intermediate cause(s), and root cause(s) that resulted in the mishap. The MIB was also instructed to identify any observations and contributing factors related to the mishap. Finally, the MIB was asked to generate recommendations that could be implemented within NASA to prevent similar mishaps and to correct organizational issues that may lead to additional mishaps occurring in the future. The MIB's intent and purpose were not to place blame or to determine legal liability for the mishap, but only to act as an Independent Investigation Authority according to the guidelines in NASA Procedural Requirement (NPR) 8621.1B.

Executive Summary

General Information

On April 29, 2010, at 08:08 a.m. Australian Central Time (ACT), a NASA High Visibility, Type B Mishap occurred at the Alice Springs International Airport in Alice Springs, Northern Territory (NT), Australia. The incident was given the Incident Reporting Information System (IRIS) case number: S-2010-119-0007.

Personnel from the Columbia Scientific Balloon Facility (CSBF), a NASA contractor, were attempting to launch the Nuclear Compton Telescope (NCT) scientific balloon payload using a conventional balloon. NCT was a balloon-borne gamma-ray telescope designed to study astrophysical sources of nuclear line emission with high spectral and spatial resolution. The launch team reported to duty around 2 a.m. on April 29, 2010, ACT. Weather conditions were deemed favorable for a launch attempt, so the launch team assembled the balloon and payload hardware at the launch site. All pre-launch preparations were nominal and after the balloon bubble was inflated with helium, the Launch Director (LD) was given authority to launch by the Site Director (SD) who was communicating with Melbourne Air Traffic Control. After the balloon bubble was released from the spool, it took flight and lifted the flight train. While initially maneuvering the launch vehicle for the launch attempt, the balloon slightly overtook the launch vehicle's position. The LD instructed the driver to make a left turn in order to make up ground on the balloon. Approximately 76 seconds after initiating motion of the launch vehicle, the LD slowed the vehicle for a launch attempt. During the launch attempt, in which the LD pulls on a release lanyard, the payload failed to release from the launch vehicle. Subsequently, the launch vehicle was accelerated in an attempt to catch up with the balloon for a second release effort. Upon reaching the airport fence the CSBF team recognized that the mission would have to be terminated and the LD attempted to maneuver the launch vehicle to a safe position after observing that spectators were in harm's way. In the process of maneuvering the crane, the payload inadvertently broke free of the launch vehicle and was dragged by the wind-driven balloon through the airport fence and into an unoccupied vehicle that was owned by a public spectator. The spectator, who was photographing the launch attempt, was able to jump off the roof of his vehicle just prior to the collision. Other spectators were observed scrambling to avoid the payload. While no injuries occurred, the payload and the privately-owned vehicle suffered extensive damage and as stated, several spectators were nearly struck by the payload. Subsequently, videos produced by the Australian Broadcasting Company of the launch attempt were aired on numerous international news programs and were immediately available on the Internet.

A Mishap Investigation Board (MIB) was appointed on May 12, 2010 to perform an investigation of the incident. The incident was initially deemed a High Visibility Close Call mishap and was later reclassified as a High Visibility, Type B mishap (breakdown of cost estimates are in Appendix I).

Based on mishap site visits to Alice Springs, NT, Australia, witness interviews, analyses and assessments, structural testing, and use of the Root Cause Analysis (RCA) Tool, the MIB identified the underlying causes of the mishap. An Event and Causal Factor Tree (E&CFT) diagram (Appendix A and Section 3.6) was developed, resulting in the identification of the root causes (events or conditions that are organizational factors), proximate causes (events that occurred, including any conditions that existed immediately before the undesired outcome), and intermediate causes (events or conditions that created the proximate cause that, if eliminated or modified, would have prevented the proximate cause from occurring).

In summary, the causes for this mishap evolved from: (1) a flawed underlying assumption, (2) a problematic historical mindset, and (3) an ineffective organizational structure. First, the Balloon Program has been operating under an underlying assumption that the risks to the public only exist in the over flight of populated areas. This assumption has led to a very limited view of the hazards and their associated targets involved in launching balloons. Next, the decades of successful balloon launches under a tight budget have led to complacency and a sense that performance of safety and technical measures can be relaxed under the guise of risk acceptance. This mindset flows throughout WFF and apparently through the NASA Headquarters OSMA and SMD organizations. This mindset justified a further distinction between the safety practices in the balloon program and the safety practices of other programs at WFF. Lastly, there is an organizational structure at GSFC that bypasses the independent safety and mission assurance infrastructure that was set up at GSFC as it pertains to the Wallops Flight Facility (WFF). Hence GSFC's independent safety infrastructure does not provide an appropriate control for unsafe practices within the balloon program or an independent safety assurance organization with line authority over all levels of safety oversight.

All voting members of the board participated in the investigation, deliberations, and development of the findings and recommendations. Upon completion of the deliberations, all voting members were polled and were in agreement with the findings and recommendations as written. There were no dissenting opinions, and therefore a dissenting opinion section is not included in this report.

Summary of Findings

Per the appointment letter, the MIB was instructed to place the highest priority on determining corrective actions necessary to ensure public safety. Using evidence gathered from interviews and procedural/document reviews, the MIB conducted a Root Cause Analysis (RCA). Timelines, a fault tree (FT) and an event and causal factor tree (E&CFT) were developed, leading to the identification of 1 primary undesired outcome (PUO) that revealed 3 proximate causes, 14 significant intermediate causes, 12 observations, and 4 contributing factors. Six root causes were identified for the mishap at the organizational level under the PUO.

PUO The NCT payload caused damage to private vehicles and nearly caused death or injury to the general public.

During the course of the investigation, the MIB identified two additional undesired outcomes which will be addressed as "Secondary Undesired Outcomes (SUOs)." Even though addressing multiple undesired outcomes is not considered standard for reports, the MIB felt compelled to address these SUOs in this report.

SUO 1 NASA incurred significant loss of assets including the scientific payload, the airport

fence, and the costs associated with the failed launch attempt.

SUO 2 Contractor personnel were endangered when the payload inadvertently released from the launch head.

This resulted in the addition of one root cause and one intermediate cause. Section 3 details the causes and how they were determined.

Proximate Causes

Three proximate causes were identified that produced the PUO. Had any of these causes been eliminated or modified, neither the Primary nor Secondary Undesired Outcomes would have occurred.

P1 Proximate Cause: The NCT payload separated from the launch vehicle.

P2 Proximate Cause: The released payload was dragged downwind by the balloon.

P3 Proximate Cause: People in the general public were in the projected flight path.

Intermediate Causes

An Intermediate Cause is an event or condition that created the proximate cause that, if eliminated or modified, would have prevented the proximate cause from occurring. The following significant Intermediate Causes were identified:

I1 Intermediate Cause: WFF safety office did not perform rigorous hazard analysis.

I1-1 Recommendation

WFF Safety Office should perform a complete hazard analysis in accordance with the NPR 8715.5 section 3.2 Range Safety Analysis. All phases of the balloon launch process should be considered. This hazard analysis should be validated by independent review.

I2 Intermediate Cause: A barrier to keep the general public out of all dangerous areas throughout the launch process did not exist.

I2-1 Recommendation

In each launch location, the BPO should ensure that dedicated safety personnel thoroughly examine(s) the potential for spectators or passers-by entering hazardous areas and implement barriers or controls to prevent entry during the launch process.

I3 Intermediate Cause: No trained individual was in place to ensure public safety.

I3-1 Recommendation

WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring mission success.

I4 Intermediate Cause: The ground safety plan did not cover all relevant hazards and phases.

I4-1 Recommendation

The WFF Safety Office should revise the balloon ground safety plan to cover all phases, from inflation through recovery. The plan should address all hazards identified in the Hazard Analysis through appropriate restrictions and operational requirements.

I5 Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process.

I5-1 Recommendation

The BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3, Section 3.8 Hazardous Operations.

I5-2 Recommendation

BPO should establish Launch Commit Criteria and flight rules.

I5-3 Recommendation

BPO should establish and document firm and unambiguous criteria for aborts during the launch phase.

I6 Intermediate Cause: Launch crew training did not address failed launch attempts.

I6-1 Recommendation

BPO should ensure that training for the launch crew covers the widest possible set of anomalous occurrences in the launch process including, but not limited to, failed launch attempts, breaches and near-breaches of the Hazard Zone, loss of payload control straps, loss of communication, and scenarios that would lead to an abort.

I7 Intermediate Cause: Category A hazard area during launch phase was not well-defined.

I7-1 Recommendation

WFF Safety Office should clearly and unambiguously define the Category A hazard area and should require that it be implementable in practice with visible markings.

I8 Intermediate Cause: Terrain was rough and unimproved.

I8-1 Recommendation

BPO should perform a cost, utility, and feasibility assessment for improving the terrain at Alice Springs Airport.

I9 Intermediate Cause: CSBF has not analyzed the payload release system to establish the acceptable angular range of the balloon relative to the launch vehicle for launch attempts.

I9-1 Recommendation

BPO should perform a thorough analysis of the payload restraint and release system to establish an acceptable angular range of balloon relative to crane for launch attempt.

I10 Intermediate Cause: CSBF was not aware of hardware limitations that might give rise to a failure during a launch vehicle maneuver.

I10-1 Recommendation

BPO should evaluate balloon launch hardware mechanisms through testing and review of documentation and specifications to determine proper operating conditions and ranges. The results of this evaluation should then be used to define operating limits of launch hardware and specify abort criteria.

I11 Intermediate Cause: The ground safety plan did not explicitly address the protection of the general public.

I11-1 Recommendation

WFF Safety Office should specifically address how to deal with the general public in the ground safety plan.

I12 Intermediate Cause: The BPO did not have sufficient insight or oversight into the technical aspects of CSBF's balloon launch process.

I12-1 Recommendation

The BPO should become knowledgeable about the technical aspects of the launch process and gain an understanding of the hardware capabilities, limitations, operating bounds, and failure modes.

I13 Intermediate Cause: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program.

I13-1 Recommendation

WFF safety leadership should ensure that WFF Safety Office is implementing an effective safety program that is applicable and consistent across the facility and for all contracts.

I14 Intermediate Cause: WFF safety leadership did not thoroughly review balloon safety documentation.

I14-1 Recommendation

WFF safety leadership should review WFF balloon safety documentation for clarity and accuracy.

SUO I1 Intermediate Cause: WFF SMA did not perform systems safety analysis to identify hazards to assets.

SUO I1-1 Recommendation

WFF Safety Office should perform a complete hazard analysis, in accordance with NPR 8715.5, section 3.2 Range Safety Analysis. All phases of the balloon launch process should be considered. This hazard analysis should be validated by independent review.

This recommendation is essentially identical to Recommendation I1-1. Note that the proper execution of NPR 8715.3 and 8715.5 will encompass the analysis of hazards to the assets and the development of procedures required for mitigation.

Contributing Factors

A Contributing Factor is an event or condition that may have contributed to the occurrence of an undesired outcome but, if eliminated or modified, would not by itself have prevented the occurrence. The following Contributing Factors were identified:

CF1 Contributing Factor: Restraint pin was not sufficiently lubricated.

CF1-1 Recommendation

BPO should perform analysis and/or test to determine the relationship between pin lubrication and lanyard pull force to establish lubrication guidelines for proper operation.

CF2 Contributing Factor: Secondary release mechanism did not exist.

CF2-1 Recommendation

BPO should analyze, evaluate, and test the hardware to understand its capabilities and operating range, as well as to determine failures and associated sensitivities.

CF3 Contributing Factor: Wind created a challenging environment.

CF3-1 Recommendation

The BPO should establish firm, written criteria for wind limits and factor these into all go/no-go and abort criteria and any specific restrictions on a particular launch.

CF4 Contributing Factor: The launch process is fragile

CF4-1 Recommendation

A. Identical to **I5-1**

B. Identical to **I6-1**

Root Causes, Intermediate Causes, Contributing Factor, and Recommendations

Using FTA and E&CFT methodology, the board determined several root causes and established a number of recommendations that, if implemented, should prevent similar mishaps from occurring in the future. The following root causes were identified by the MIB:

A. Wallops Flight Facility (WFF) Safety Leadership

R1 Root Cause: WFF safety leadership did not ensure complete flow down of agency requirements to protect the public.

R2 Root Cause: WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements (WFF Safety Office and BPO as implementing organizations).

A-1 Recommendation

WFF safety leadership should verify that all elements of the public (people in nearby populated areas, spectators, and passers-by) as well as NASA workforce, high-value equipment and property and the environment are protected from all credible hazards, identified by thorough, formal, hazard analysis, covering all phases of balloon operations from set-up through termination and recovery. (R1, R2)

A-2 Recommendation

WFF safety leadership should regularly verify, through a minimum annual audit, BPO's oversight of safety at balloon launches and the WFF safety office's activities to ensure safety at balloon launches. (R2)

A-3 Recommendation

WFF safety leadership should review and become knowledgeable about all safety requirements and plans implemented for the balloon program and ensure the proper flow-down of safety requirements, including but not limited to NPR 8715.3 and NPR 8715.5 in order to protect the public, NASA workforce, high-value equipment, property and the environment. (R1, R2)

B. WFF Safety Office

R3 Root Cause: WFF Safety office was not sufficiently knowledgeable about the details of the balloon launch process.

B-1 Recommendation

WFF safety office should obtain expertise in the precise details of the balloon launch process through training and direct interaction to ensure their own capability to produce balloon ground safety documentation.

C. GSFC Safety Leadership

R4 Root Cause: GSFC safety leadership did not verify or provide corrective action for flow-down of NASA requirements to protect the public.

C-1 Recommendation

GSFC safety leadership should provide oversight to ensure that exhaustive measures are taken to safeguard the public in the balloon program with no less fervor than is imparted to other activities and programs at GSFC. The GSFC safety leadership should also provide oversight to ensure protection of the NASA workforce, high-value equipment, property, and the environment.

D. Headquarters (HQ) Range Safety Program Office

R5 Root Cause: NASA Agency Range Safety Program failed to ensure corrective actions were accomplished from previous agency audits.

D-1 Recommendation

NASA Agency Range Safety Program should exhaustively follow up on audit recommendations and report to senior management any conditions of inaction for safety-related concerns to prevent unsafe activities from continuing.

D-2 Recommendation

NASA Range Safety audit functions should be added to the NASA Safety Center Audits and Assessments responsibilities.

E. BPO, WFF, GSFC, and HQ Science Mission Directorate (SMD)

R6 Root Cause: Reliance on past success has become a substitute for good engineering and safety practices in the balloon program.

E-1 Recommendation

The BPO, WFF, GSFC, and SMD should avoid considering a particular mission success rate or lack of safety incidents to be a sign that activities have been or are currently safe.

E-2 Recommendation

NASA Safety Center (NSC) should generate a Case Study based on the common problem that the reliance on past success becomes a substitute for good engineering and safety practices.

SUO R1 Root Cause: WFF Safety Leadership did not provide appropriate oversight to WFF asset safety.

Recommendation

WFF safety leadership should review and become knowledgeable about all safety requirements and plans implemented for the balloon program and ensure the proper flow-down of all safety requirements, including but not limited to NPR 8715.3 and NPR 8715.5 in order to protect the public, NASA workforce, high-value equipment and property and the environment.

This recommendation is identical to Recommendation A-3.

Other Observations and Recommendations

O1 Observation: The hanging heavy payload was not identified as a hazard.

O1-1 Recommendation

WFF Safety Office should identify the hanging payload as a hazard and follow relevant standards and requirements for hanging payloads to ensure protection of personnel and the general public.

O2 Observation: The Launch Director was not wearing protective equipment for his hands while pulling the launch lanyard.

O2-1 Recommendation

WFF Safety Office should determine whether gloves or other Personal Protective Equipment (PPE) should be required for pulling the launch lanyard.

O3 Observation: The audits conducted of WFF safety in 2002 resulted in recommendations that, if properly implemented, would have made the undesired outcome extremely unlikely.

O3-1 Recommendation

WFF Safety Office should ensure that all actions from the 2002 independent assessment are closed out thoroughly and completely, in particular, Items 5, 6, 9, and 21 referenced from the document "WFF Range Safety Independent Assessment Response". GSFC safety leadership and the NSC should verify compliance with these recommendations.

O4 Observation: Leaving the BPO and the CSBF responsible for classifying mishaps gives rise to sidestepping the requirements of a NASA incident response team.

O4-1 Recommendation

WFF safety leadership should ensure that the mishap and contingency plans along with contracts associated with balloon campaigns adhere to requirements for an incident response team put forth in NPR 8621.1B.

O5 Observation: The Balloon Ground Safety Plan (BGSP) identifies an institutional RSQA, but it's not clear whether this is a person, organization, or a virtual entity.

O5-1 Recommendation

The RSQA for CSBF should be an approving authority and knowledgeable about the BGSP and should be responsible for ensuring its completeness and proper implementation in the field.

O6 Observation: The Australia's Civil Aviation Safety Authority (CASA) operating permit contains an ambiguous definition of "the approved area" at the Alice Springs Airport.

O6-1 Recommendation

The BPO should determine the full intention of CASA operating permits issued by the Australian government and be sure that they are properly implemented by CSBF and UNSW, along with stand-alone NASA range requirements.

O7 Observation: Documented mishap response and recovery contingency plans do not meet the requirements of NPR 8621.1B.

O7-1 Recommendation

WFF safety leadership should develop a mishap preparedness and contingency plan for BPO that adheres to the requirements put forth in NPR 8621.1B.

O8 Observation: The requirements in 820-PG-8621.1.1B do not meet the Agency's requirements documented in NPR 8621.1B.

O8-1 Recommendation

WFF needs to ensure that mishaps are appropriately classified and investigations are accomplished in accordance with NPR 8621.1B. Any program level procedures for mishap investigation and reporting should be coordinated with GSFC Safety and Mission Assurance (Code 300) and if necessary with OSMA to ensure they meet the Agency level requirements.

O9 Observation: The safety organization at WFF is not independent from projects and lacks the direct SMA reporting path that exists at GSFC at Greenbelt Md.

O9-1 Recommendation

GSFC should establish an organizational structure for safety that is consistent across Goddard's Greenbelt and Wallops facilities, where the entire chain of the safety organization below the GSFC Center Director is independent of the projects, as is currently in place for the Code 300 organization at GSFC at Greenbelt, MD.

O-10 Observation: CSBF personnel seemed unaware of a number of operational hazards and constraints.

O10-1 Recommendation

The WFF Safety Office should ensure CSBF completes a job hazard analysis and that CSBF personnel have appropriate hazard awareness training for all the hazards associated with each launch operation.

O-11 Observation: Members of the CSBF launch crew were not wearing hard hats during the launch operation as required by Section 4.1 of the Ground Safety Data Package.

O11-1 Recommendation

The WFF Safety Office and the BPO should assign an independent, trained safety officer for each launch. Both the safety officer and the campaign manager should ensure that all designated hazard controls, including PPE are implemented for each launch operation.

O-12 Observation: The Corrective Actions from a previous balloon close call in 2000 were not implemented for this program despite their apparent applicability (use of protective cage and PPE).

O12-1 Recommendation

The BPO and the WFF Safety Office should ensure that all applicable lessons learned relating to balloon launches, including IRIS reports are examined and if applicable, that the corrective actions are implemented across the balloon program.

1.0 Charter and Response

1.1 Transmittal Letter

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

September 7, 2010

Reply to Attn of: 350

TO: 100/Director

FROM: 350/ Nuclear Compton Telescope (NCT) Balloon Launch Mishap Investigation Board

SUBJECT: Final Mishap Investigation Board (MIB) Report of the Nuclear Compton Telescope (NCT) Balloon Launch Mishap

Reference your memo dated May 12, 2010, which established the Mishap Investigation Board for the Nuclear Compton Telescope Balloon Launch High Visibility Type B Mishap that occurred on April 28, 2010, and defined the Board's responsibilities.

The investigation was conducted in accordance with NPR 8621.1 "NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping." The final report of the Mishap Investigation Board's activities, findings, and recommendations are enclosed.

Michael L. Weiss

MIB Chair

Enclosure

1.2 Appointment Letter

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

May 12, 2010

to Attn of: 100

TO: Distribution

FROM: 100/Director

SUBJECT: Formation of a Mishap Investigation Board (MIB) to Investigate the Aborted Launch of the Nuclear Compton Telescope (NCT) Mission

On April 28, 2010, the scientific balloon launch from Alice Springs, Australia in support of the Nuclear Compton Telescope (NCT) was declared a mishap. The payload got dragged along the ground, impacting a SUV, and nearly injuring spectators. While no injuries were reported, the payload impacting the vicinity of personnel represents a failure of the safety operations process.

An assessment of NCT payload damage is underway. Based upon the Balloon Program basis of accepted risk for these types of missions, the investigation will proceed as a high visibility investigation given property loss (other than payload) and potential to personnel injury. Due to the severity of the proximity to the aborted launch to the spectators, the mishap investigation will place a high priority in addressing corrective actions needed to ensure public safety in future launch operations.

All pertinent equipment and documentation has been impounded. There will be no other NASA balloon launches until GSFC understands the failure, understands the required corrective actions and I am assured of the safety of our people and the public.

In accordance with the NPR 8621.1B, I am establishing the Australia Balloon MIB to gather information; analyze the facts; identify the proximate cause(s), root cause(s) and contributing factors relating to the mishap; and to recommend appropriate actions to prevent a similar mishap from occurring again. The chairperson and members of the MIB are listed in the enclosure. The Chairperson of the MIB will report to me on all aspects regarding this investigation.

The MIB will:

- Obtain and analyze whatever evidence, facts, and opinions it considers relevant.
- Conduct tests and any other activity it deems appropriate.
- Interview witnesses and receive statements from witnesses.
- Impound property, equipment, and records as considered necessary (consistent with the agreements with the international partners and contractors).

- Develop a timeline.
- Determine the proximate cause(s), root cause(s), and contributing factors relating to the mishap.
- Develop recommendations to prevent similar mishaps.
- Review launch procedures to ensure all steps were appropriately completed.
- Review the proximity of spectators to the launch, the actions taken to ensure public safety during the mishap, and corrective actions needed to ensure public safety at remote sites in the future.
- Review associated mechanical and electrical designs to assess adequacy for launch operations.
- Assess prelaunch planning and operations testing that was conducted and the procedures that were used for adequacy in preventing this type of mishap.
- Provide recommendations and lessons learned to be incorporated into the development of a Corrective Action Plan by the Balloon Program Office.
- Provide a final written report that will conform to all requirements in the referenced NPR.

The Chairperson will:

- Conduct MIB activities in accordance with the requirements in NPR 8621.1.
- Establish and document, as necessary, rules and procedures for organizing and operating the MIB, including any subgroups, and for the format and content of oral or written reports to and by the MIB.
- Designate any additional representatives, advisors, consultants, experts, liaison officers, or other individuals who may be required to support the activities of the MIB and define the duties and responsibilities of those persons.
- Designate another voting member of the MIB to act as chairperson in his or her absence.
- Document meetings and retain records.

The WBS to be used for charging hours in support of this investigation is 911542.06.01.01. The travel WBS is 911542.01.02, SCEX222010D.

The Columbia Scientific Balloon Facility (CSBF) contractor shall provide additional ad-hoc support as requested by the board. The Balloon Program Office will provide an in brief with copies of the relevant documentation to the MIB. The MIB will be supported by Code 820 and the Physical Science Laboratory/CSBF contractor personnel, as required.

MIB will provide a preliminary written report containing the proximate cause(s), root cause(s), and recommendation(s), and submit it to me by May 28, 2010. The MIB is solely responsible for the implementation of this review.

Robert Strain

Distribution:
100/Mr. Strain
100/Mr. Obenschain
100/Mr. Figueroa
300/Dr. Leitner
300/Ms. Bruner
321/Ms. Hamilton
350/Mr. Lopez
350/Ms. Cutler
455/Mr. Weiss
500/Mr. Nelson
598/Mr. Simpson
800/Mr. Wrobel
800/Ms. Bass
800/Mr. Purdy
803/Ms. Smith
803/Mr. Patterson
803.1/Mr. Leibig
820/Ms. Gramlich
820/Mr. Gregory
820/Mr. Pierce
HQ/Science Mission Directorate/Astrophysics Division/Dr. Jones
HQ/Science Mission Directorate/Astrophysics Division/Mr. Sistilli
HQ/Science Mission Directorate/Astrophysics Division/Dr. Morse
HQ/Office of the Chief Engineer/Dr. Ryschkewitsch
HQ/Office of Communications/Mr. Jacobs
HQ/Office of Communications/Ms. Dickey
HQ/Office of General Counsel/Mr. Wholley
HQ/Office of General Counsel/Mr. Thomas
HQ Office of International & Interagency Relations (OIIR)/Mr. O'Brien
HQ Office of International & Interagency Relations (OIIR)/Mr. Besha
HQ/Office of Legislative & Intergovernmental Affairs (OILA)/Mr. Statler
HQ/Office of Legislative & Intergovernmental Affairs (OILA)/Mr. Flaherty
HQ/Associate Administrator/Mr. Scolese
HQ/Office of Safety and Mission Assurance/Mr. O'Connor
KSC/Mr. Schumann

NSC/Ms. French
PSL/Mr. S. Hottman
PSL/CSBF/Mr. Ball
PSL/CSBF/Mr. Orr

1.3 Signature Pages

Investigating Authority Signatures

To the best of our knowledge the report contents are accurate and complete, and we concur with the documented findings and recommendations.

Michael Weiss
Chairman
Code 455
Goddard Space Flight Center, MD

Gerald Schumann
Alternate Chair
SA-F
Kennedy Space Center, FL

Carol Hamilton
Member - Human Factors
Code 321
Goddard Space Flight Center, MD

Joel Simpson
Member - Technical
Code 598
Goddard Space Flight Center, MD

Jesse Leitner
Member - Safety
Code 300
Goddard Space Flight Center, MD

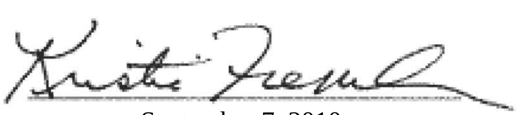
Ex Officio Signature

I assure the following:

- The investigation was conducted in conformance with NASA policy and NASA Procedural Requirements 8621.1,
- The investigation process is fair, independent, and non-punitive,
- The mishap report contains all the required elements,
- Adequate facts have been gathered and analyzed to substantiate the findings,
- The mishap report accurately identifies the proximate cause(s), root cause(s), and contributing factor(s),
- The recommendations reasonably address the causes and findings, and
- Each recommendation can be tied to a finding.

I also concur with this report.

Kristie French
Ex-Officio
NASA Safety Center



Kristie French
Ex-Officio
NASA Safety Center

Advisors' Signatures

I sign this report indicating that the report sufficiently meets the legal requirements for NPR 8621.1B.

Dan Thomas
Legal Advisor
Office of the General Counsel
NASA Headquarters

I sign this report indicating that it is consistent with the policies and procedures in my functional area.

Patrick Besha
International Affairs Advisor
OIIR
NASA Headquarters

I sign this report indicating that it is consistent with the policies and procedures in my functional area.

Beth Dickey
Public Affairs Advisor
Office of Communications
NASA Headquarters

I sign this report indicating that it is consistent with the policies and procedures in my functional area.

Chris Flaherty
Legislative Affairs Advisor
Office of Legislative and Intergovernmental Affairs
NASA Headquarters

I sign this report indicating that the report is technically correct in my functional area.

Rodger Farley
NASA, Code 543
Goddard Space Flight Center, MD

I sign this report indicating that the report is consistent with the policies and procedures in my functional area and that any ITAR information and EAR information has been identified and marked as non-releasable to the public (e.g., NASA Sensitive But Unclassified).

Kenneth M. Hodgdon
NASA, Export Control Advisor
NASA Headquarters

2.0 Overview

In 1981, NASA began conducting balloon operations at the Alice Springs airport. Approximately 50 NASA balloon missions have been launched there since that time. Before NASA's involvement, other organizations had conducted balloon launch operations in Australia for approximately 20 years.

NASA's Balloon Program Office (BPO) is physically located at Goddard Space Flight Center's (GSFC's) Wallops Flight Facility (WFF) on Wallops Island, Virginia. The BPO manages all balloon program activities and programmatically reports to the Astrophysics Division within NASA's Science Mission Directorate (SMD) at NASA Headquarters. The New Mexico State University, Physical Sciences Laboratory's Columbia Scientific Balloon Facility (CSBF) is under contract to the BPO to conduct balloon operations at all launch facilities, including the Alice Springs Balloon Launch Facility at Alice Springs Airport in Australia (Figures 1 through 3). The University of New South Wales manages the Alice Springs Balloon Launch Facility under the direction of the Site Director (SD). The CSBF Launch Director (LD), who reports to the CSBF Campaign Manager (CM), directs launch operations.

Figure 1. Central Continent Location of Alice Springs, Australia

Figure 2. Location of Airport in Relation to Alice Springs

Figure 3. NW End of Alice Springs Airport

2.1 Balloon Launch (General)

Balloon flights offer unique opportunities to obtain scientific data. The launch concept involves suspending the science payload from a mobile launch crane using a plate retained with safety restraint cables.

One end of the plate is affixed to the balloon flight train by attaching cables, a parachute, termination components, and the balloon. The balloon geometry is initially constrained by a collar to keep the balloon from becoming a spinnaker sail when it first takes flight. On launch day, the payload and balloon components are laid out once the LD verifies favorable weather conditions. The collar-constrained balloon bubble is inflated with helium. Once the balloon is launched, the LD maneuvers the launch crane so that the balloon passes directly overhead.

Launched by releasing the spool, a balloon achieves the direct overhead position generally in about 25 to 35 seconds. Ideally, when the balloon is overhead, the LD pulls down on a release lanyard, which in turn releases the payload from the launch vehicle.

The balloon launch process employs several components: the spool trailer which holds the balloon through layout, inflation, and release; up to two standard helium trailers to inflate the balloon; and the launch vehicle. The hardware setup is shown in Figure 4.

The launch vehicle is a mobile crane rented by CSBF. CSBF specifies vehicle requirements to prospective suppliers in a request for quotation (RFQ). (Refer to Appendix M.) The requirements stated in the RFQ are as follows:

- Crane vehicle is in very good mechanical condition and has good acceleration.
- Wheelbase length from the front axle to the rear axle is a minimum of about 20ft.
- Total vehicle weighs a minimum of 50 tons.
- Crane lifting capability is 59 tons.
- Crane boom extends out from the front of the vehicle by at least 10.5 ft when at a height of ~40 ft from the ground.

The crane must be modified to hold and release a payload. Stabilizers are added to the crane so it can be moved with the boom in an upward position. This is done by fitting three pieces of hardware onto the crane: (a) a pair of stabilizer bars equipped with swivel wheels connected to outriggers parallel to the crane body (Figure 5), (b) a specially designed launch head unit fixed to the end of the crane boom, and (c) a platform with railings on the front of the vehicle for the LD and payload launch assistant allowing access to the tag lines and the release lanyard.

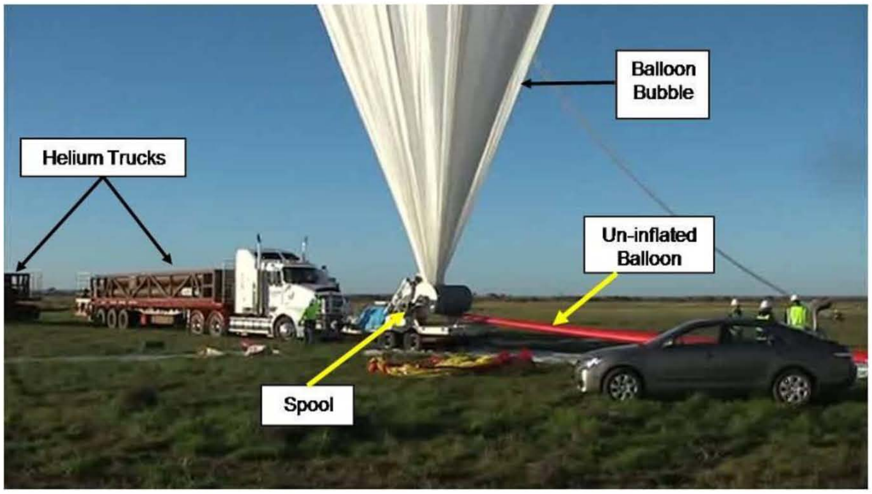


Figure 4. Balloon Bubble and Spool

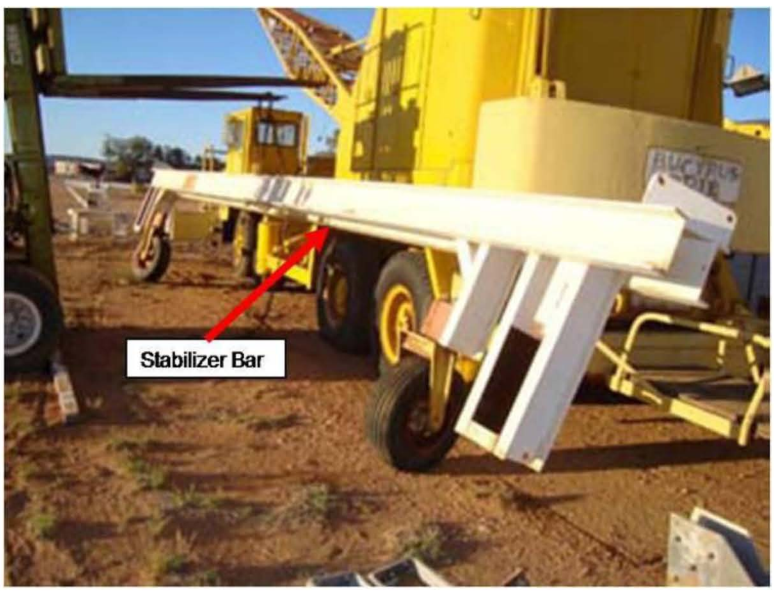


Figure 5. Stabilizer Bar

The launch head is designed to be pinned to the crane head employing the existing pins and pin holes used for the light boom extension. The scientific payload is suspended from the launch head by a pin that points away from the crane boom. At launch, the launch head unit releases the payload with a release arm mechanism (Figure 6).

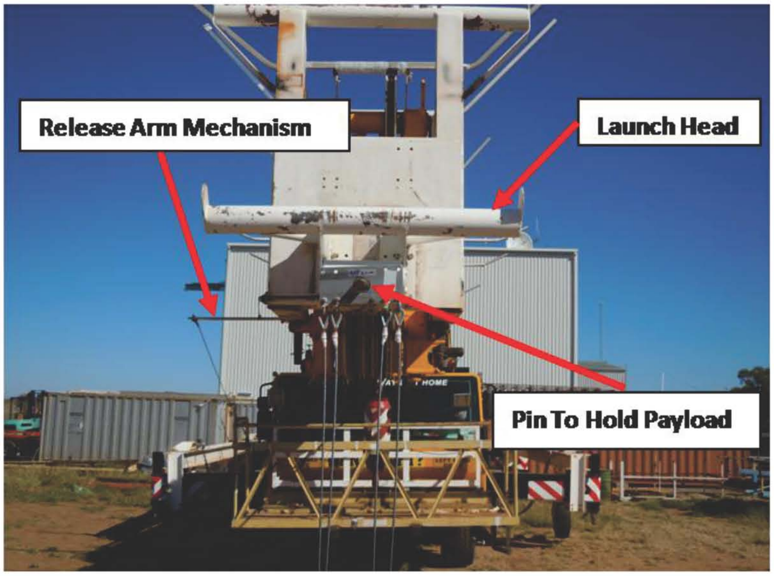


Figure 6. Launch Head Attached to Crane Boom

2.2 Balloon Launch Process

On the day of flight, given favorable weather conditions, CSBF support personnel use the launch vehicle to pick up the payload (Figure 7).

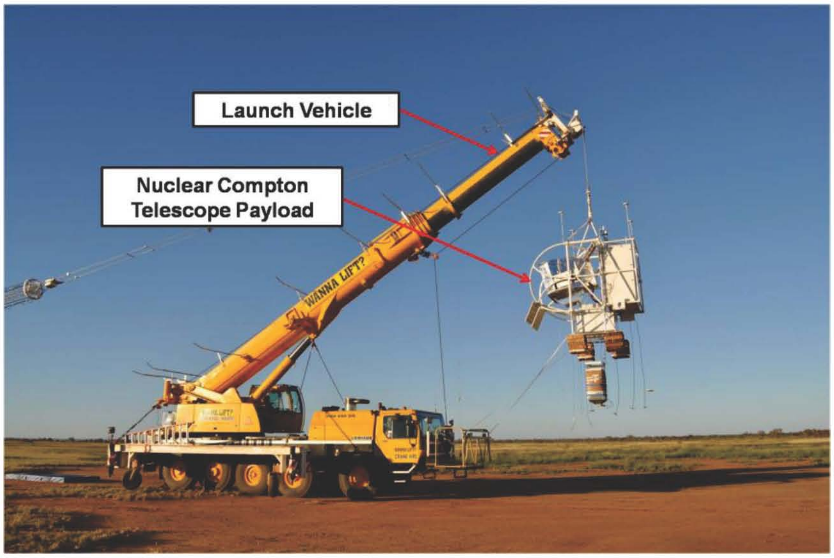


Figure 7. Launch Vehicle With Payload

CSBF and the science team perform preflight electronics checks and then interface the CSBF balloon hardware with the scientific equipment. The flight line crew then places a protective ground cloth the entire length of the flight train and balloon to prevent ground contact damage to the flight train equipment, parachute, and balloon. The parachute stream is arranged onto the ground cloth and checked. After the flight train and parachute are extended at length, the balloon is put down and attached to the parachute as shown in Figure 8. The CSBF flight crew then performs the flight line checkout.

Figure 8. Balloon Being Laid Out

NASA uses a standard process, called the “dynamic launch,” for launching a large stratospheric balloon system. Basically, a large spool holds the top portion of the balloon (called the “bubble”) in place while it is filled with the appropriate amount of helium. The helium acts as a lifting gas, displacing the heavier gas mixture of air. The launch vehicle holds the payload in place downwind of the balloon’s inflated top portion. The basic configuration for launch is shown in Figures 9 and 10. Details of the balloon and spool area are shown in Figure 11.

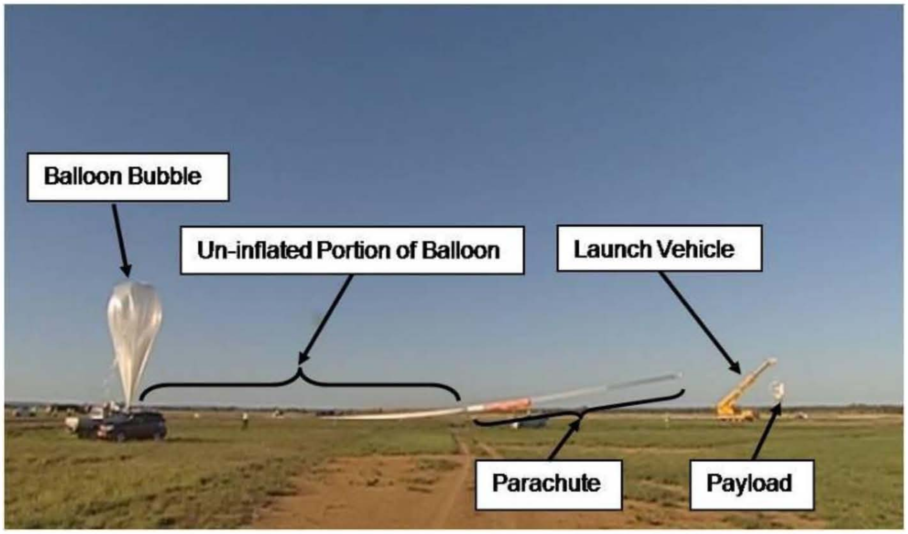


Figure 9. Balloon Configuration for Launch

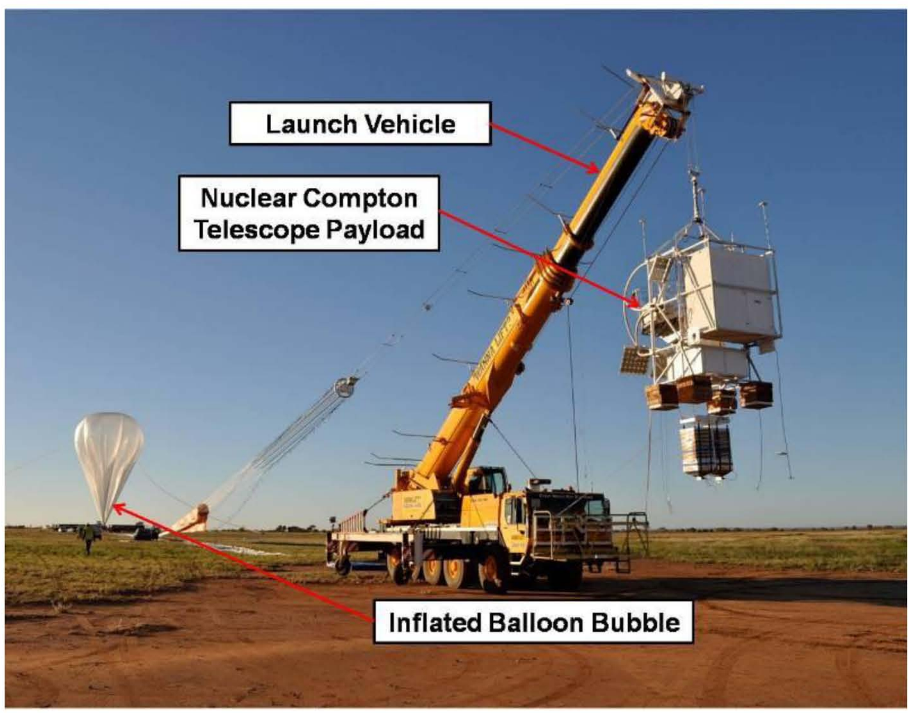


Figure 10. NCT Launch Configuration

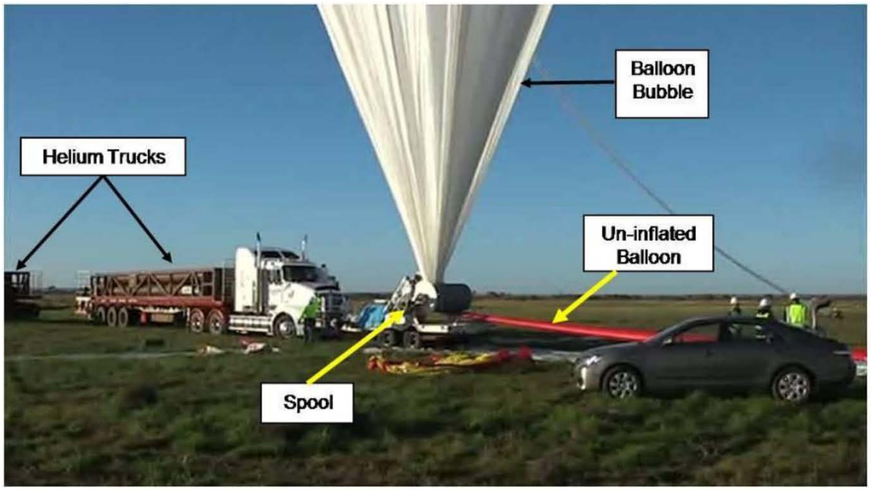


Figure 11. Balloon Bubble and Spool

Because helium gas expands as the balloon rises in the atmosphere, only a portion of the balloon, the bubble, is inflated. The bubble is restrained by passing the uninflated "rope" section of the balloon under the spool (Figure 11). The uninflated portion is protected during the inflation process by an extra layer of film known as "red wrap." The spool trailer is connected to the helium truck vehicle to provide necessary anchoring. The payload end of the system is restrained at the launch vehicle.

When the balloon and payload are cleared for launch and the LD is ready, a release handle (Figure 12) on the spool is activated, allowing the balloon bubble to rise rapidly. Initially, the lifting force is many times the mass of what it is lifting because the launch vehicle is supporting the payload weight and much of the balloon and flight train is on the ground.

Figure 12. Spool Release Handle

After release, the bubble size is constrained by a collar device to prevent the bubble from "sailing" as a result of its rapid forward progress. The collar is released through remote command when the balloon flight train is nearly vertical above the launch vehicle. Collar release can occur before or after the payload is released from the launch vehicle. Collar installation is shown in Figure 13.

Figure 13. Collar Installation

Since the balloon system layout is arranged with the local wind direction, the balloon bubble and flight train rise up over the launch vehicle and continue with the wind. The launch vehicle then is moved so that the balloon is kept close to directly overhead or slightly ahead of the launch vehicle until the launch release is accomplished. Figure 14 depicts the balloon layout aligned with the lower level winds.

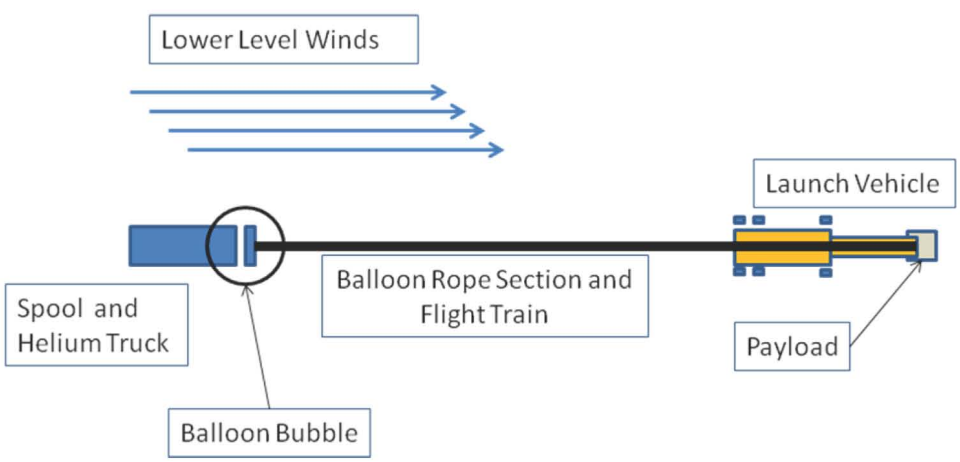


Figure 14. Balloon Layout Aligned With Lower Level Winds

The desired position for a release is shown in Figure 15.

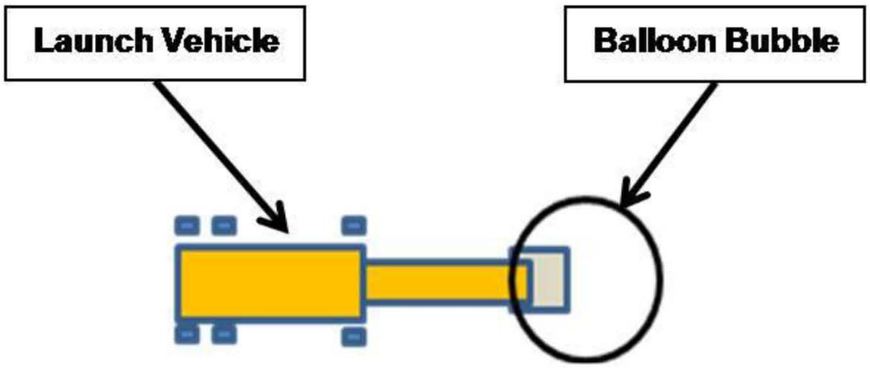


Figure 15. Desired Balloon Position for Release

After the balloon is in the proper position, the LD releases the payload by pulling on the release cable. This in turn pulls on a spring-loaded restraint pin that restrains the truck plate on the launch head pin through two safety restraint cables as shown in Figure 16. The truck plate, which is attached to the payload and the balloon train, can then slide off of the launch head pin.

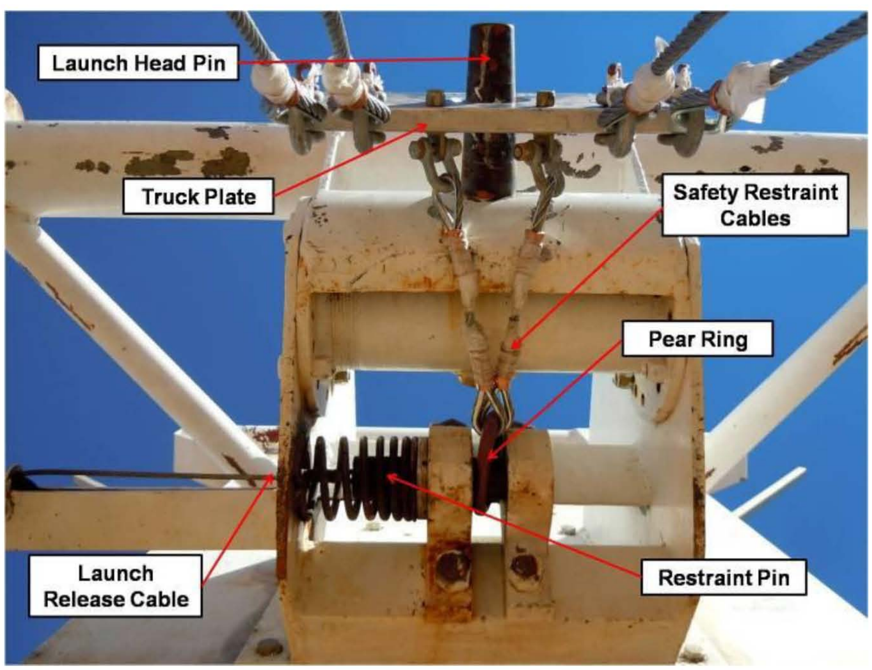


Figure 16. Launch Head Components

The balloon and its payload then begin the ascension to float altitude (Figure 17). Data collection and command and control are maintained continuously from prelaunch until the end of flight. Termination is accomplished using a Payload Parachute Recovery System (PPRS), which is rigged unpacked and in line with the flight train (Figure 18) and attached to the balloon's base. The recovery parachute deploys immediately upon command activation, initiated at the flight termination. The balloon, now physically detached from the parachute and payload, descends back to earth. The balloon, parachute, and payload are then recovered.

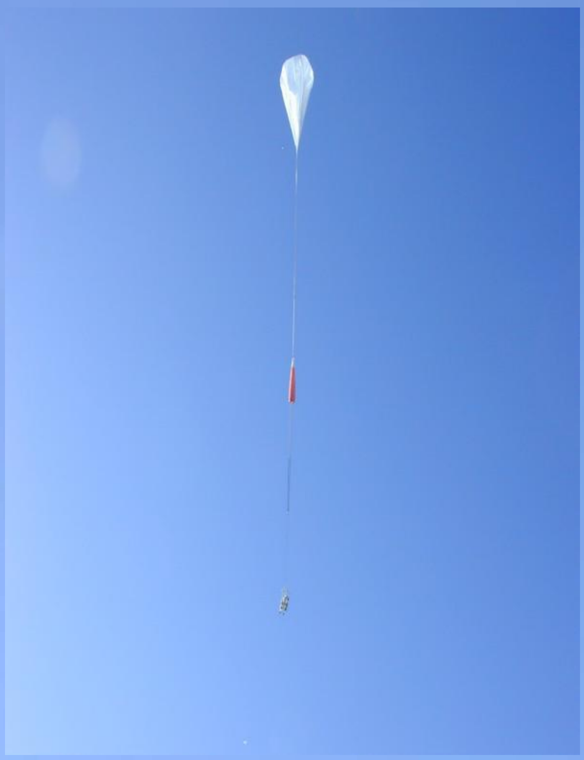


Figure 17. Balloon Ascending

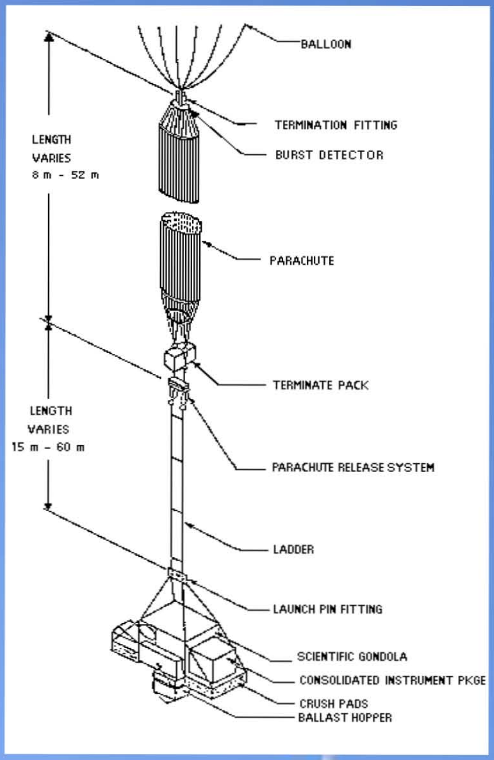


Figure 18. Flight Train Components

2.3 Description of Mishap

On April 29, 2010, personnel from the CSBF, on behalf of NASA, attempted to launch the NCT at the Alice Springs Balloon Launch Facility, Alice Springs Airport, Australia (Figures 1 through 3). The University of New South Wales manages the Alice Springs Balloon Launch Facility under the direction of the SD. The CSBF LD, who reports to the CSBF CM, directs launch operations. On launch day, weather conditions were deemed acceptable throughout launch setup operations. Preparations for launch and flight line setup were nominal. Balloon inflation was nominal as was spool release. The payload did not release despite repeated attempts to activate the launch mechanism. The LD attempted to catch back up with the balloon for another launch attempt but ran out of room at the airport fence. The LD realized that spectators behind the fence were in harm's way from the falling balloon train if the abort command were to be initiated and decided to back the launch vehicle away from the fence. While the launch vehicle (crane) was being positioned for abort procedures, the payload inadvertently separated from the launch vehicle. The airborne balloon dragged the NCT payload along the ground. The payload breached the airport security fence and struck a privately owned vehicle. Another vehicle suffered cosmetic damage. Several spectators ran for safety after seeing the payload separated from the crane. While the payload was being dragged, the mission was aborted by commanding the balloon to separate from the parachute. The balloon came to rest approximately 0.25 mile downwind from the site of separation.

2.4 General Events Occurring Before the Mishap

The MIB derived the facts provided in this section from existing documentation, mishap site visits, witness interviews, photographic and video evidence, and data supplied by the CSBF and NASA's BPO. These supporting data are further described in Section 3.0.

Three missions were planned during the March/April/May campaign of 2010. On April 15, 2010 Greenwich Mean Time (GMT), the Tracking and Imaging Gamma Ray Experiment (TIGRE) mission was successfully launched. TIGRE conducted science for 2 days and 9 hours before the planned termination and recovery on April 18, 2010.

After the launch of TIGRE, launch preparations were made for the NCT Mission. The NCT Principal Investigator (PI) declared the science payload flight-ready on April 14. Between April 19 and 28, the crew and PI staff were on station for potential launch attempts, but were unable to proceed because of unfavorable weather conditions.

On April 29, the crew and PI arrived for launch at approximately 2 a.m. The LD and campaign manager, after consulting with the meteorologist, decided that weather conditions were favorable for launch. Atmospheric conditions were continuously monitored by the meteorologist who was obtaining data from pilot balloons (PiBals), Australian weather data sources, and other accessible data sources. Between 2 a.m. and 6 a.m., the payload was prepared for flight, picked up by the launch crane, ballast added, and the payload was taken, along with the balloon, to the launch area on the northwest end of Alice Springs Airport. The LD decided on a layout orientation of 110 degrees based on continuous PiBal data (Figure 19). The balloon layout, flight train connections, electrical tests, and other standard launch preparations continued nominally. At approximately 6:43 a.m., balloon inflation commenced.

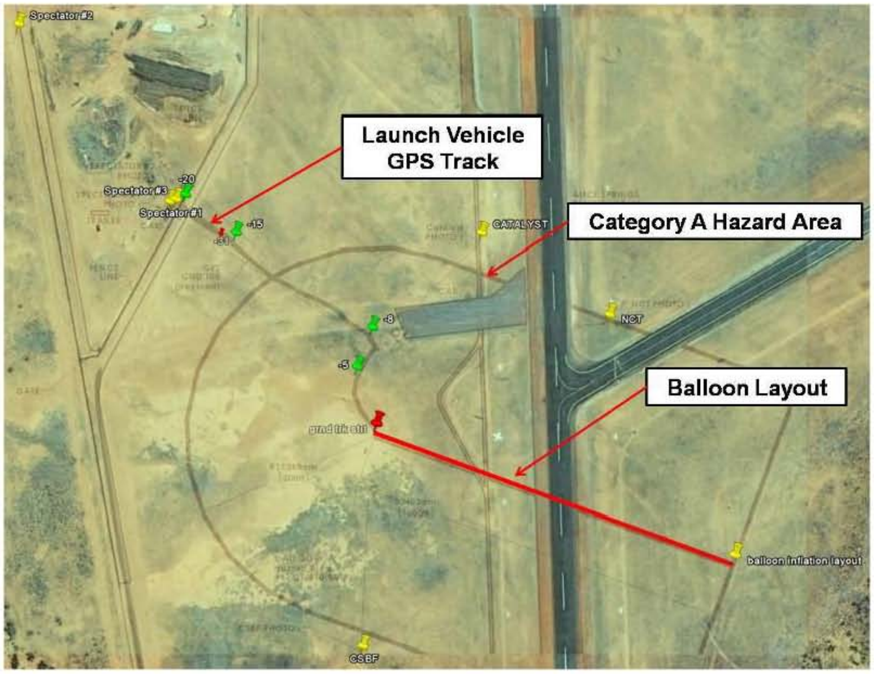


Figure 19: NCT Launch Attempt Layout at the Alice Springs Airport

2.5 Specific Events Occurring On the Day of the Mishap

On April 29, 2010 at 2:18 a.m. ACT, the mission meteorologist performed a pilot balloon (PiBal) sounding to determine wind conditions at the launch site. By 2:30 a.m., the rest of the CSBF launch team had reported to the Alice Springs Airport Balloon Facility to prepare for the NCT launch attempt. A second PiBal run was conducted at 2:59 a.m., yielding a wind profile that led the LD to decide to use a balloon layout direction of 110 degrees. Concurrently, the NCT payload was picked up and transported to the launch vehicle. The launch vehicle picked up the payload by about 3:00 a.m. A half hour later, the launch vehicle with payload and the balloon were transported to the flight line area.

Several more PiBal runs were accomplished at 3:32, 4:18, 4:48, and 5:18 a.m. At 5:18 a.m., the SD updated the Notice to Airmen (NOTAM) of launch to reflect a 1-hr launch delay. At 5:54 a.m., the LD requested the launch team to begin laying out the balloon. PiBal runs were performed again at 5:54, 6:30, and 6:43 a.m. Balloon inflation commenced at 6:43 a.m.

At about this time, the LD noticed spectators downwind along the projected path of the balloon and requested over the open voice line (hand-held radios used in the field) that these persons be moved. The launch team used a tethered PiBal on the face of the launch vehicle to indicate wind direction between 800 and 1,000 ft. The tethered PiBal indicated that the balloon would drift slightly north as it took flight. At this time, an off-duty CSBF crew member (CCM) was observing the launch from outside the fence area and heard the request to move the spectators over his hand-held radio. The CM also responded by calling the SD and relaying the request to relocate the spectators. The SD then requested his deputy to perform the relocation. The deputy SD proceeded to a position along the fence slightly south of the projected flight path and requested persons in two vehicles to move further north toward facility buildings. Soon afterward, the aforementioned CCM volunteered to move spectators that were located slightly north of the projected flight path to what he thought was a safer location which was south from the spectators' current positions. One spectator told the CCM when asked to relocate further south that he had just been asked to move north. Specific direction regarding safe locations was not provided to the individuals who relocated spectators, and the resulting actions actually relocated spectators into the eventual path of the balloon and launch vehicle.

By 7:40 a.m., another PiBal run was performed indicating the wind had shifted slightly and was now more from the south, at about 121 degrees. Inflation was completed at 7:50 a.m. and the operational positions of Collar 1 and Collar 2 were manned. Also, at about 7:50 a.m., the SD requested Air Traffic Control (ATC) clearance for launch from Melbourne. (Because of the time of this particular launch attempt, the Alice Springs tower was closed.) ATC directed the SD to hold because of local air traffic in the area. Approximately 10 minutes later, the SD received launch clearance from ATC.

Key Events (from the time of spool release)

The critical events directly leading to the mishap (Key Events) are described here and coincide with the detailed timeline (Table 2).

In many of the subsequent portions of this report, the times will refer to the elapsed time from the moment of the spool release. This is referred to as the "Phased Elapsed Time" or PET. The reference time of spool release is PET=0.0. Times referenced are based on a review of all factual data collected from detailed interviews and pertinent documentation, and numerous videos and photographs. The accuracy of the relative times presented is limited to about 2 seconds. A detailed chronological timeline was developed and is available in Section 3.5.

Key Event 23: The launch spool was released at approximately 8:05:19 a.m. (**PET=0**). The balloon rose in a nominal fashion and took about 5 sec to lift the flight train from the ground.

Key Event 24: At about **PET=10 sec**, the LVD, under direction from the LD, began driving forward (WNW) and to the right (NNE) in a sweeping right turn as the balloon continued to rise and be pushed to the north of the layout line by the lower level winds.

Key Events 25 and 26: At **PET=37 sec** and **39 sec** the primary and secondary calls were made to release the collar that prevents the balloon bubble from "sailing" during the early rise phase. Both collar callers observed nominal collar release. The CM was serving as Collar 2. Both collar callers were required to observe the balloon's flight and collar release.

Key Event 27: At **PET=45 sec**, the sweeping right turn was completed. After finishing the sweeping right turn, the launch vehicle was located approximately 200 ft to the right of the original 110 degree flight layout.

Key Events 28 and 29: The LD instructed the LVD to turn left in line with the balloon direction. At **PET=45 sec** the launch vehicle momentarily came to a stop while beginning a left turn to realign with the balloon's flight direction. At **PET=46 sec**, voice confirmation of "collar off" occurred. At about **PET=47 sec**, the vehicle began moving again and then completed the left turn. In summary, the completion of the nearly 90-degree sweeping right turn, a NNE traverse of about 200 ft, then a nearly 90-degree left turn put the launch vehicle back on a path nearly parallel to the original layout line.

Assuming the Category A Hazard Area (as defined in the OF610 CSBF Ground Safety Plan) is attached to the launch vehicle and dynamically moves with the launch vehicle, then the Category A Hazard Area breached the location of spectators at the perimeter fence at PET=48 sec (approximately 3 sec after initiating the left turn).

Key Event 30: At **PET=62 sec**, the vehicle lost traction and slowed down. It quickly regained traction and resumed its forward motion. The launch vehicle proceeded along a path parallel to the layout direction.

*Assuming the Category A Hazard Area is fixed relative to the original launch vehicle position, then at **PET=79 sec**, the launch vehicle breached the Category A Hazard area.*

Key Event 32: Approximately 7 sec later, at **PET=86 sec**, the LD instructed the LVD to slow and stop to attempt a launch. When the LD pulled on the launch release lanyard, the launch restraint pin did not release the payload. During this launch attempt, the payload swung out away from the launch vehicle as a result of its inertia, and a team member riding on the launch vehicle with the LD lost hold of the payload controlling straps. The payload continued to swing as the LD tried again to pull the launch release lanyard to release the payload. Again, the payload did not release. The launch attempt, as viewed from the front of the launch vehicle, is shown in Figure 20. By about PET=90 sec, the vehicle was at a complete stop.

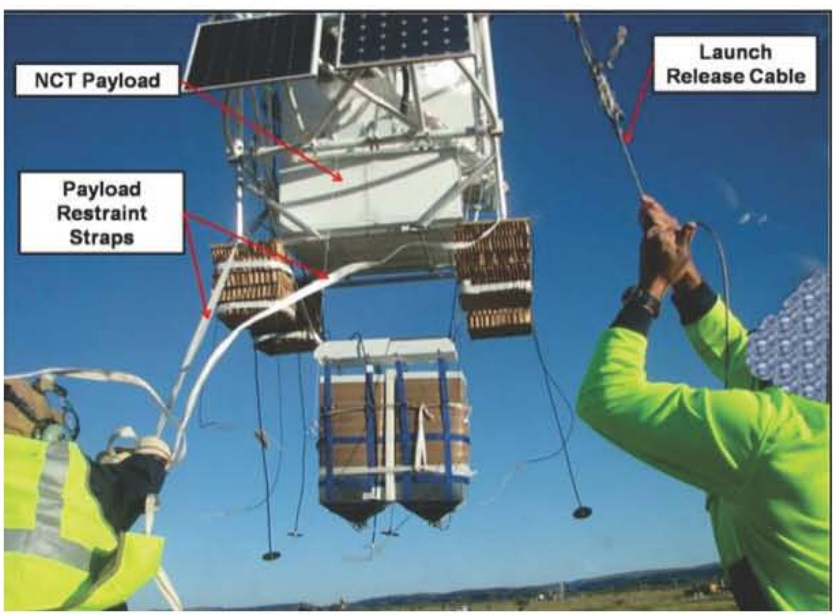


Figure 20. Actual NCT Launch Attempt

After unsuccessful attempts to release the payload, the LD instructed the LVD to proceed forward to try to “catch” the balloon.

Key Event 39: At about **PET=105 sec**, the launch vehicle arrived at the perimeter fence and stopped. The LD realized that the mission would have to be aborted, but because spectators were in the flight path, did not order an abort. After several seconds at the fence, the LD ordered the vehicle to be backed away from the fence. Spectator locations during this event are shown in Figure 21.

Key Events 41 through 43: The vehicle began backing away at **PET=118 sec** and continued backing until about **PET=150 sec**. At this time, the vehicle no longer had traction to continue backing as a result of the tires slipping in the loose soil. At this point, the launch vehicle was still about 150 ft beyond the Category A Hazard Area (fixed interpretation). The LD instructed the LVD to proceed forward and make a left turn in an attempt to move the system away from the spectators. Spectator locations during this event are shown in Figure 21.

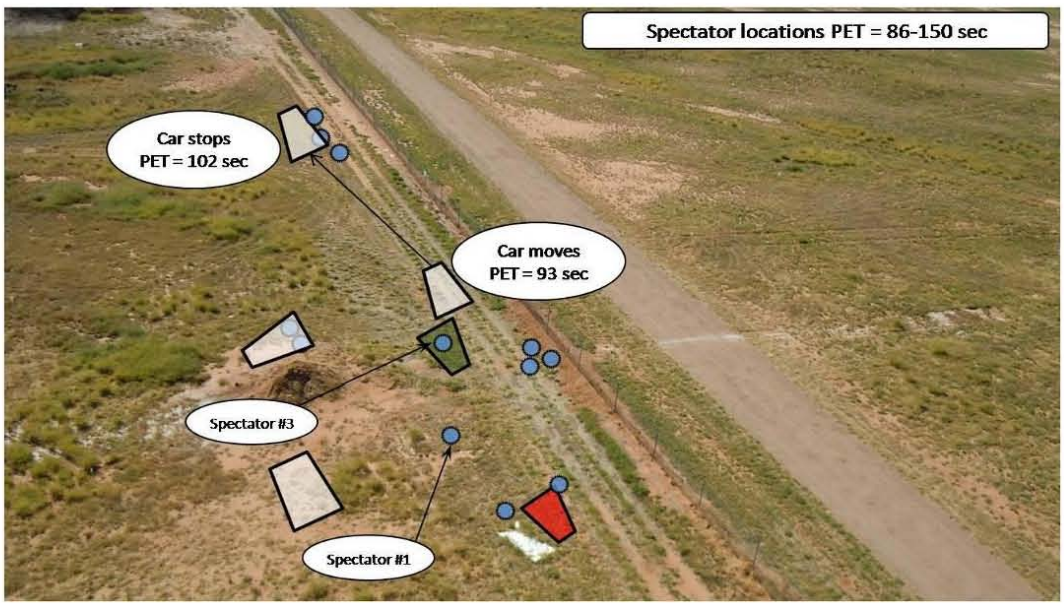


Figure 21. Spectator Location at PET 86-150 Seconds

Key Event 44: During the left turn, the payload inadvertently released from the launch vehicle at **PET=171 sec**. The balloon pulled the payload downwind, where it breached the Airport security fence and continued moving towards spectators’ cars and spectators who were in the path of the payload’s motion. Spectators were able to run to safety.

During the dragging event, a call was made by the CM to abort the balloon. The mishap site and spectator locations at the time of the mishap are shown in Figures 22 through 25.

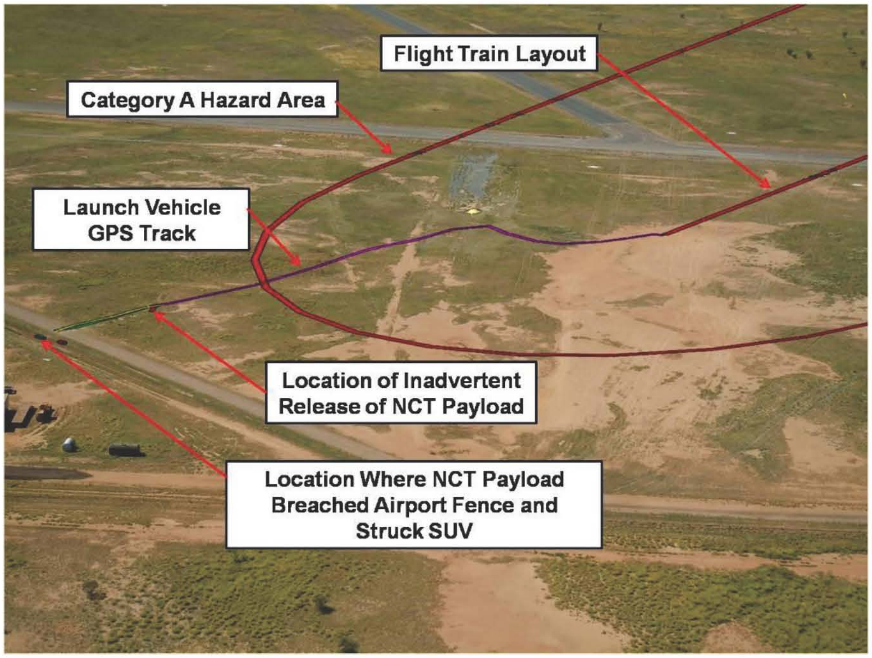


Figure 22. Location of Mishap Site at the Alice Springs Airport

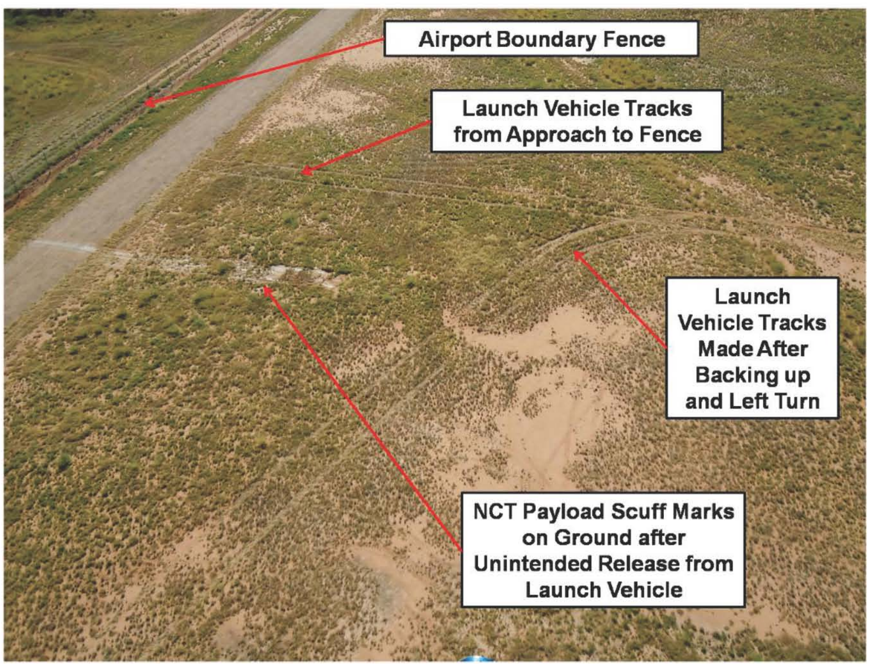


Figure 23. Location of Inadvertent Payload Release From Launch Vehicle

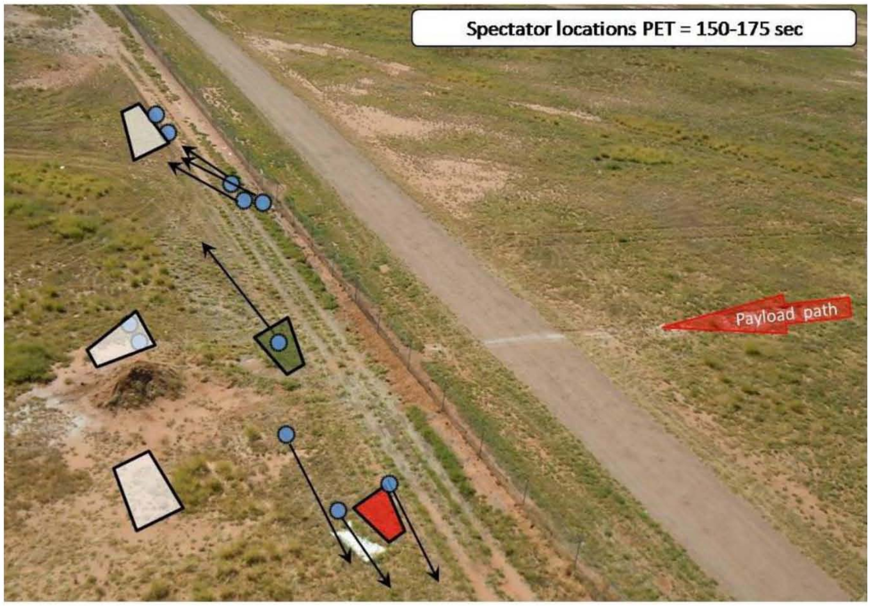


Figure 24. Spectator Location at PET 150-175 Seconds

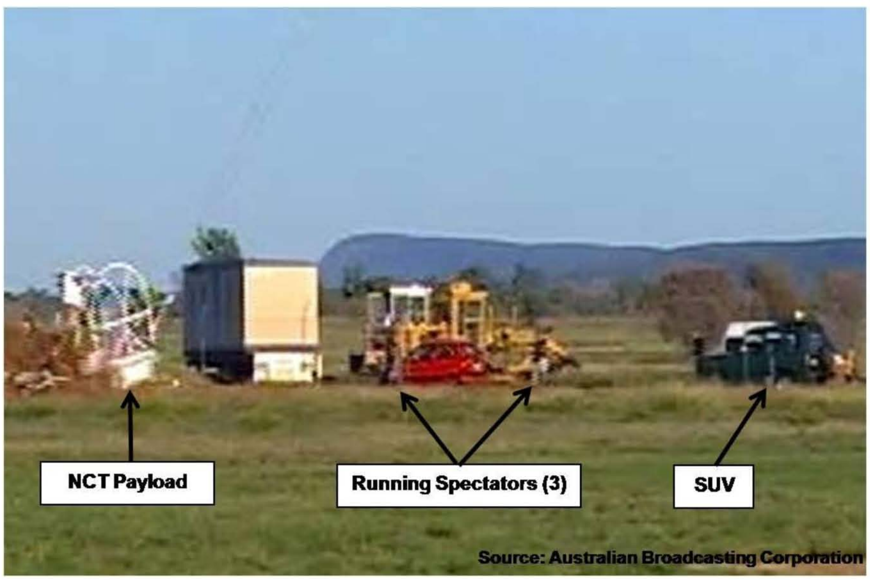


Figure 25. Spectators Seen Running at PET 171 Seconds

Key Event 47: At **PET=177 s** the dragging payload hit a spectator's vehicle. At approximately the same time, the abort command was sent, releasing the balloon from the top of the parachute. After the balloon was separated from the parachute, the payload came to rest. Spectator locations at the time of impact and property damage are shown in Figures 26 and 27.

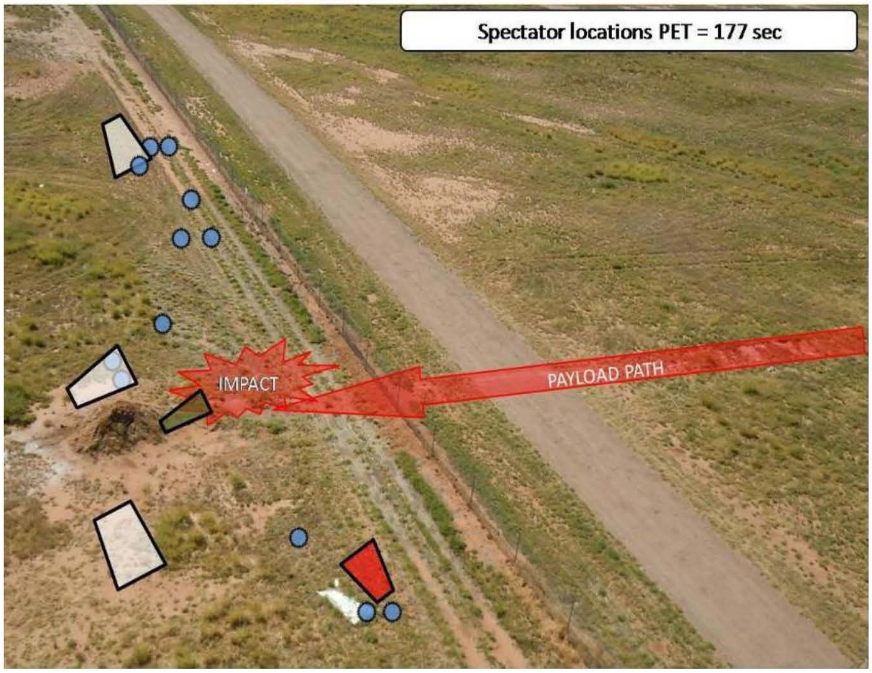


Figure 26. Spectator Location at PET 177 Seconds

Figure 27. Damaged Vehicles and Airport Fence

Key Event 49: The parachute and flight train were fully on the ground by **PET=199 sec**. The balloon came to rest on the ground some time later about ¼ miles downwind in a field outside the airport indicated in Figure 28.

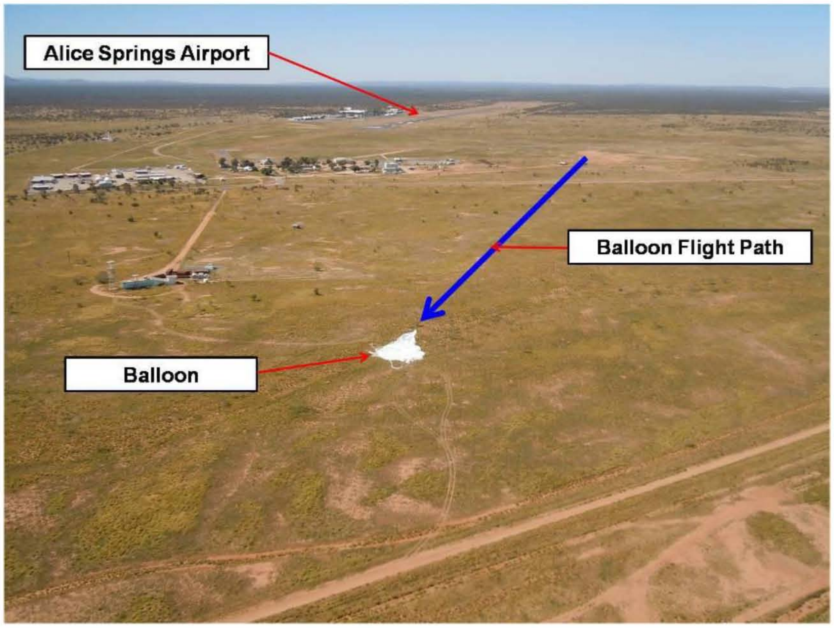


Figure 28. Balloon Landing Location

Immediately after the payload came to rest, spectators checked on the health of each other and all were found to be uninjured. The spectator that was on top of the impacted vehicle saw the danger and ran to protect himself as shown in Figure 29.

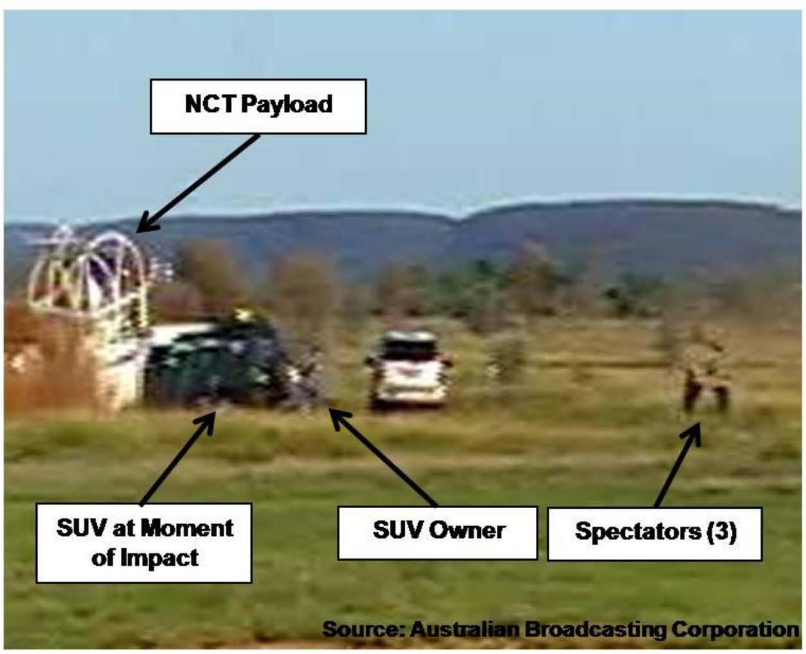


Figure 29. SUV Owner Running Just Before the SUV Was Impacted

The vehicle near the impacted vehicle had two spectators inside. This vehicle suffered cosmetic damage. Within 30 seconds after the event, spectators and camera crew had approached the damaged payload shown in Figure 30.

Figure 30. Camera Crew and Spectators After the Mishap

2.4 Emergency Response and Extent of Injury

Realizing that a vehicle was hit and spectators were involved, the campaign manager did attempt to call emergency response personnel, but became confused between the United States “911” emergency number and the Australian “0” emergency number, and was unable to make the call. However, airport emergency response personnel did respond to the mishap scene in a timely manner owing to notification from the airport tower. Despite the fact that a private vehicle was hit and the general public outside the airport fence were observed running from the location at the time of the mishap, there were no injuries.

2.5 Events Occurring After the Mishap

Right after the mishap, the CM initiated the CSBF mishap response requirements, notifying the CSBF Site Manager (Palestine, TX) and the BPO. Team members were assigned to various activities including gathering information, photographing the site, taking witness statements, and impounding flight and other appropriate data. CSBF personnel and NCT personnel began recovering the damaged payload and balloon flight train wreckage. NCT personnel set aside parts of the payload gondola to later be taken to a scrap yard for recycling.

The MIB chairman dispatched the board's field investigator to Alice Springs, Australia, ahead of the rest of the board, to start impounding evidence and collecting pictures, statements, and other vital information for the board process. Upon arrival to Alice Springs, the MIB field investigator learned that parts of the payload gondola were taken to the local scrap yard and demanded that such evidence be retrieved and impounded. BPO and CSBF management provided all other information gathered by the NCT and CSBF balloon teams. All balloon launch hardware, records, video recordings, and photographs were immediately impounded according to NPR requirements.

Because of the actions of the CSBF personnel in the recovery and removal of the wreckage from the mishap site to a holding location within the area, the physical evidence had to be declared as contaminated by the field investigator.

The NASA MIB was officially established on May 12, 2010.

3.0 Investigation

3.1 Approach

The MIB visited the mishap site in Alice Springs, Australia, identified and interviewed witnesses, analyzed events and conditions, and inspected and tested the crane launch head device to determine its operational conditions. These activities helped to identify the proximate, intermediate, and root causes of the mishap. Each element of the investigation is further described in the following sections.

3.2 Mishap Investigation Chronology

The mishap was originally classified as a High Visibility, Close Call Mishap. Commissioned on May 12, 2010, the MIB collected information gathered by WFF BPO and the CSBF prior to May 12, 2010. The MIB's first visit to the mishap site occurred on May 8, 2010 by the MIB field investigator. The remainder of the board arrived at the mishap site on May 13, 2010.

The MIB kick-off meeting was held on May 13, 2010 at the Alice Springs Airport Conference Center in Alice Springs Australia (Figure 31). The NSC's Mishap Investigation Support Office (MISO) representative provided a mishap investigation process briefing. The Field Investigator briefed the board on safety in the "Australian Outback" and also provided the MIB with a status of the initial investigation efforts to date. The MIB chair assigned tasks to the MIB members. Initial pictures and documentation of the mishap area were reviewed by the MIB. Then the incident details were reviewed and site visits to the NASA Balloon Facility and mishap site were conducted.

Figure 31. Alice Springs Airport, Alice Springs, Australia

The MIB conducted three performance tests on the launch crane head and the payload release system at Alice Springs. Tests were performed to determine (1) performance characteristics of an unloaded launch release mechanism, (2) if a load placed on the pear ring would keep the payload from being released and (3) performance characteristics of the launch release system when loads were introduced through the truck plate.

After performing the review of witness statements and the CSBF Balloon documentation, an initial interview list was developed. Interviews of the CSBF personnel, payload personnel and members of the public watching the balloon launch attempt were scheduled and conducted.

Most members of the MIB departed back to GSFC to start board deliberations on May 15, 2010. The MIB co-chair remained at Alice Springs to complete onsite interviews and additional photography of evidence and mishap site mapping. He departed on May 20, 2010 to GSFC to rejoin the rest of the MIB.

A timeline of the key events leading up to the mishap was initially constructed, identifying all of the events related to the mishap, along with the dates/times that were known. The timeline of the mishap remained a working document, continually being updated as more data were received.

Due to unavailability of the Site Deputy Manager during the site visit to Alice Springs, a telephone interview was scheduled and accomplished at a later date. During the course of the investigation, additional BPO documentation was requested, and the interview list was expanded to include BPO and WFF Safety Management. A follow up interview with the LD was also accomplished.

3.3 Data Collection and Development

3.3.1 Evidence, Interviews and Documentation

During the course of the investigation into the Nuclear Compton Telescope Balloon Launch Mishap, the MIB collected data and reviewed 18 witness statements that were taken by CSBF management prior to the MIB's arrival in Alice Springs. The MIB photographed evidence at the mishap site and obtained aerial photographic records of the mishap site. Photographs of the broken safety restraint cables are shown in Figures 32 and 33. The MIB conducted a total of 21 witness interviews. In addition, the MIB reviewed balloon launch operation procedures, equipment certifications, past balloon anomaly reports, equipment drawings, personnel certification training records, range and ground safety requirements, video and photographic evidence, and physical evidence. The MIB also performed strength testing on safety restraint cables that were manufactured as test samples for the board.

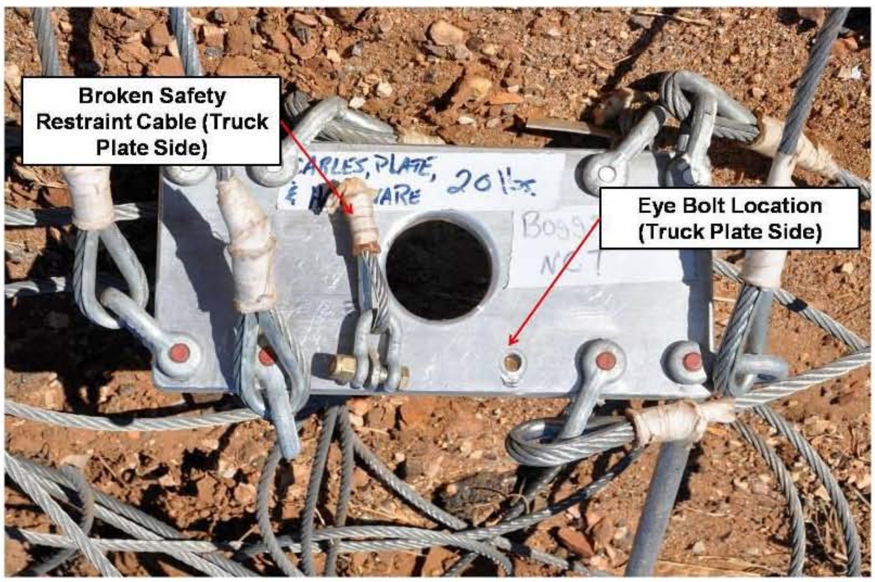


Figure 32. Truck Plate as Photographed at the at Mishap Site

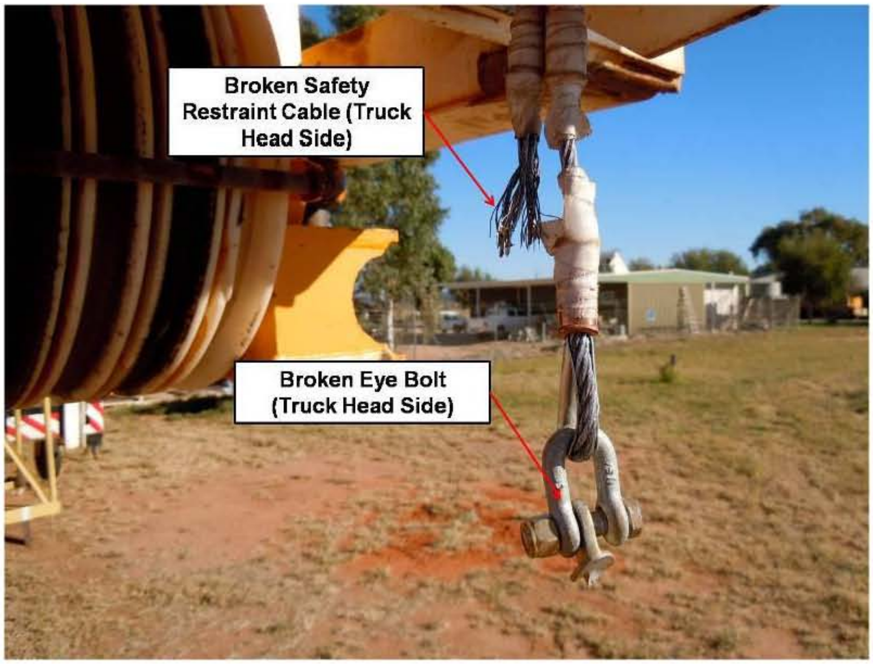


Figure 33. Broken Safety Restraint Cables on Launch Vehicle

3.3.2 Type of Data Gathered

3.3.2.1 List of Documents

The MIB reviewed documentation in the process of the investigation, including BPO Program Procedures, CSBF Procedures, Statement of Work, NASA Audit Reports, NCT Launch Checklist, CSBF Contract Requirements and others. Table 1 provides the list of documents reviewed by the MIB.

Table 1—List of Reviewed Documents

Title	Date	Type	Author
820-PG-1060.2.1A	February 16, 2005	Balloon Program Management Review and Reporting for Programs and Projects	BPO
820-PG-1410.2.1	February 16, 2005	BPO Configuration Management Procedure	BPO
820-PG-5100.1.1B	February 16, 2005	Management of the National Scientific Balloon Support Contract	BPO
820-PG-7120.1.1B	February 16, 2005	Management of the NASA Scientific Balloon Program	BPO
820-PG-7120.1.2C	February 16, 2005	Management of the NASA Balloon Flight Operations	BPO
820-PG-7120.1.3B	February 16, 2005	Management of Balloon Program Development Projects	BPO
820-PG-7120.1.4B	February 16, 2005	Management of the Balloon Program's Safety Implementation	BPO
820-PG-8621.1.1B	February 16, 2005	Investigation and Reporting Procedures for Balloon Program Mishaps, Failures, and Anomalies	BPO
820-CMPP-1002	February 16, 2005	NCT Mission Project Plan	CSBF
800-PG-1060.2.1F	September 8, 2008	Suborbital and Special Orbital Projects Directorate Review	Code 800/Directorate
800-PG-8715.0.4A	January 25, 2005	Certification Procedures for Operations Safety	Code 803/Safety Office

Title	Date	Type	Author
		Supervisors at Wallops Flight Facility (WFF)	
800-PG-8715.1.1	June 23, 2004	Unmanned Roadblocks for Hazardous Operations	Code 803/Safety Office
800-PG-8715.0.3	November 29, 2005	Viewing Locations for Personnel Not Essential to Launch Operations	Code 803/Safety Office
803-PG-8715.1.1E	August 20, 2008	Range Safety Operations Process	Code 803/Safety Office
803-PG-8715.1.13E	August 20, 2008	Ground Safety Process	Code 803/Safety Office
803-PG-8715.1.4D	August 20, 2008	Range Safety Project Planning Process	Code 803/Safety Office
803-PG-8715.1.14D	August 20, 2008	Safety Review Process	Code 803/Safety Office
CSBF Memo		NCT Mishap Quick Look Report	CSBF-Campaign Manager
OF-695-21-P-B		CSBF Mishap Procedures	CSBF-Campaign Manager
OF-610-00-P-B		CSBF Ground Safety Plan	CSBF-Campaign Manager
EL-500-00-F		CSBF NCT Flight Application	CSBF-Campaign Manager
EL-500-00-F-C		NCT Waiver of Claims	CSBF-Campaign Manager
OM-100-10-C		Launch Equipment Configuration & Certification	CSBF-Campaign Manager
OF-300-00-D		Flight Requirements	CSBF-Campaign Manager
OF-317-01-D-A		Gondola Certification	CSBF-Campaign Manager
OF-314-00-F		Pre-Flight Minimum Success Criteria	CSBF-Campaign Manager
OF-310-00-P-B		CSBF Flight Plan	CSBF-Campaign Manager
UNSW Memo		UNSW ASP-BLS Security Procedures	UNSW
C1000-09		Weight Sheet	CSBF-OPS
OF-322-00-M-A		Flight Data Summary	CSBF-OPS
OF-324-00-D-C		Inflation Computation	CSBF-OPS
OF-322-10-C-B		Launch Director Checklist	CSBF-OPS
OF-329-00-D		Balloon Condition Flt Line Rpt	CSBF-OPS
CSBF Memo		Helium Residual	CSBF-OPS
OF-306-00-D-A		Recovery Form	CSBF-OPS
NCT Memo		Recovery Instructions	CSBF-OPS
CSBF Memo		Post Flight Gauges & Scales	CSBF-OPS
OF-330-00-D-A		Balloon QC Info Sheet	CSBF-OPS
OF-328-00-C-A		Collar Flight Record	CSBF-OPS
OF-318-00-D		Rigging Job Assignments	CSBF-OPS
EC-500-02-P-D		Collar Electronics Certification	CSBF-Electronics
EC-700-05/04-F-B		Electronic Compatibility Checklist	CSBF-Electronics
NPR 8615.3	April 17, 2009	General Safety Program Requirements	HQ-OSMA
NPR 8615.5	July 8, 2005	NASA Range Safety Program	HQ-OSMA
NPR 8621.1B	May 23, 2006	NASA Procedural Requirements for Mishap and Close	HQ-OSMA

Title	Date	Type	Author
		Call Reporting, Investigating, and Recordkeeping	
NASA Std. 8719.9	May 9, 2002	Standard for Lifting Devices and Equipment	HQ-OSMA
RSM 2002-Rev B	July 14, 2008	Range Safety Manual for Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF)	WFF-OSMA
EC-100-01-F-B		CIP (Consolidated Instrument Package) Pack Record	CSBF-Electronics
EC-100-03-P-B		CIP Receiver	CSBF-Electronics
EC-100-02-P-B		CIP Command Demodulator	CSBF-Electronics
EC-100-04-P-B		CIP VCO Calibration	CSBF-Electronics
Cal. Printout		MKS (Baratron) Calibration	CSBF-Electronics
EC-100-05-P-B		CIP Environmental Record	CSBF-Electronics
EC-500-03-P-B		ATC Transponder Check	CSBF-Electronics
EC-700-12-C-A		CIP GAPR Flt Line Checklist	CSBF-Electronics
EC-800-02-F-B		GSE Tape Recording (Setup)	CSBF-Electronics
EC-300-11-P-D		RFU (Remote Firing Unit) Calibration	CSBF-Electronics
EC-300-04-P-E		UTP (Universal Termination Package) Battery Procedure	CSBF-Electronics
EC-700-13-C-F		UTP/RFU Preflight Test	CSBF-Electronics
EC-300-12-P-B		UTP/RFU Environmental Record	CSBF-Electronics
Abort 23 GSE DATA		CD of GSE LOS Data	CSBF
UNSW/CASA Doc		UNSW-CASA Letter of Agreement	UNSW/CASA
Meteorology Davis Weather Station		Surface Weather Conditions	Meteorologist
Weather Documentation		Meteorology Flight Forecast	Meteorologist
Weather Documentation		Meteorology Climbout and Descent Vector Forecast	Meteorologist
Weather Documentation		Meteorology Abort 23 OBS Report	Meteorologist
Weather Documentation		Meteorology Radiosonde Data	Meteorologist
Weather Documentation		Meteorology PIBAL Runs (Data)	Meteorologist
Weather Documentation		Meteorology Weather Surface Charts	Meteorologist
Training Records		Launch Crew Training and Reclass Action	CSBF
Interviews		Notes From Interviews	MIB
Interviews		Original CSBF Witness Statements	CSBF
Weather Documentation		TIGRE Meteorology Records	CSBF
Weather Documentation		Weather Summaries From Previous Alice Springs Launches	CSBF-Meteorologist
WFF Safety		April 2001 Flight Safety Analysis	BPO
GFSC/WFF Report		517N Report	BPO
GFSC/WFF Report		533N MIB Report	BPO
Audit Report		Safety Audit Reports	WFF Safety
RFP NAS5-03003	January 9, 2003	Balloon Program and National Scientific Balloon Facilities Contract – Safety and Health Plan	Physical Science Laboratory, New Mexico

Title	Date	Type	Author
			State University
LTM 1100/2 Liebherr		Crane Operations Manual	Liebherr Crane
S-2000-231-00012	August 8, 2000	IRIS Report, Close Call	GSFC
S-2000-246-00001	September 2, 2000	IRIS Report, Type A	WFF
S-2001-177-00013	June 26, 2001	IRIS Report, Incident	GSFC
S-2001-263-00009	September 20, 2001	IRIS Report, Incident	GSFC
S-2001-267-00009	September 24, 2001	IRIS Report, Close Call	GSFC
S-2005-206-00003	July 24, 2005	IRIS Report, Type C	WFF
S-2006-269-00001	September 25, 2006	IRIS Report, Close Call	WFF
S-2007-058-00015	February 22, 2007	IRIS Report, Close Call	WFF

3.3.2.2 List of Tests

The MIB accomplished four tests in the process of the investigation. The purpose of these tests was to determine the performance characteristics of the launch release mechanism under various loading conditions. The release mechanism, which was still attached to the launch crane, was impounded at the time of the mishap. The first field test was a no-load functional test of the launch release mechanism. The subsequent tests were performed under various loading conditions. Table 2 lists the tests performed.

Table 2—List of Tests Performed

Name of Test	Place Performed	Purpose
Field Test 1	Alice Springs	No-load lanyard pull test
Field Test 2	Alice Springs	Pull force required to release launch restraint pin under direct load
Field Test 3	Alice Springs	Pull force required to release launch restraint pin under simulated balloon load
Field Test 4	GSFC/WFF	Determine ultimate strength of safety restraint cables

3.4 Data Analysis

The MIB used the NASA Root Cause Analysis process to analyze the mishap. To support or rule out potential causal factors, tests and analyses were conducted. A summary of the test results is provided below. Test and analysis details are provided in Appendix C.

Summary of Test and Analysis Results

Launch Attempt—(1) At the time of the launch attempt, the balloon was ahead of the launch vehicle. (2) The combined loads from the helium and the wind caused forces on the launch release pin in excess of 1000 lb. (3) The forces on the release pin resulted in release lanyard pull forces that exceeded reasonable human capabilities.

Inadvertent Release—(1) Tests show that the safety restraint cables have a break strength near 8000 lb. (2) Analysis shows that during the straight backing maneuver, rupture loads were not exceeded on the safety restraint cables. (3) After the left turn (event 43 in Table 3 in Section 3.5) the load was not equally shared by the cables. (4) The load on a single cable exceeded its ultimate strength capability.

3.4.1 Test Results and Related Data

Due to the nature of the mishap involving the inadvertent release of the payload, inspections and field tests were deemed to be of immediate importance after the MIB team arrival in the field. It was confirmed that the launch head and crane had been generally preserved in the launch configuration. One exception was that the crane boom had been lowered in order to promote easier transportation. It should be noted that the boom height is constrained for the flight by adjustable restraint chains on the crane. These restraint chains were left in the launch configuration so that the boom height was easily reproducible during Field Test 3.

3.4.1.1 Field Test 1

Background—The launch release mechanism was impounded immediately following the mishap. It remained attached to the launch crane and was preserved in the condition that existed after the inadvertent release of the NCT payload. After visually inspecting the hardware involved in the mishap at the mishap site, the MIB defined a series of tests to determine the performance characteristics of the launch release mechanism under various loading conditions. The first test was a functional operation test of the unloaded launch release mechanism.

Summary of Test—With no shear load on the restraint pin, an operator pulled on the release cable lanyard.

Significance of Test—It was first necessary to determine if the release mechanism would function properly under a no-load condition to determine if there were any mechanical or configuration-dependent conditions that may have prevented proper operation of the release mechanism.

Test Conclusions—The release mechanism functioned nominally when operated in the no-load condition.

3.4.1.2 Field Test 2

Background—Evidence indicated that there was an attempt to pull the lanyard cable that retracts the release pin during the launch attempt, but the lanyard did not release the pin as expected. The test was designed to determine the approximate lanyard force required to release the pin under several conditions. Since the release pin can be loaded through a ring via the safety restraint cables, a variety of loads was applied to a flight-identical pear ring using suspended loads. The test configuration is shown in Figure 34.

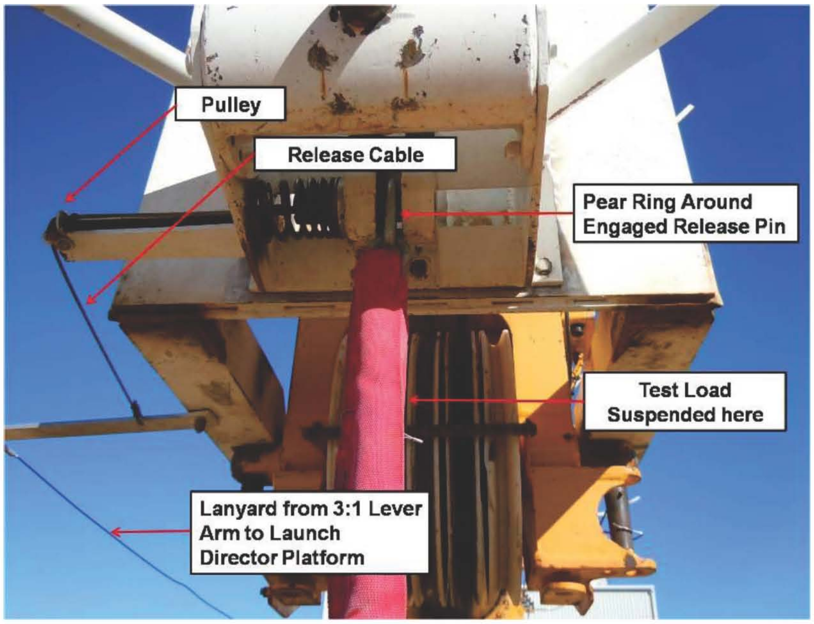


Figure 34. Field Test 1 Configuration

Summary of Test—A simple test was performed aimed at discovering the approximate forces required to pull the lanyard cable and retract the safety restraint cable release pin. The pear ring hanging from the release pin was subjected to a range of loading from zero to 1400 lb in order to determine the relationship between the pin loading and the load required to pull the release lanyard. The resulting lanyard forces ranged from approximately 50 lb at no load to 300 lb at 1400 lb load and are shown in Figure 35. The full test report is contained in Appendix C.

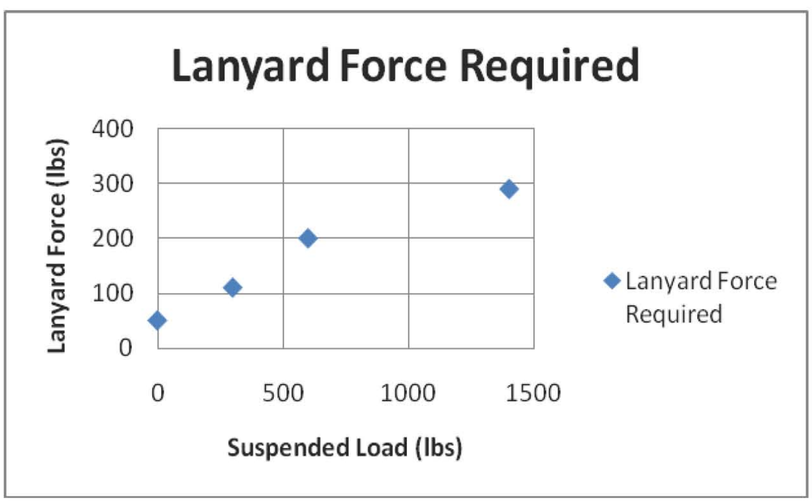


Figure 35. Lanyard Pull Force vs. Pear Ring Load

Significance of the Test—During the launch process, the LD is required to release the truck plate from the launch pin via the release lanyard. The required lanyard pull force increases with increase pin loading. Resisting forces are created through friction with the pear ring and with the pillow block. The test is intended to determine the relationship of pear ring loading to the required lanyard pulling force.

Test Conclusions—The results of this test were generally as expected, showing an increase of the required lanyard pull force with increasing load on the pear ring. The pull force without any pear ring load is about 50 lb (an intentional design feature achieved with a pre-load spring). Human factors research indicates that the pull force would become difficult for the average adult male at about 100 lb, which is reached between 200 and 350 pounds of suspended weight (There is a 3:1 mechanical advantage between the release lanyard and the launch restraint pin).

3.4.1.2 Field Test 3

Background—Evidence indicated that there was an attempt to pull the lanyard cable that retracts the release pin during the launch attempt, but the lanyard did not release the pin as expected. This test was designed to determine the approximate lanyard force required to release the pin under loaded conditions. For this test, the balloon loads were simulated by applying loads with a crane through a cable harness and then through the truck plate. The configuration is shown in Figure 36.

Figure 36. Field Test 2 Configuration

Summary of Test—A simple set of tests was performed aimed at discovering the approximate forces required to pull the lanyard cable and retract the restraint cable release pin as a result of applied loads to the truck plate. The purpose of the test was to determine if loads applied to the truck plate (translated into loads on the pear ring and subsequently the restraint cable pin) through the flight train during launch operations would be sufficient to make release difficult for personnel. The truck plate was loaded in several representative ways to simulate potential launch loads. The applied test loads were limited in magnitude for two reasons: (1) To keep the crane and fitting loads well below the equipment ratings for safety, and (2) To keep the required lanyard loads small enough for two people to be able to actuate the release. Loads of approximately 1000 and 2000 lb were applied at forward and side angles of approximately 8 degrees and 15 degrees, including combinations of forward and side angles. The resulting lanyard forces ranged from approximately 100 lb at 1000 lb applied with zero forward and side angles (pulling straight up) to approximately 215 lb at 2000 lb with 15-degree forward angle and 0-degree side angle. Sample data are shown in Figure 37. The full test report is contained in Appendix C-1.

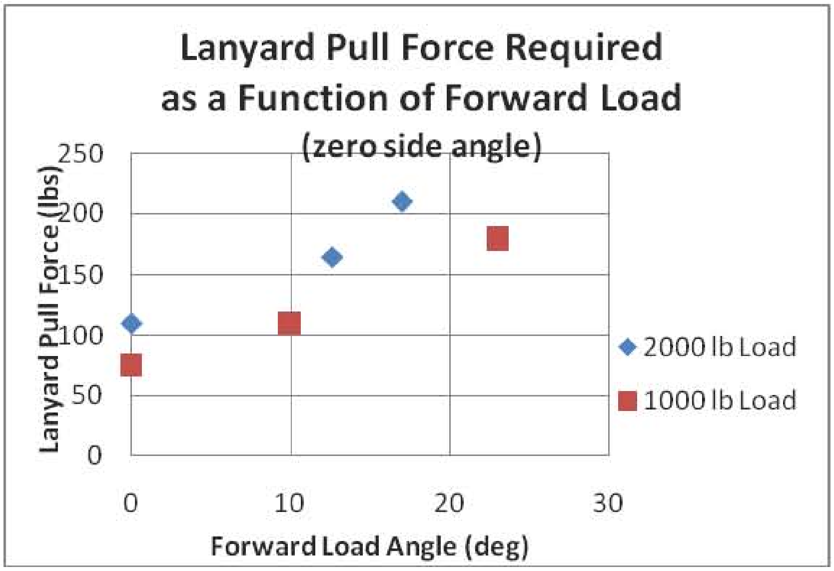


Figure 37. Lanyard Pull Force vs. Truck Plate Loading

Significance of the Test—During the launch process, the LD is required to release the truck plate from the launch pin via the release lanyard. The required lanyard pull force increases with increased pin loading. Resisting forces are created through friction with the pear ring and with the pillow block. The test was intended to determine the relationship of truck plate loading to the required lanyard pulling force.

Test Conclusions—The results of this test were generally as anticipated. Increasing loads through the truck plate increased the lanyard pull force. Increasing forward load angle increased the lanyard pull force. Increasing side angle increased the lanyard force only mildly, except for some combined load conditions where the lanyard force appeared to decrease.

Considering that the designed free lift (net lifting force on the launch pin) is about 985 lb, the lanyard force required for a balloon directly overhead would seem reasonable at about 80 pounds (in a no-wind condition). However, the tests indicate that with relatively small forward angles of 10 to 15 degrees (balloon ahead of the launch crane), the lanyard force could rise to 125 to 150 pounds. Adding loads created by the wind on the balloon could easily result in required lanyard pull forces well in excess of 200 pounds.

3.4.1.3 Field Test 4

Background—During the attempted launch operation and subsequent mitigation actions, the safety restraint cables ruptured, allowing the payload to disengage from the launch head and be pulled free by the balloon.

The cable ultimate strength for the ¼" 7x19 aircraft cable is reported to be 7000 lb by document OM-200-18-D. The complete test report is contained in Appendix C-1.

Summary of Test—A simple destructive pull test was performed at WFF on safety restraint cable sets similar to those used for the NCT launch attempt to determine the actual break strength of the safety restraint cables. The cable sets were supplied by the CSBF. Two break tests were performed showing the breaking strength to be 8,000 (+/- 20) lb. Figure 38 shows the test setup.

Figure 38: Safety Restraint Cable Strength Test Configuration

Significance of the Test—Forces in the range of 7,000 pounds (cable specification) to 8,000 pounds (pull test of representative cables) must have existed in order to rupture the restraint cables.

Test Conclusions—The test confirms the ultimate cable strength used by the CSBF.

3.4.2 Engineering Analysis

3.4.2.1 Analysis of Applied Forces by the Balloon and Flight Train System

Static and dynamic simulations were conducted to estimate the forces present in the balloon and flight train elements during the Nuclear Compton Telescope inadvertent payload release and to predict the ground track of the balloon. These analyses were important to help support or refute conclusions drawn from observations and evidence. The analyses included approximations of the balloon and flight train distributed weights, the drag forces produced by the relative wind on all elements, and the lift forces generated by the buoyant forces on the contained helium. While these analyses were conducted to understand the loading conditions during the entire timeline, the focus was on the following four most significant loading events: launch attempt, arrival at the Airport fence, the backing maneuver, and inadvertent payload release.

The system of structural elements and forces produces a complex catenary (the catenary is the characteristic curved shape typically produced by the combination of weight and tension forces on a suspended cable-like structure). The geometry is well represented in Figure 39, which shows the system upon arrival at the Airport fence.

Figure 39. Catenary When Launch Vehicle Arrives at Fence

This catenary system was modeled using two different methods, a multi-element, equilibrium, steady-state “shooting method” and a dynamic, elastic model that solves the accelerations of a lumped mass and spring system. Wind profiles were modeled using actual PiBal data. The two models agree well for compared static conditions. The results of the static and dynamic assessments were correlated with photo and video evidence and show agreement with catenary photo comparisons. Results predict considerable forces at the truck plate during the four key events.

With regard to the accuracy of the analytical predictions, it should be noted that the launch vehicle position data from GPS was limited to 1/5 Hertz frequency. There were no data providing the actual position of the balloon bubble (except for some video evidence early after spool release). Wind data were limited to several altitudes at times prior to the event and after the event. In addition, the actual effective drag coefficients on each element of the system as a function of time are difficult to characterize. A complete discussion of the analysis is included in Appendix C-2.

Summary of Analysis Results

The estimated forces are consistent with the inability of the LD to actuate the release lanyard successfully during the launch attempts. In addition, the estimated forces are also consistent with the rupture of the restraint cables at the time of inadvertent payload release.

3.4.2.1.1 Analysis Results at Time of Launch Attempt (PET=86 seconds)

For the launch attempt analysis, the important result is to determine the pull force required on the release lanyard at the time of the launch attempt. Due to the shear forces applied to the release pin through the pear ring, the lanyard pull force is a function of the forces generated by the balloon and the relative position of the balloon to the launch vehicle. At the time of the attempted launch (attempted actuation of the retention pin release lanyard), the geometry of the balloon and flight train was somewhat different than it was at the time the launch vehicle arrived at the fence as depicted in Figure 39. From photographic evidence, the forward angle appears to be about 10 degrees (80 degrees from horizontal). At this angle, the load in the safety restraint cables after resolving the force along the launch head pin is reduced to about 60% of the load in the flight train (assuming no appreciable reduction due to friction). Both the static and dynamic analyses show a total flight train force introduced into the truck plate of about 6000 lb once the vehicle slowed for the launch attempt. The resulting total safety restraint cable force is then about 1500 lb, or 750 lb on each cable.

Using the data from Field Test 1, the resulting lanyard pull force would be predicted to be in excess of 300 lb (test data only covered up to 1400 lb suspended). Predicted loads on the launch mechanism and the resulting required lanyard pull force at the time of the launch attempt are shown in Figures 40 and 41.

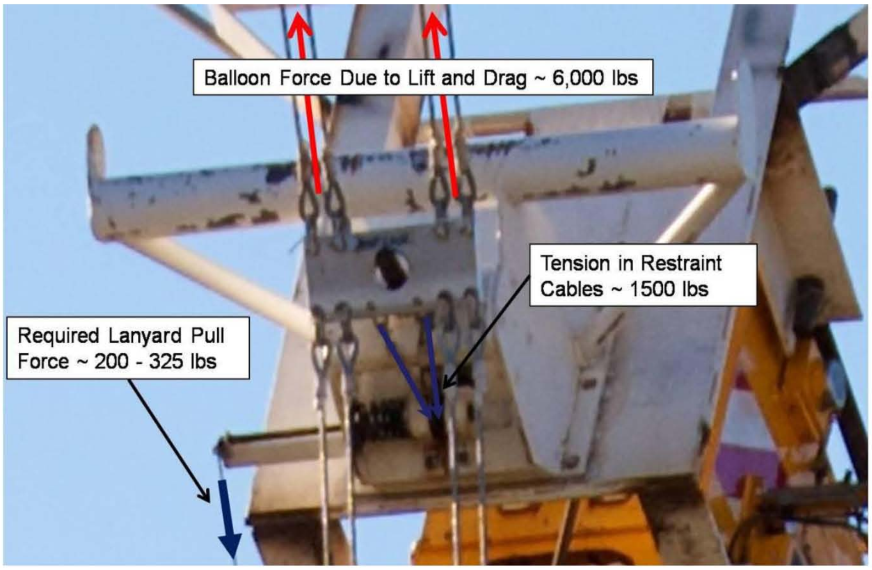


Figure 40. Forces on Launch System at Launch Attempt Created an Unviable Condition

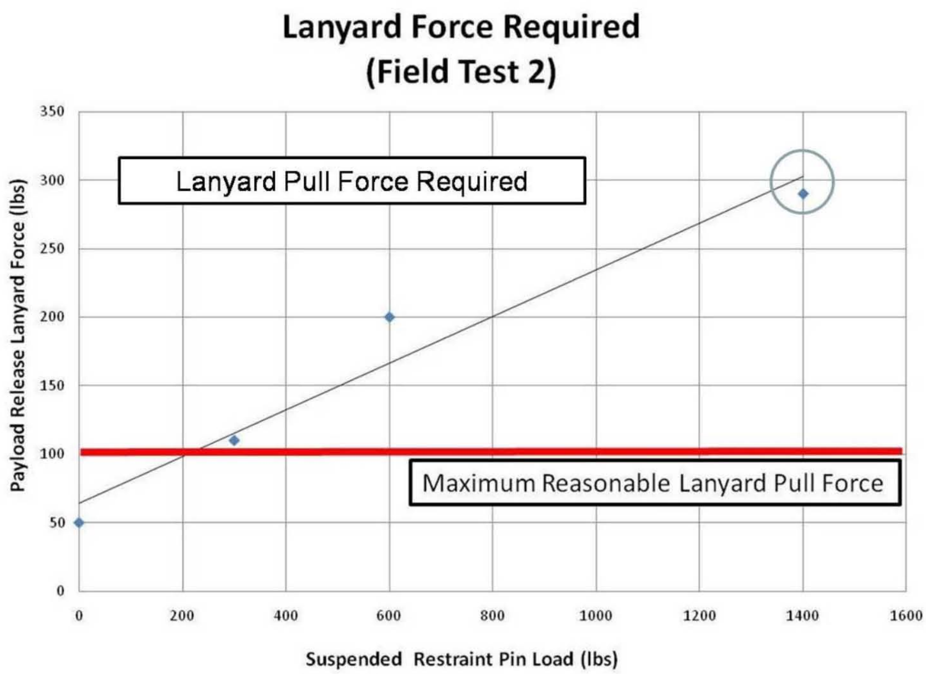


Figure 41. Required Lanyard Pull Force at Time of Launch Attempt

Using the dynamic analysis and assuming the attempted lanyard actuation was before the vehicle began to slow, the lanyard force would be estimated as low as 200 lb. Therefore it is estimated that at the time of the launch attempts, the predicted lanyard pull force resulting from the balloon and flight train catenary was likely in the range of 200 to 300 lb. The required pull force during the launch attempts was clearly well in excess of human capabilities. This is consistent with the inability of the LD to effect a successful release.

Analysis Finding: The lanyard pull force at the time of attempted release exceeded reasonable human capability.

3.4.2.1.2 Analysis Results for Vehicle at Fence (PET=112 seconds) and During the Backing Maneuver (PET=118 to 148 seconds)

The catenary Steady State Equilibrium analysis solution produced a good geometric fit with the photographic evidence as shown in Figure 42 when the launch vehicle was stopped at the Airport fence. The necessary forces at the truck plate to support the system weight and drag through the catenary were calculated to be approximately 9350 lb at approximately 38 degrees from horizontal. The associated horizontal drag force component was approximately 7300 lb.

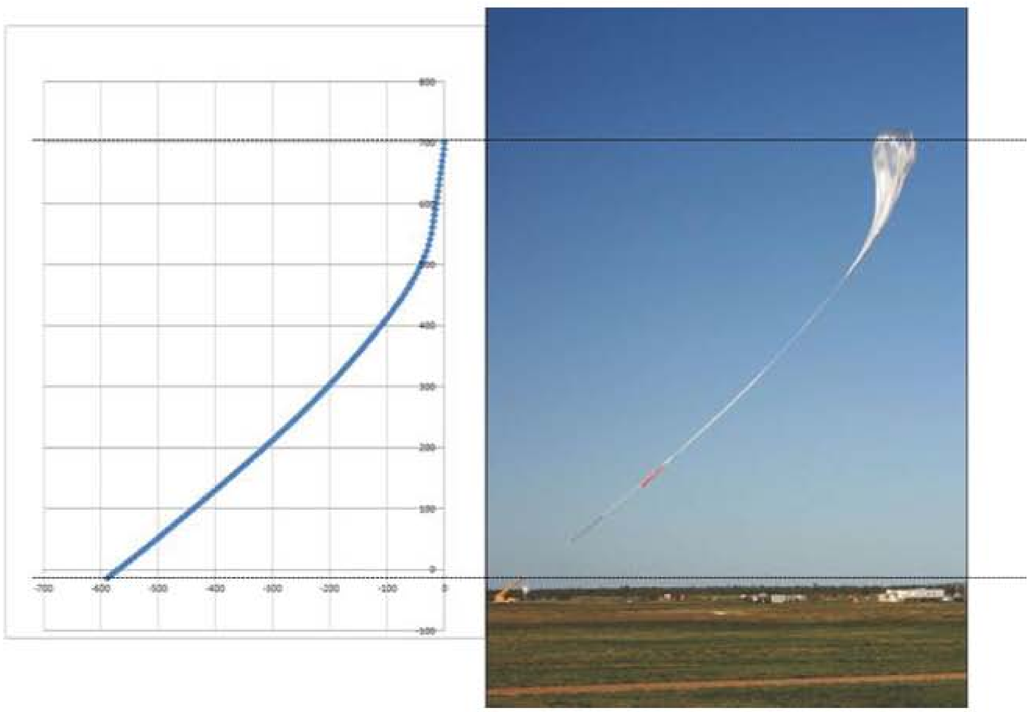


Figure 42. Static Catenary Assessment

Those forces are reacted at the launch head pin (this is not the *release* pin). The launch head pin has an operation angle of approximately 25 degrees from the horizontal as determined from photographic evidence. Resolving these applied forces along the launch head pin gives a force along the pin direction of about 9200 lb. Considering the contribution of the payload weight on the bottom of the truck plate leaves a force of approximately 6300 lb transmitted directly to the restraint cable pair, pear ring and release pin. This compares to the specified ultimate load of the restraint cables of 7000 lb each, or 14,000 lb for the pair.

During the backing maneuver, the added relative wind speed on the balloon produced a further depressed catenary and increased forces at the launch head. Similar analysis yields total forces at the launch head from 11,800 to 15,000 lb and cable forces of 10,500 lb or more.

Conclusions—For the condition when the system was stopped at the fence and during the backing maneuver, it is reasonable to suspect that both safety restraint cables were sharing the load. This assumption is supported by photographic evidence. With approximately 14,000 (using the specification) to 16,000 (using the pull test results) pounds of strength to break available, it would be expected that the predicted applied cable loads while stopped at the fence and during the backing maneuver would not result in a failure condition. The loading condition during the backing maneuver is illustrated in Figure 43.

Analysis Finding: Predicted loads in the safety restraint cables while the launch vehicle was at the fence would not have resulted in cable rupture.

Analysis Finding: Predicted loads in the safety restraint cables during the backing maneuver would not have resulted in cable rupture.

Analysis Finding: The safety restraint cables were used in a backing operation that the cables were not designed to perform. The implemented factor of safety was approximately 1.3, which is inadequate for this operation.

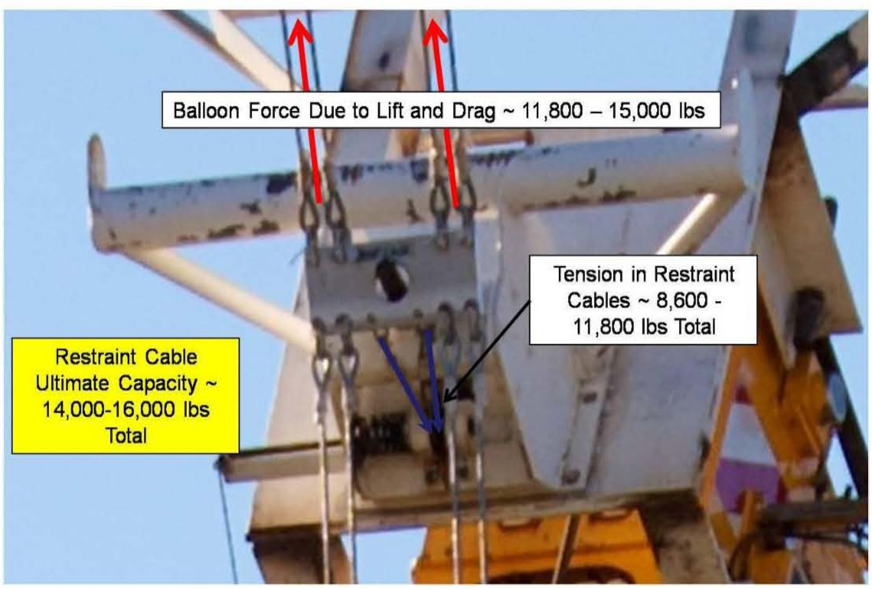


Figure 43. Forces on Launch System During Backing Maneuver Created Unsafe Operating Condition

3.4.2.1.3 Analysis Results for Vehicle at Time of Unintended Release (PET=171 seconds)

For the condition when the vehicle was turned left in an attempt to pull the system away from the people, it is reasonable to suspect that the load was unevenly distributed between the cables due to the twisting action that is produced when the truck plate is loaded from the side. The MIB simulated the oblique loading condition on the truck plate during the site visit to Alice Springs in order to understand the behavior characteristics of the restraint cables. As seen in Figure 44, an oblique loading condition on the truck plate, such as the condition that existed at the time of restraint cable rupture, causes one restraint cable to be un-loaded. It is in a side-loaded condition that the cable assemblies ruptured.

Loads analysis predicts that the total load at the launch head produced by the balloon system was on the order of 10,000 to 12,000 lb at the time of release. This translates into about 7000 to 8000 lb in the restraint cables, which is at the rupture limit of the cables. Additionally, any pendulous motions would have the potential of adding to the maximum forces seen by the restraint cables. If most of the 8000 lb were applied to one cable, rupture would be expected in first one cable, then the other. The predicted load conditions at the time of restraint cable rupture are shown in Figure 45. Any other conditions caused by the twisting truck plate that produced combined loads (e.g., bending and tension) on the eyebolt elements would only have exacerbated the problem.

During the left turn maneuver of the launch crane, one restraint cable became off-loaded. The remaining restraint cable reacted the loads from the wind-driven balloon, which exceeded the cable’s ultimate strength capability. One restraint cable ruptured, causing the unloaded cable to pick up the load. The second cable assembly also broke due to the loading condition. The load conditions and predictions of hardware behavior are consistent with hardware evidence collected in the field at Alice Springs.

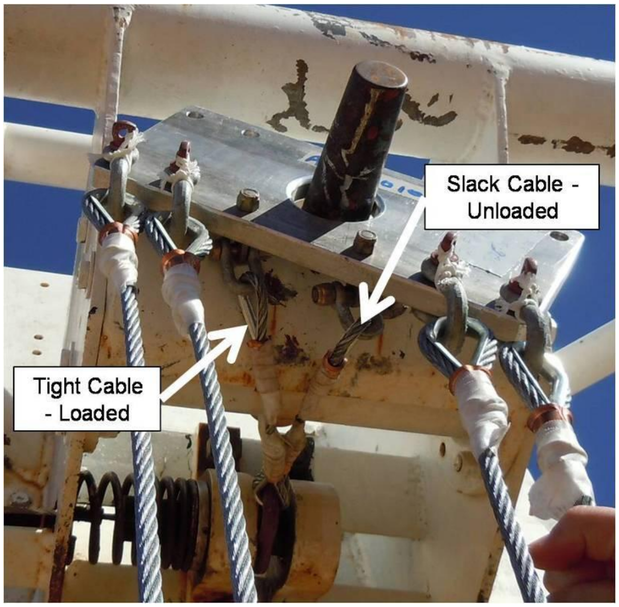


Figure 44. Oblique Truck Plate Loading Off-Loads One Restraint Cable

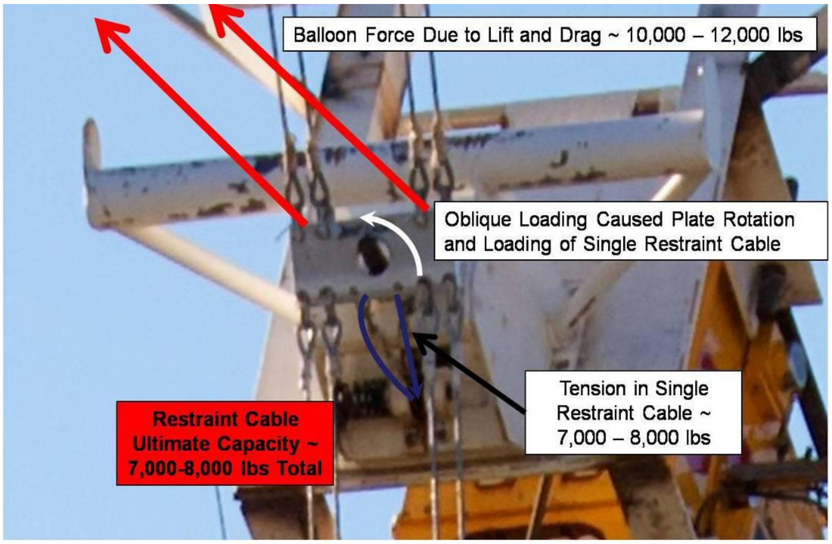


Figure 45. Forces on Launch System During Turning Maneuver Resulted in Cable Rupture (Note that there was no face-on photograph of the hardware at the time of rupture.)

Analysis Finding: **Analysis of the balloon, flight train, and crane system predicts that the loads on the safety restraint cable assemblies exceeded the load carrying capability of the cable assembly at the time of the inadvertent payload release due to the magnitude and relative geometry of the loads on the flight train.**

3.4.2.1.4 Analysis Results for Launch Head Forces Required for a Hypothetical Case of No Collar Release

An analysis was performed to determine the likely level of forces at the crane launch head mechanism for a condition where the reefing collar had not been released prior to release from the launch pin in order to determine if collar release timing played a role in the mishap.

The drag areas were determined based on photographic evidence of the balloon just prior to the collar release. In this condition, the drag area is somewhat less than that observed after the collar release. The new drag area was used with the same effective drag coefficient that was shown to cause analysis agreement with both the overall catenary shape and terminal angle at the launch head.

Application of the same analytical technique yielded an ultimate force at the launch head of approximately 8000 lb with the collar compared to 10,000 lb without the collar. Resolving the 8000 lb into the safety restraint cables leads to a total cable pair force of 5500 to 6500 lb. This compares to the 7000 to 8000 lb predicted for the actual launch attempt condition.

Conclusions

While maintaining the collar until after pin release would have reduced the cable load on the safety restraint cables, perhaps enough to prevent rupture, the load would have still been well in excess of a safe load for one cable. In addition, other real loading conditions, such as pendulous modes of the payload would have likely caused the restraint cable to be exposed to loads exceeding its capability. Further, it is unlikely that collar release would have been postponed until after the backing maneuver, given current standard operations implementation.

Analysis Finding: Retaining the collar until release reduces the total loading in the launch head and improves the likelihood of successful lanyard pull in the event of non-optimal balloon position.

Analysis Finding: It cannot be concluded from the analysis that retention of the collar until after release would have prevented safety restraint cable rupture.

3.4.2.2 Analysis of Applied Forces by Pendulous Payload Dynamics

During the launch process, when the launch vehicle is moving, the payload generally exhibits pendulous motion due to the inertia of the payload and the applied forces at the suspension point (truck plate) applied at the launch head pin. The forces generated on the truck plate due to the dynamics of the payload can then be translated into the safety restraint cables and thereby have an effect on the lanyard pulling force required for a successful release of the payload.

The forces of interest in this pendulum system are produced by two accelerations. One is from the acceleration of gravity, producing the weight component, and the other is from the acceleration due to the circular motion, producing the centrifugal force component.

For the launch conditions here, peak angular amplitudes were observed up to approximately 20 degrees, which could produce horizontal forces up to approximately 1400 lb.

Conclusions

It is sufficient to say that pendulous motions have the potential for generating significant forces that add to the forces transmitted through the flight train and truck plate into the restraint cables. This can result in increased difficulties regarding the lanyard pull and increased likelihood of restraint cable rupture during the time of inadvertent release.

Analysis Finding: Analysis shows that in the absence of any additional force, the pendulous motion of the gondola had the potential to produce significant forces in the restraint cable system, which may have added to the inability to effect payload release at the release attempt.

Analysis Finding: Analysis shows that in the absence of any additional force, the pendulous motion of the gondola had the potential to produce significant forces in the restraint cable system, which may have contributed to the forces causing restraint cable rupture.

3.4.2.3 Analysis Results for Hypothetical Case of No Loss of Traction at PET=62 sec

During the process of maneuvering the launch vehicle for launch attempt the vehicle lost traction. This occurred at about 62 seconds. Because this caused a delay in the acceleration of the crane, an analysis was completed to determine if assuming good traction throughout would have likely improved the launch release situation.

The dynamic analysis tool was used to simulate the hypothetical case. As expected, assuming better traction improved the launch situation due to the increased average velocity of the launch vehicle. Significant improvement was achieved by maintaining traction and also taking a better path (more toward the South). For this condition, by 86 seconds, the estimated release lanyard force is less than 100 lb.

Analysis Finding: It is unlikely that improved traction would have reduced the release lanyard pull force to acceptable levels, but analysis is inconclusive.

Analysis Finding: The combination of better traction and a better steering path for the launch vehicle would have likely increased the chances of a successful release.

Analysis Finding: Given the initial wide right turn and correcting left turn, in all cases the launch vehicle would have been outside the Category A hazard area by the time a launch could have been affected.

3.4.2.4 Analysis of Photo and Video Evidence and Correlation with Dynamic Analysis

The MIB obtained six video recordings and approximately one thousand photographs of the NCT launch attempt. In order to help construct the timeline and analyze the events of the launch attempt, all six video sources were time-synchronized by identifying key and common features and landmarks. The MIB produced several composite video compilations of the entire timeline sequence. The catenary predictions from the dynamic simulation were then correlated with the same events as observed in both the video compilations and the photographic evidence. This correlation was excellent and demonstrated that the dynamic simulation accurately predicted the catenaries for the timeline events. (Figures 46 through 51) show the video evidence and positions of the balloon and launch vehicle for 6 key events.

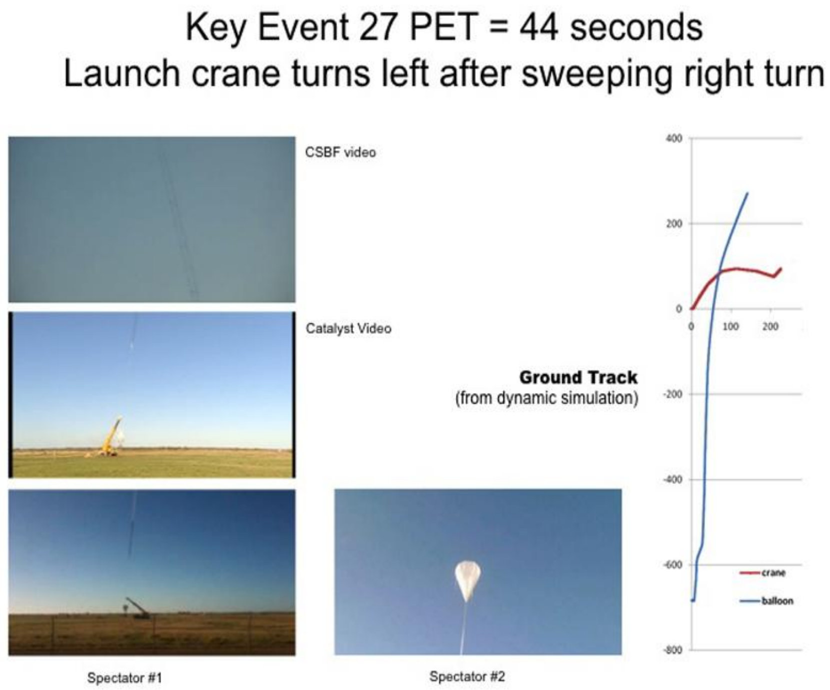


Figure 46. Video Evidence and Ground Tracks for Key Event 27

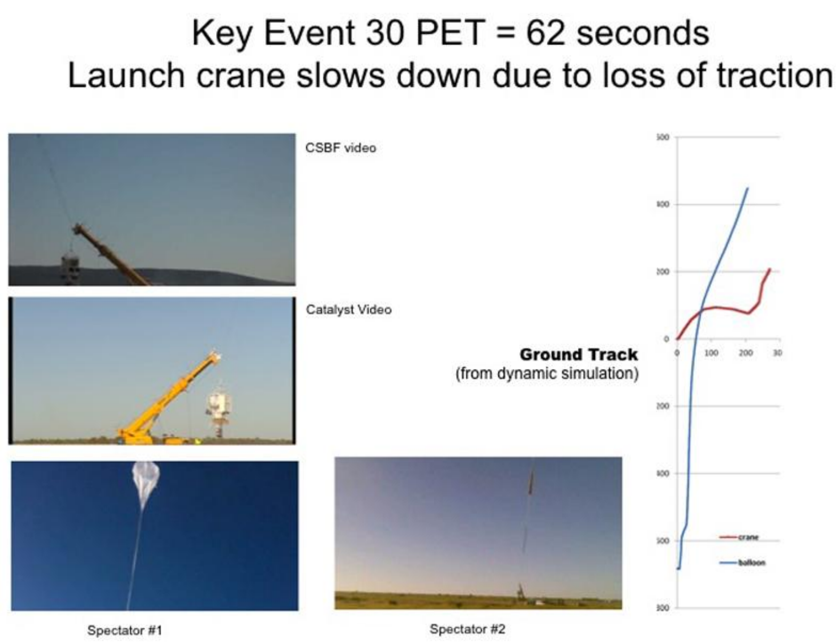


Figure 47: Video Evidence and Ground Tracks for Key Event 30

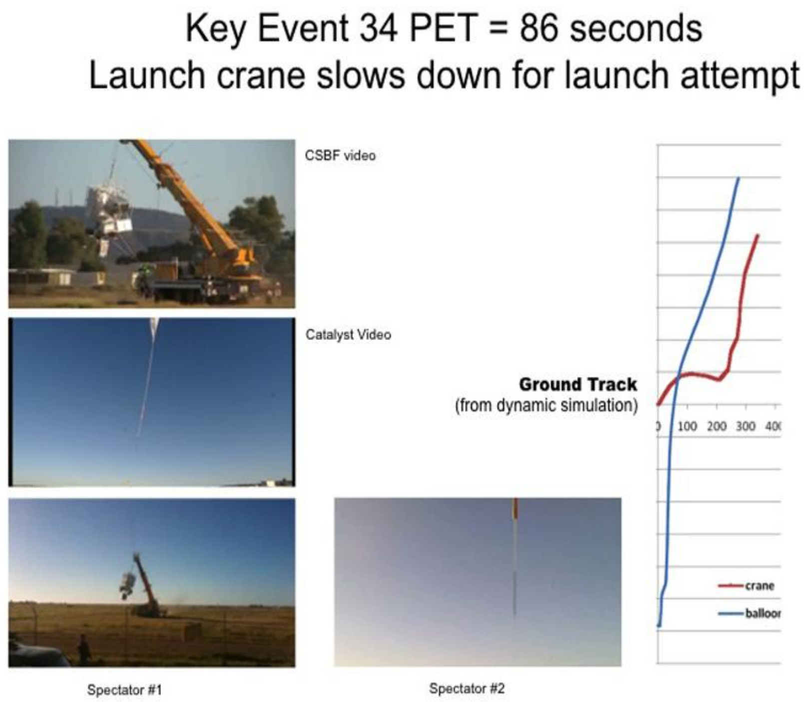


Figure 48. Video Evidence and Ground Tracks for Key Event 34

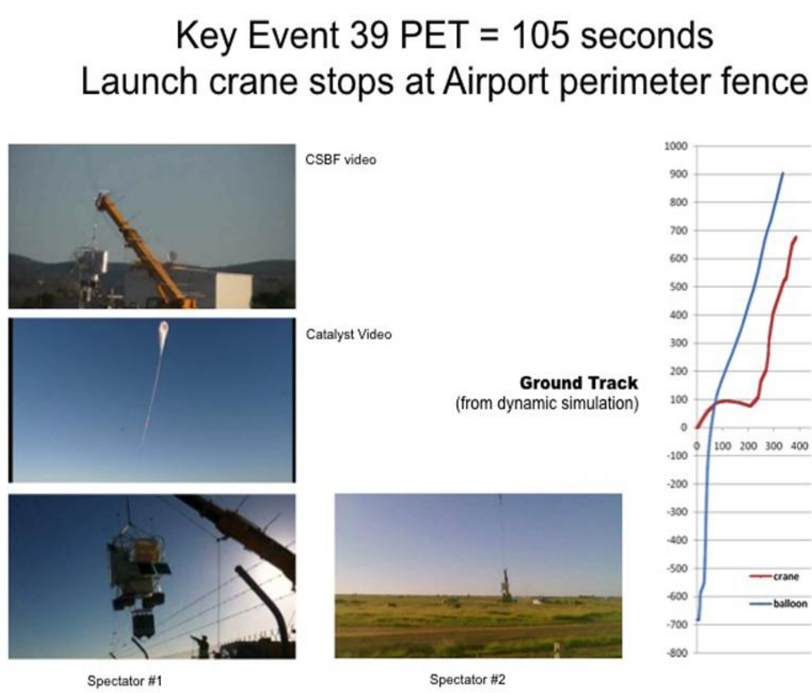


Figure 49. Video Evidence and Ground Tracks for Key Event 39

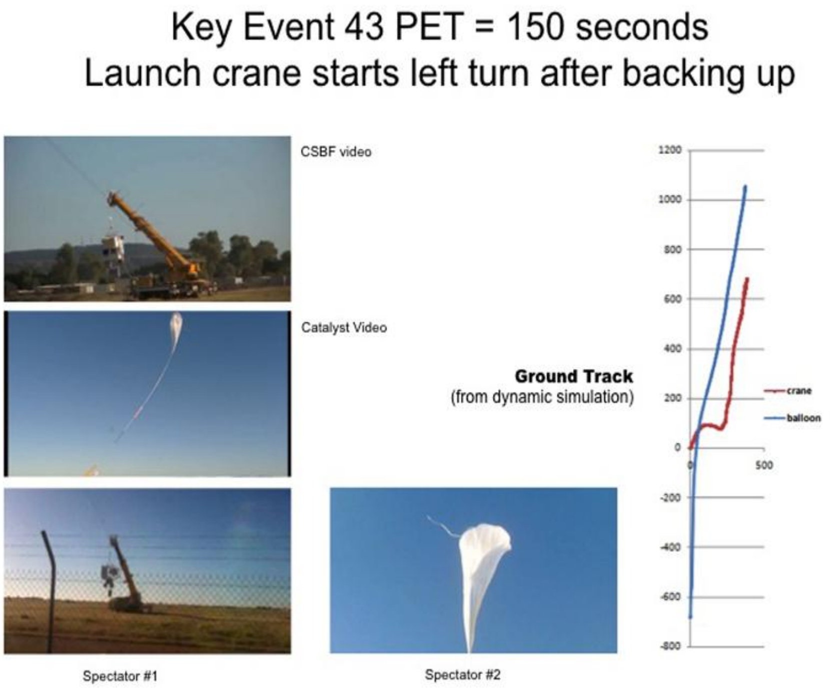


Figure 50. Video Evidence and Ground Tracks for Key Event 43

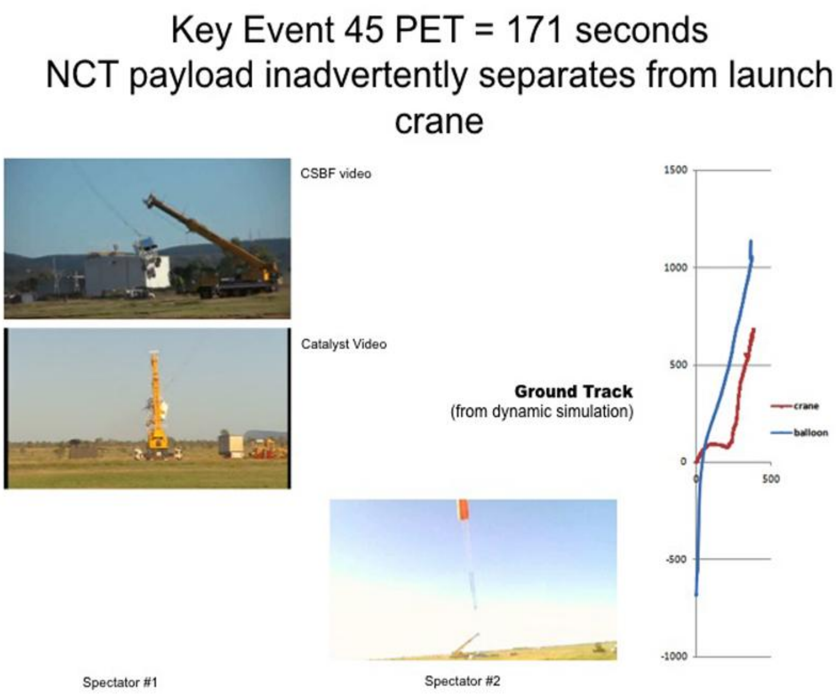


Figure 51. Video Evidence and Ground Tracks for Key Event 45

3.4.3 Safety Requirements Assessment

The MIB conducted a Safety Requirements Assessment to determine areas where the applicable safety requirements were either overlooked (constituting non-compliance) or implemented poorly (constituting nonconformance with intent of the requirement). The MIB examined the following areas: Personnel Protection, Hazard Analyses, Ground Safety Plan, Hazardous Operations, Safety Oversight, Past Safety Audits, Crane Operations, Safety Independence, Operator Training, and Effectiveness of the Mishap response plan. The requirements documentation examined for compliances included, but were not limited to: NASA Policy Directives; NASA Procedural Requirements; NASA Standards; NASA Range Safety Manuals; GSFC/Wallops Procedural Requirements; Suborbital and Special Orbital Project Balloon Procedures and Guidelines; Program Office Procedures and Guidelines; WFF Safety Office Procedures and Guidelines; WFF Safety Office work instructions; and the CSBF Contract documentation.

These requirements were compared with the information gathered through review of GSFC/WFF and CSBF program documentation and records, witness statements, witness interviews, video documentation, and still photography.

The findings of the requirements assessment are provided in Appendix D. Matrices mapping the results of this assessment to the root cause and intermediate cause findings, along with listings of the referenced safety requirements and excerpts of referenced requirements, are located in Appendix D of this report. The results of this safety assessment were used as inputs to the Root Cause Analysis that is described in Section 3.6.

3.4.4 Human Error Assessment

The Alice Springs balloon launch mishap was assessed for human events and conditions that may have caused or contributed to the incident. The purpose of this assessment was to generate recommendations that will reduce human error and/or mitigate the negative consequences of human actions.

This assessment was based on the evidence collected via interviews as well as documentation, photographic, and video evidence. It was determined that internal shaping factors such as human limitations of physical strength, division of attention, and mental workload capacity were contributors as well as external factors including deficiencies in information (availability, clarity, quality) and designation of tasks, design of equipment, enforcement of rules, regulations and policies, and conflict of goals. The highlighted human events are taken from the E&CFT and are categorized for the purpose of this assessment by action type (error of omission, error of commission, or failed or changed state) and error type (perception, interpretation, decision-making, or action execution or failure). Next, potential barriers and control methods are evaluated to determine why they either failed or did not exist. The recommendations generated are designed to prevent similar occurrences and are closely related to and mapped to the general findings of the report found in Section 1. The results of the Human Error Assessment can be found in Appendix D-3.

3.5 Timeline

While gathering data, the MIB developed and maintained a timeline of the events leading up to the mishap. This timeline initially started with the events immediately prior to the mishap. As the RCA progressed, the time line expanded further back in time to include events that were related to the intermediate causes and the proximate causes. The MIB time-synchronized all six video evidence recordings to help determine the PET of events following spool release. The detailed timeline is shown below in Table 3. Significant key events from this timeline are shown overlaid with the launch vehicle's GPS track in Figure 52.

Table 3—Detailed Timeline

Date	Time	PET	Name	Description
4/29/2010	02:18:00 AM		Event 1	PIBAL run accomplished by meteorologist.
4/29/2010	02:30:00 AM		Event 2	CSBF team reports to station at Alice Springs Australia to attempt NCT balloon launch
4/29/2010	02:59:00 AM		Event 3	Meteorologist runs another PIBAL.
4/29/2010	02:59:00 AM		Event 4	PIBAL readings indicate winds resulting in Launch Director determining a 110 degree balloon layout.
4/29/2010	03:00:00 AM		Event 5	NCT payload picked up and transported to launch vehicle.
4/29/2010	03:30:00 AM		Event 6	Launch vehicle and balloon train rolled out to flight line.
4/29/2010	03:32:00 AM		Event 7	PIBAL run accomplished.
4/29/2010	04:18:00 AM		Event 8	PIBAL run accomplished.
4/29/2010	04:48:00 AM		Event 9	PIBAL run accomplished
4/29/2010	05:18:00 AM		Event 10	PIBAL run accomplished and NOTAM updated to reflect a 1 hour delay
4/29/2010	05:54:00 AM		Event 11	Launch Director requests the balloon to be laid out for launch.
4/29/2010	05:54:00 AM		Event 12	PIBAL run accomplished
4/29/2010	06:30:00 AM		Event 13	PIBAL run accomplished
4/29/2010	06:43:00 AM		Event 14	PIBAL run accomplished.
4/29/2010	06:43:00 AM		Event 15	Inflation of the balloon started.
4/29/2010	06:43:00 AM		Event 16	Launch Director notices spectators in the downwind flight path and request their relocation.
4/29/2010	07:40:00 AM		Event 17	PIBAL run accomplished.
4/29/2010	07:40:00 AM		Event 18	PIBAL run indicated a wind shift to 121 degrees.
4/29/2010	07:50:00 AM		Event 19	Balloon inflation completed.
4/29/2010	07:50:00 AM		Event 20	Collar 1 and Collar 2 manned.
4/29/2010	07:50:00 AM		Event 21	Site manager requested ATC clearance to launch.
4/29/2010	08:02:00 AM		Event 22	Clearance received from ATC for launch.
4/29/2010	08:05:19 AM	0 sec.	Event 23	Spool released to launch balloon.
4/29/2010	08:05:29 AM	10 sec.	Event 24	Launch Director orders launch vehicle driver to drive forward making a sweeping right 90-degree turn.

Date	Time	PET	Name	Description
4/29/2010	08:05:56 AM	37 sec.	Event 25	Collar 1 called for collar release.
4/29/2010	08:05:58 AM	39 sec.	Event 26	Collar 2 called for collar release
4/29/2010	08:06:04 AM	45 sec.	Event 27	Launch vehicle comes to a stop.
4/29/2010	08:06:05 AM	46 sec.	Event 28	Voice confirmation of “collar off”
4/29/2010	08:06:06 AM	47 sec.	Event 29	Launch Director orders launch vehicle driver to turn left to align with balloon’s flight path
4/29/2010	08:06:21 AM	62 sec.	Event 30	Vehicle slows down due to loss of traction and then speeds up to catch the balloon.
4/29/2010	08:06:38 AM	79 sec.	Event 31	Launch vehicle breaches the Category A hazard area.
4/29/2010	08:06:45 AM	86 sec.	Event 32	Launch vehicle decelerates for launch attempt.
4/29/2010	08:06:46 AM	87 sec.	Event 33	Team member controlling the taglines to the payload loses hold of the payload restraint straps and the payload starts swinging wildly.
4/29/2010	08:06:46 AM	87 sec.	Event 34	First visible launch attempted by pulling on the release cable without effect.
4/29/2010	08:06:48 AM	89 sec.	Event 35	Second visible launch attempted by pulling on the release cable without effect.
4/29/2010	08:06:50 AM	91 sec.	Event 36	Launch vehicle comes to a stop.
4/29/2010	08:06:52 AM	93 sec.	Event 37	Launch Director orders launch vehicle driver to go forward to catch the balloon.
4/29/2010	08:06:53 AM	94 sec.	Event 38	Launch vehicle lost traction while accelerating.
4/29/2010	08:07:04 AM	105 sec.	Event 39	Launch vehicle stops at airport perimeter fence.
4/29/2010	08:07:04 AM	105 sec.	Event 40	Due to spectators being in the downwind path and close proximity Launch Director cannot order flight termination.
4/29/2010	08:07:17 AM	118 sec.	Event 41	Launch vehicle starts moving in reverse.
4/29/2010	08:07:47 AM	148 sec.	Event 42	Launch vehicle loses traction in soft dirt and cannot continue in reverse.
4/29/2010	08:07:49 AM	150 sec.	Event 43	Launch Director orders the launch vehicle driver to pull forward making a left 90-degree turn.
4/29/2010	08:08:10 AM	171 sec.	Event 44	Safety restraint cables snapped.
4/29/2010	08:08:10 AM	171 sec.	Event 45	Uncontrolled release of the Nuclear Compton Telescope payload resulting in the payload impacting the ground, then a privately owned vehicle and nearly causing injury or death to public spectators. (Undesired Outcome)
4/29/2010	08:08:10 AM	171 sec.	Event 46	Abort called.
4/29/2010	08:08:16 AM	177 sec.	Event 47	Payload impacted the POV
4/29/2010	08:08:19 AM	180 sec.	Event 48	Abort accomplished.
4/29/2010	08:08:38 AM	199 sec.	Event 49	Parachute and flight train come to rest on ground
4/29/2010	08:10:00 AM	281 sec.	Event 50	Final PIBAL run accomplished after abort.

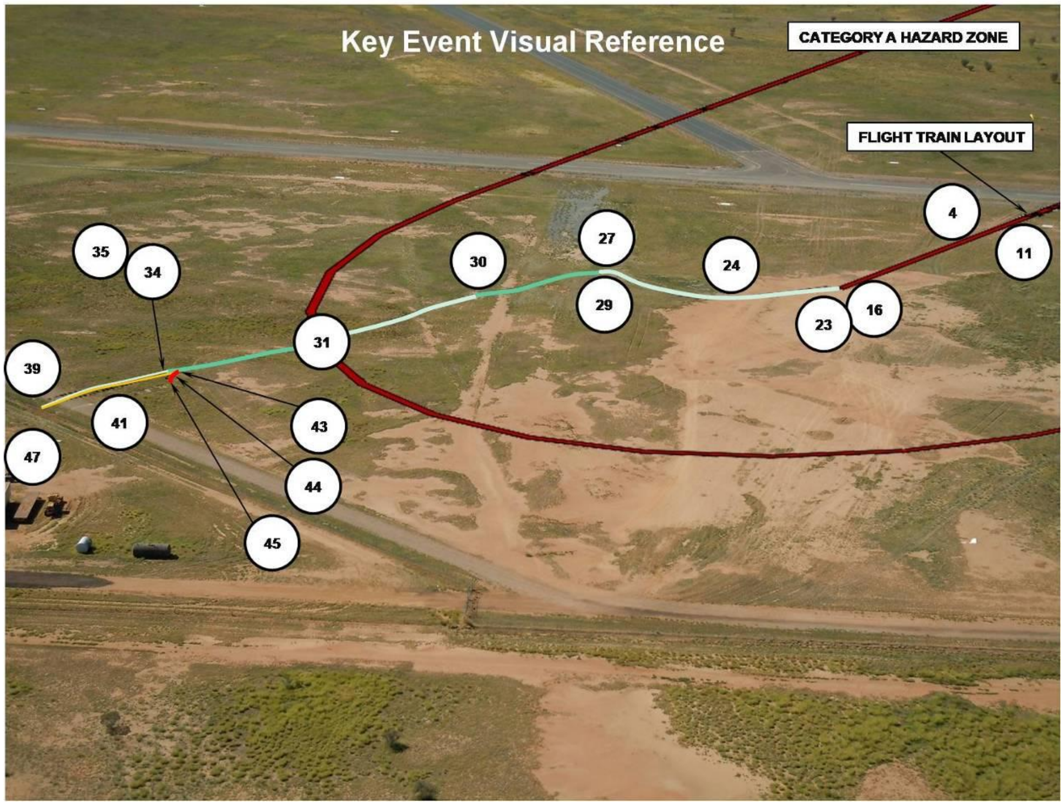


Figure 52. Significant Key Event Visual Reference

3.6 Root Cause Analysis

The Root Cause Analysis (RCA) process was aided by the use of the Root Cause Analysis Tool, known as the RCA Tool, version 2.0.0.22, developed by the NASA HQ Office of Safety and Mission Assurance. The MIB accomplished the RCA by first determining: (1) what was unknown, (2) what data were needed, (3) what was thought to be known, and 4) what was definitely known. Following this process, a timeline of events leading up to the mishap was developed and maintained. Next an FT was developed that outlined all known possible causes of the mishap.

As data were gathered, elements on the FT were ruled out if they could not be substantiated, or ruled-in if there were sufficient supporting data, and the timeline was subsequently updated. All of the substantiated causal events, conditions, and contributing factors that were ruled-in were reflected on an E&CFT.

The tree was expanded by continually asking “why” for each element above until all data were exhausted. The RCA Tool produced an .rca file for the mishap which contains all of the data about the events and conditions. The .rca file for this mishap RCA will be stored in IRIS along with this report.

3.6.1 Identification of the Undesired Outcome

The MIB defined the Undesired Outcome as follows: **Unintended release of the Nuclear Compton Telescope payload caused damage to private vehicles, and nearly caused death or injury to the general public**. This defined the scope of the investigation.

3.6.2 Fault Tree Analysis

A fault tree analysis (FTA) was accomplished as part of the RCA. The FT was used to capture and identify all known possible causes of the mishap.

Each element of the FT was entered in actor-verb descriptor format. As data were gathered, elements on the FT were ruled out if they could not be substantiated, and such elements are indicated in Section 3.6.4.

All causes, events, conditions, and contributing factors that were ruled-in were carried over on an E&CFT. All elements on the E&CFT were considered causal to the undesired outcome. The FT can be viewed by opening the .rca file in the RCA Tool.

3.6.3 E&CFT Analysis

An event and causal factor analysis was accomplished as part of the RCA. Once all the causal events, conditions, and contributing factors were determined on the FT and supported with data, an E&CFT was produced. The tree was expanded by continually asking "why" for the elements above. This process ended when sufficient data were no longer available, or when the answer to the "why" question reached outside of NASA and NASA support contractors. During the investigation, the MIB identified three Undesired Outcomes, each of which would have been sufficient to convene an independent Mishap Investigation Board. Based on the instructions in the appointment letter, the MIB focused on the undesired outcome that was primarily associated with the safety of the public, and heretofore will be discussed throughout this section as the Primary Undesired Outcome (PUO). Two Secondary Undesired Outcomes (SUOs) were identified and will be addressed in Section 3.6.4.

The MIB identified three Proximate Causes that resulted in the Primary Undesired Outcome: **Unintended release of Nuclear Compton Telescope payload caused damage to private vehicles, and nearly caused death or injury to the general public (PUO)**. Figure 53 shows the Primary Undesired Outcome and Proximate Causes.

The Proximate Causes are the events that occurred, including any condition(s) that existed immediately before the Primary Undesired Outcome that directly resulted in the occurrence of the Primary Undesired Outcome and, if eliminated or modified, would have prevented the Primary Undesired Outcome. These are also known as the direct causes. First, **the payload separated from the launch vehicle (P1)**, then the **released payload was dragged downwind by the balloon (P2)**, and the condition existed that **people in the general public were in the projected flight path (P3)**.

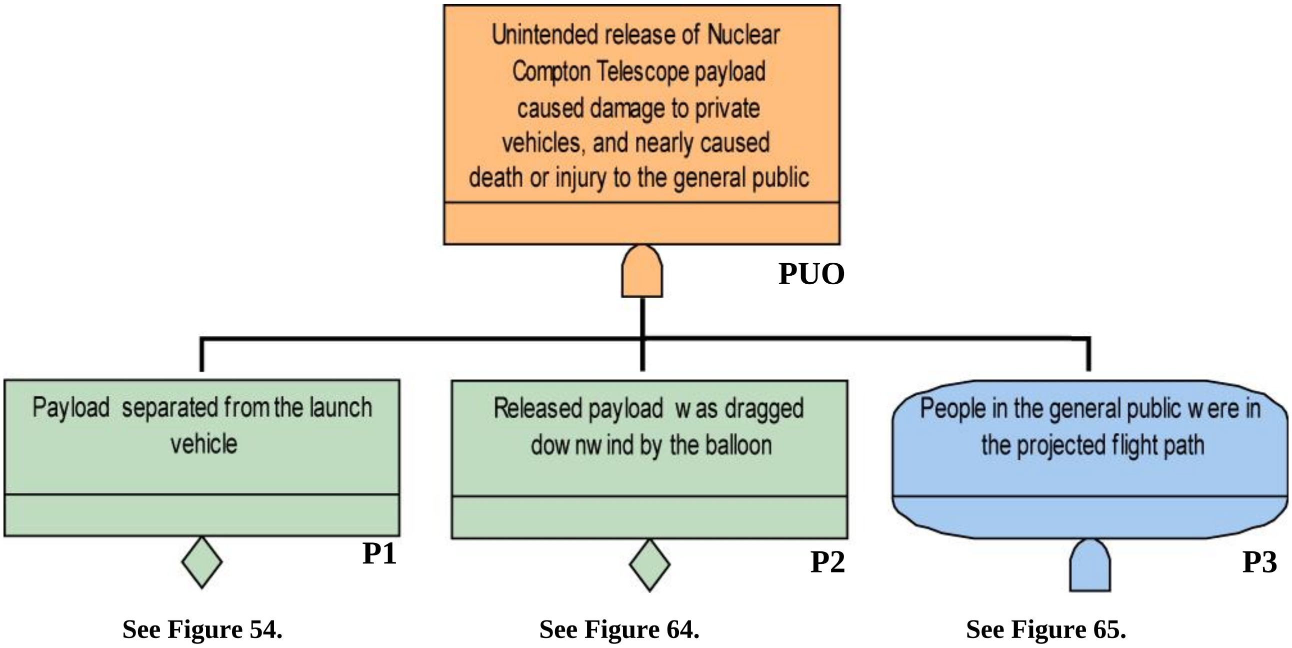
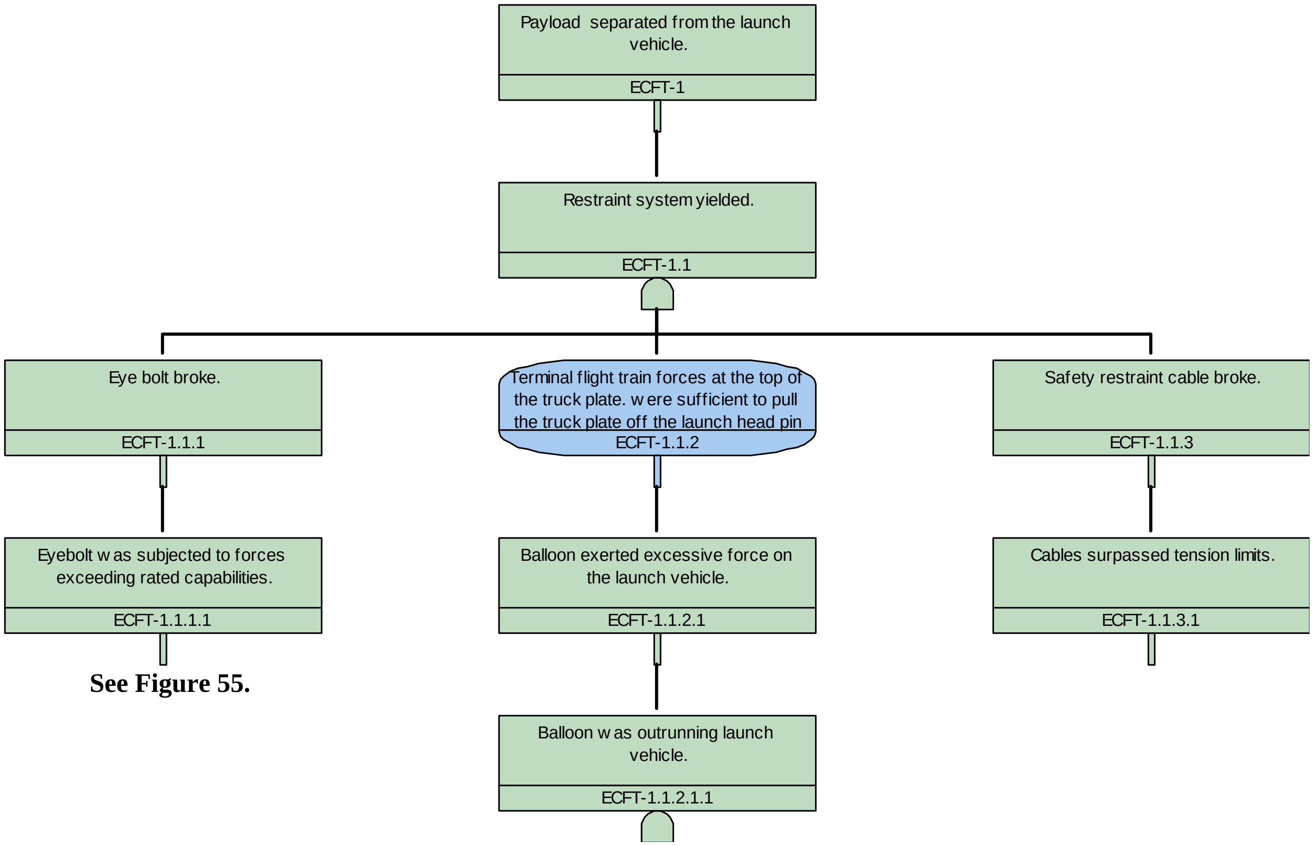


Figure 53. Primary Undesired Outcome and Proximate Causes



See Figure 55.

See Figure 57.

Figure 54. Payload Separated From Launch Vehicle

Per video and witness interview, the payload unexpectedly separated from the launch vehicle after several vehicle maneuvers at Alice Springs Airport. The factors leading to the payload separation are as follows:

A. Eyebolt broke. This was verified by inspection of the impounded hardware. The eyebolt served to hold the safety restraint cable on the truck plate in order to secure the payload to the launch vehicle. According to photographic evidence and analysis, stress on the bolt caused the bolt to exceed its rated capabilities resulting in a structural failure.

B. Based on video evidence and analysis, terminal flight train forces at the top of the truck plate were sufficient to pull the truck plate off the launch head pin. The truck plate serves as a mechanical interface to secure the payload to the crane head. The alignment of the balloon relative to the launch vehicle combined with the wind speed and direction were sufficient to remove the truck plate from the launch head pin.

    1. The balloon exerted excessive force on the launch vehicle. Based on video evidence, the distance (projected on the ground) between the balloon and the launch vehicle caused a significant horizontal force on the launch vehicle.

a. According to video evidence, the balloon was outrunning the launch vehicle and the challenge to catch it was becoming too great.

C. Safety restraint cable broke. This was verified by inspection of the impounded hardware. The safety restraint cable was used to secure the payload to the launch vehicle. Based on video evidence, test results and analysis, the board determined that the tension in the cable surpassed the cable's rated limits and subsequently the cable broke. The causes follow the same line of reasoning for item A. above and will not be repeated in the report.

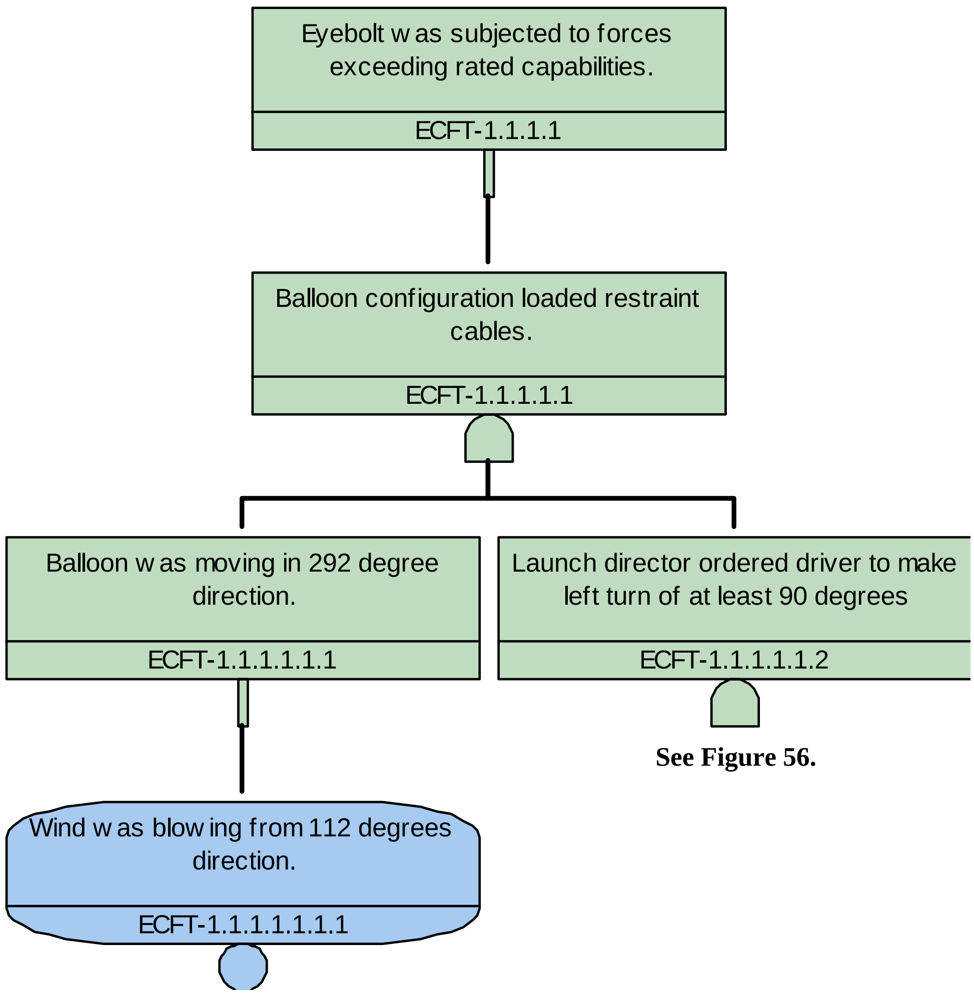


Figure 55. Eyebolt Was Subjected to Forces Exceeding Rated Capabilities

A. According to video evidence, testing, and analysis, the balloon configuration loaded the restraint cables. The relative position of the balloon to the launch vehicle placed a significant tensile load on the restraint cables that secured the payload to the launch vehicle.

   1. According to written meteorology records, the balloon was moving in a 292-degree direction, relative to magnetic north, along with the direction of the wind.

   2. According to video evidence and interview, the launch director ordered the driver to make a left turn of at least 90 degrees. This motion directly opposed the balloon motion, maximizing the stress applied to the system used to secure the payload to the launch vehicle.

      a. According to meteorology records, the wind was blowing from the 112 degree direction.

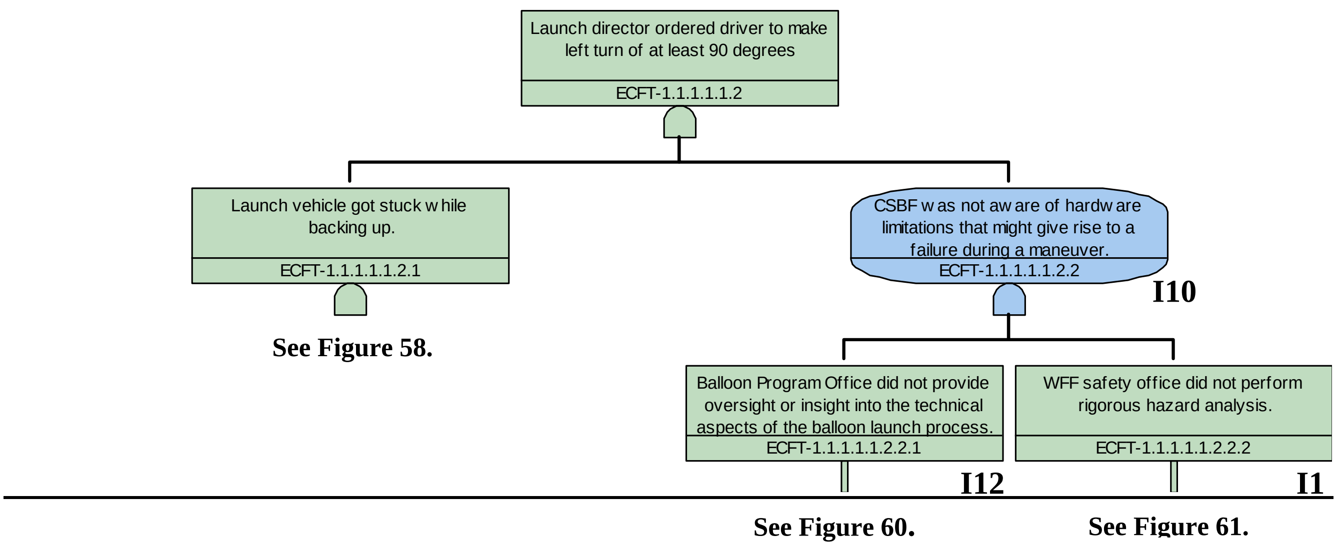


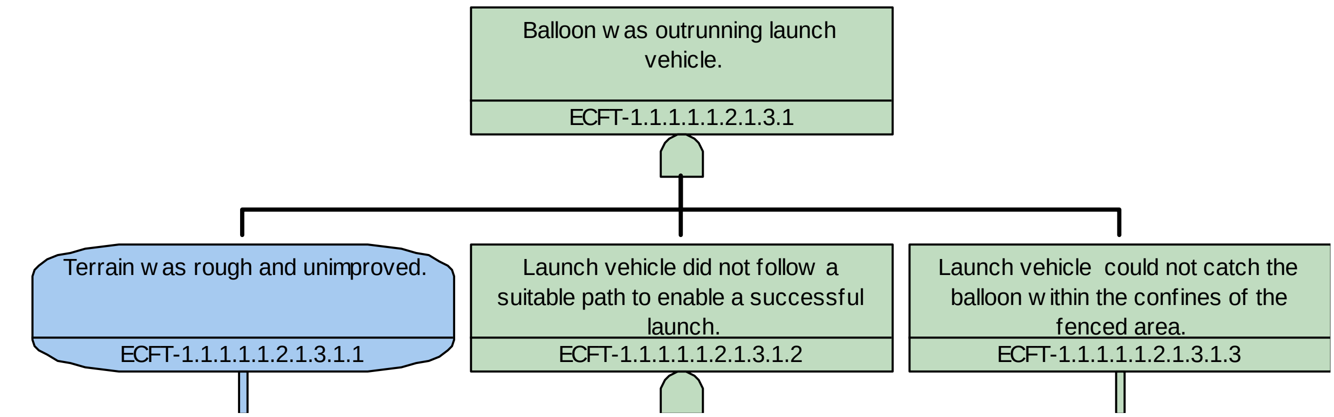
Figure 56. Launch Director Ordered Driver to Make a Left Turn of at Least 90 Degrees

A. Video evidence and interviews indicated that the launch vehicle got stuck while backing up. The wind and terrain prevented the vehicle from moving a safe distance from the spectators.

B. Based on interviews and the lack of specific reference in the hardware documentation evidence received by the board, it became apparent that CSBF was not aware of hardware limitations that might give rise to failure during a maneuver. There were no limitations put on what types or durations of maneuvers under what wind or terrain conditions might cause the hardware to exceed its strength limitations. **Intermediate Cause I10**

   1. Interview evidence indicated that the BPO did not provide oversight or insight into the technical aspects of the balloon launch process. The technical implementation is left to CSBF through the performance-based contract. **Intermediate Cause I12**

2. Review of documentation indicates that WFF Safety Office did not perform a rigorous hazard analysis. WFF Safety Office is responsible, through RSM 2002 Rev B, for developing the balloon ground safety plan, which includes the hazards in the ground process, including launch. Several hazards are mentioned, but for the most part, the hazards are just those specifically identified with individual payloads, plus the pyrotechnic hazard. **Intermediate Cause I1**.



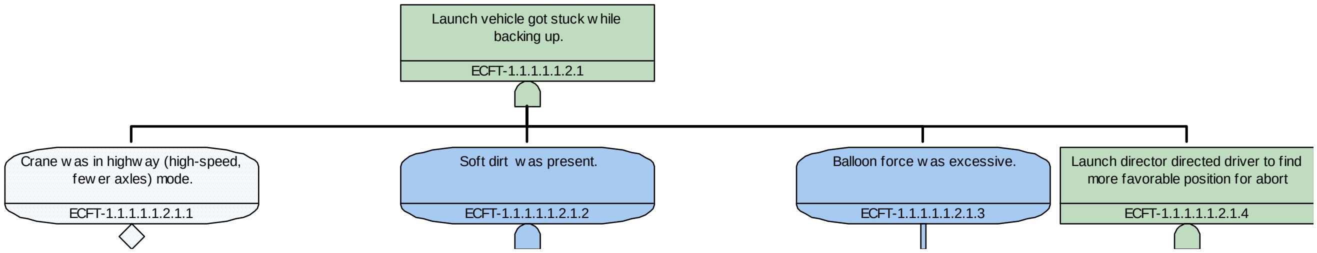
See Figure 63. **See Figure 62.**

Figure 57. Balloon Was Outrunning the Launch Vehicle

A. The terrain was rough and unimproved. Interviews and site inspection indicate that the terrain was loose and sandy in spots, not an ideal setting for traction.

B. The launch vehicle did not follow a suitable path to enable a successful launch. Video evidence indicates that the vehicle took inefficient and, in some cases, overly sharp turns to catch the balloon.

C. Launch vehicle could not catch the balloon within the confines of the fenced area. This is due to the fact that the flight train layout (direction, in particular) restricted the range of motion for the launch vehicle (block not shown). This is indicated from video evidence.



See Figure 85. **See Figure 59.**

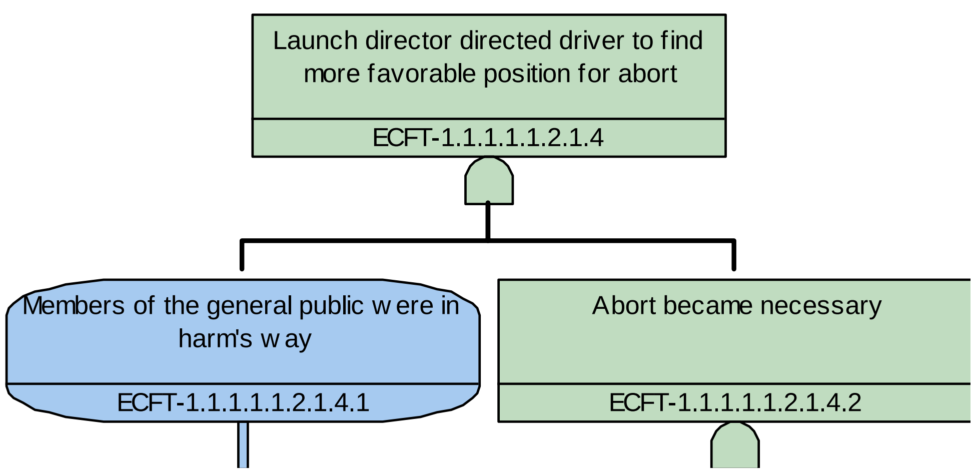
Figure 58. Launch Vehicle Got Stuck While Backing Up

A. The crane was in highway (high-speed, two-axle) mode, according to information provided from the BPO. This enabled higher speed motion with a better chance to catch the balloon while it was ahead, but there was accordingly less traction when really needed. Strictly speaking, this is a contributing factor, but the fact is that whatever mode the crane was in would have been a contributing factor and there was no determination by the board that any possible mode would have made more of a contribution to this mishap.

B. Soft dirt was present, based on on-site inspection and interviews. This permitted less traction when there was high tension from the balloon. The rest of this branch is not shown, but the logic leads to a combination of recent rainy weather and Root Cause R6.

C. Balloon force was excessive. The vehicle could not overcome the force with the traction available. This was based on analysis and simulation.

D. Launch director directed driver to find more favorable position for abort, based on interview and video evidence. He did not want to abort with people ahead, in-line with the balloon.



See Figure 65. **See Figure 82.**

Figure 59. Launch Director Directed Driver to Find a More Favorable Position for Abort

A. People in the general public were in harm's way. People behind the fence were at risk due to the hazard of falling balloon and flight train hardware.

B. Abort became necessary. It became clear that based on all of the factors and previous attempts to launch that there would not likely be a chance for successful launch.

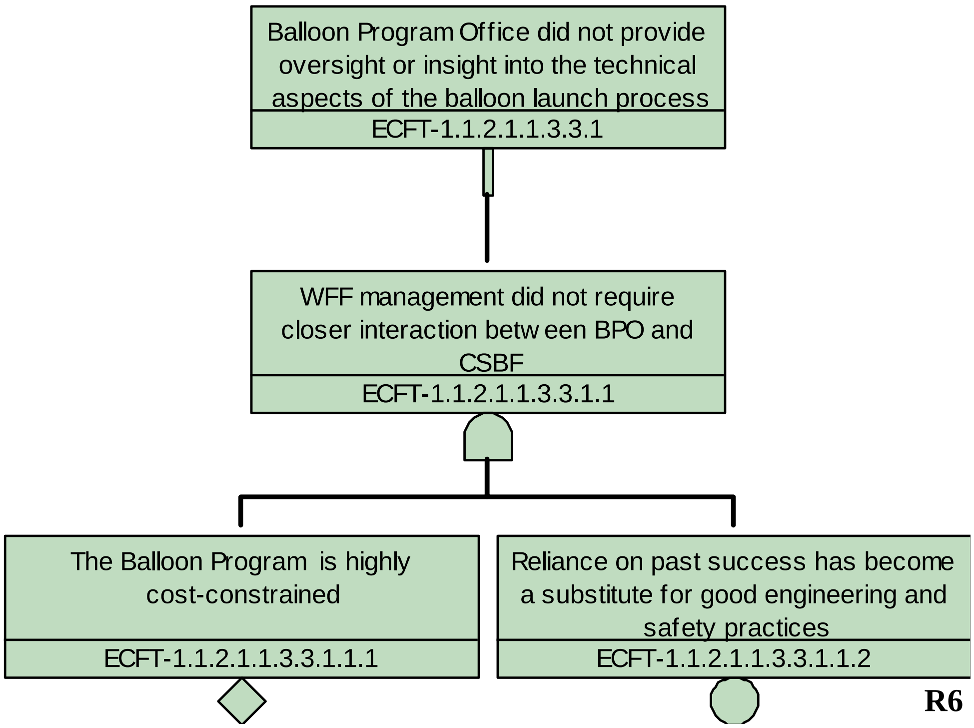


Figure 60. Balloon Program Office Did Not Provide Oversight or Insight Into the Technical Aspects of the Balloon Launch Process

A. WFF management did not require close interaction between BPO and CSBF. This is evident from interviews.

   1. The Balloon Program is highly cost-constrained. Interviews have indicated the perception that too much burden on the balloon program with additional requirements "will kill the balloon program."

   2. Reliance on past success has become a substitute for good engineering and safety practices. Interviews have indicated a consistent theme that the balloon program success rate has been sufficiently high, so therefore there have not been problems to correct or additional scrutiny required. **Root Cause R6.**

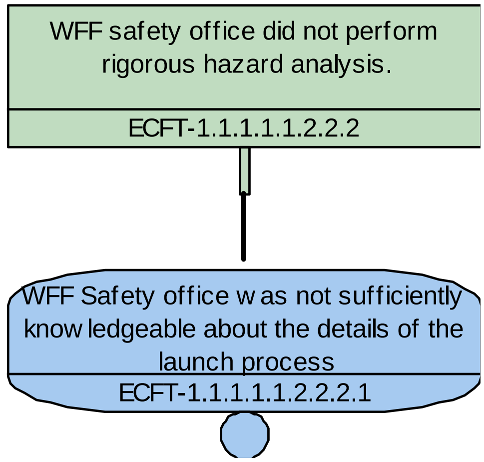
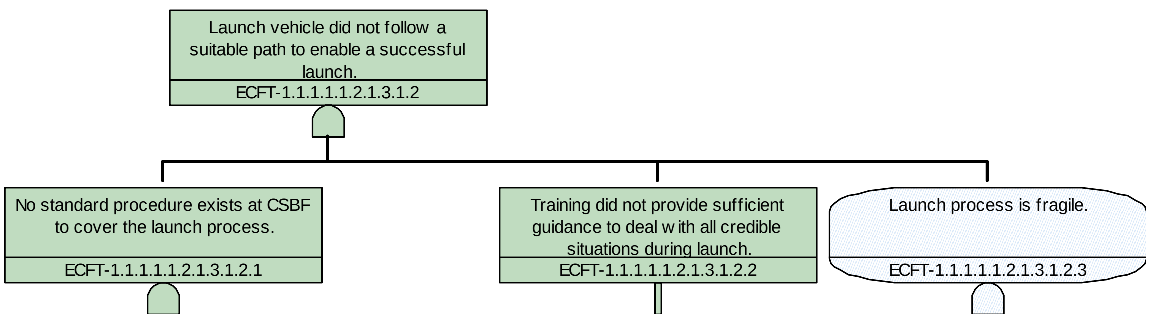


Figure 61. WFF Safety Office Did Not Perform Rigorous Hazard Analysis

A. WFF Safety Office was not sufficiently knowledgeable about the details of the launch process. Interviews and documentation indicate that there is no one in the office cognizant of the details of the operations or hazards involved in launching balloons. **Root Cause R3**.



See Figure 69. **See Figure 90.**

Figure 62. Launch Vehicle Did Not Follow a Suitable Path to Enable a Successful Launch

A. No standard procedure exists at CSBF to cover the launch process. After reviewing all of the procedural documentation, no prescribed process was found for launching the balloon and there was minimal information provided in the documentation for on-the-job training.

B. Training did not provide sufficient guidance to deal with all credible situations during launch. Interviews indicated that no specific training is provided to deal with anomalies or failed launch attempts. After this point, the logic follows the path shown in Figure 60 and will not be repeated in the report.

C. Launch process is fragile. Without clear definition and procedures for dealing with anomalies, the launch process is highly sensitive to human error and general awareness as well as environmental conditions, such as terrain and weather. This is evident from interviews and documentation review.

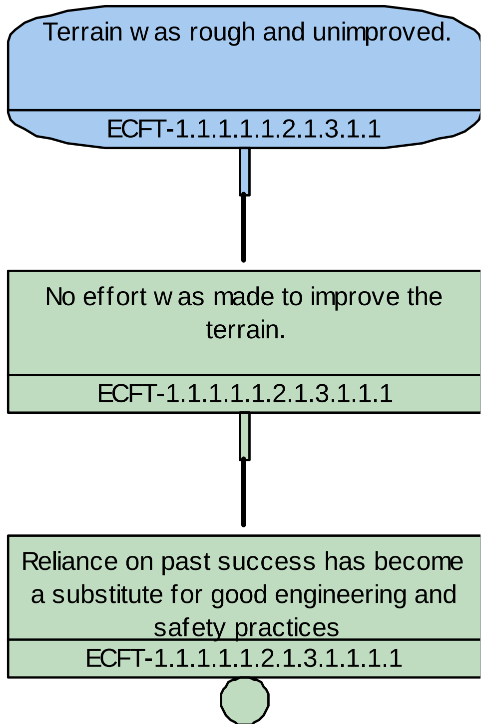
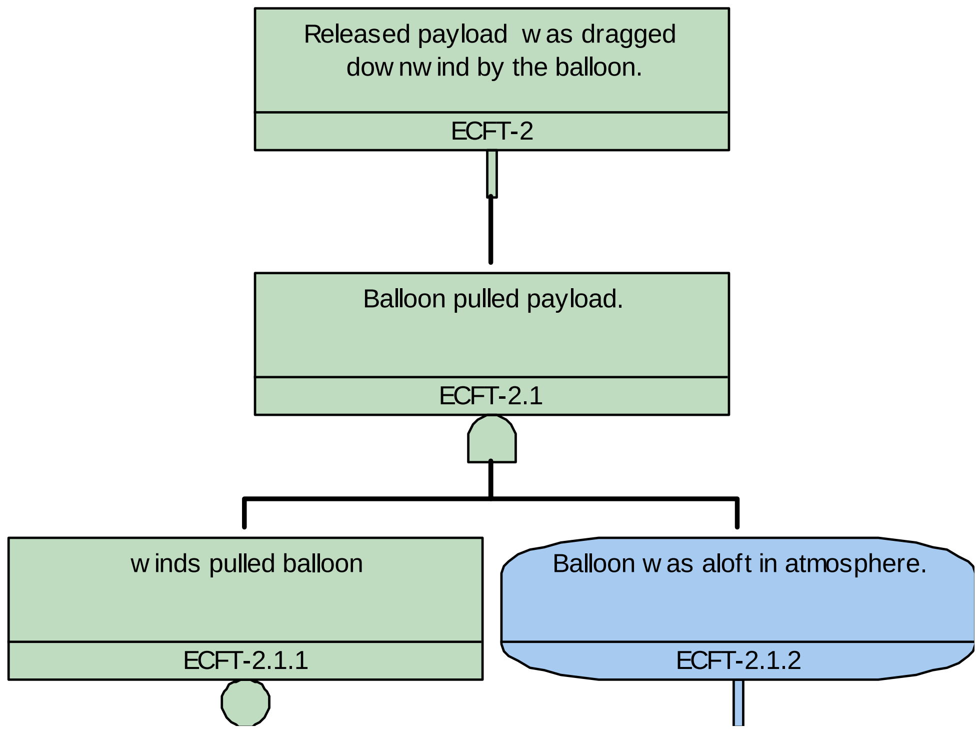


Figure 63. The Terrain Was Rough and Unimproved

A. No effort was made to improve the terrain. Interviews indicate that requests were made to improve the terrain but that the requests never made it to NASA officials.

   1. Reliance on past success has become a substitute for good engineering and safety practices. **Root Cause R6**.



See Figure 67.

Figure 64. The Released Payload Was Dragged Downwind by the Balloon

Video evidence indicates that the payload, having been separated from the launch vehicle after the events described in Figure 54, was dragged along the ground, pulled by the balloon under and in the direction of the prevailing wind.

A. The balloon pulled the payload, as indicated by video evidence.

   1. Winds pulled the balloon, as indicated by video evidence as well.

   2. The balloon was aloft in the atmosphere. Filled with helium, the balloon continued its motion with the prevailing winds, as indicated by video evidence.

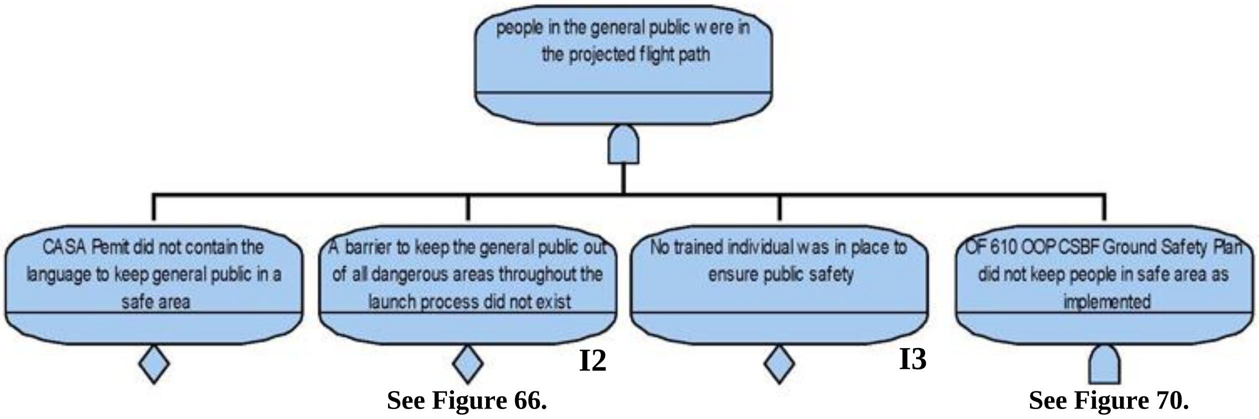


Figure 65. The General Public Was in the Projected Flight Path

An unusual situation occurred in the Balloon mishap at Alice Springs in which people of the general public, namely spectators, were in the projected flight path. The conditions leading to this were in essence a collection of failed or missing (but perhaps expected or perceived) barriers and controls, described as follows. This situation is indicated by video and photographic evidence, and interviews.

A. A permit was issued from the Australian Civil Aviation Safety Authority (CASA) that approved the area around Alice Springs airport for operation of a heavy balloon, based on documentation. The permit identifies an "approved area" as the Alice Springs airport, denoted by a single latitude/longitude point. This is ambiguous in and of itself in that there is a fence that goes around most of the airport, keeping unauthorized personnel out. There is an area where many of the people were and where the payload traversed after becoming separated from the launch vehicle that, oddly enough, is also the area that happens to be on the airport property but is outside of the security fence. While at first glance it appears that this permit is intended to establish a safe area to protect the public, the ambiguity of the boundaries of the area and the lack of specific reference to people in the area during the launch indicate that it does not address public safety.

B. There was no barrier in place to keep the general public out of all dangerous areas throughout the launch process. There was free access to a broad area downwind of the balloon to spectators and passers-by on public roads. There was a fence that kept unauthorized personnel out of an area downwind of the balloon but it still allowed people to be present within a hazardous area. This is indicated by video evidence, documentation, interview, and on-site assessment.
Intermediate Cause I2

C. No trained individual was independently in place to ensure range safety. The closest individual to a range safety officer was the campaign manager, but his primary responsibility was to ensure mission success and during launch he performed the call to drop the collars from the balloon. Hence, he lacked independence and did not have a priority allocation of time to focus on safety. The launch director had a general responsibility to halt the launch process if the situation appeared unsafe, but he lacked independence as well and his primary responsibility was to direct the launch vehicle to track the balloon and launch at the appropriate time. Evidence was in documentation and interview. This follows the same logic flow as in Figure 66 and will not be repeated here. **Intermediate Cause I3**

D. The Balloon Ground Safety Plan did not keep people in a safe area as implemented as evidenced by video, documentation, and interview. The ground safety plan identified a set of hazards, but did not identify the actual hazard that was involved in this mishap--that of a heavy payload with high potential and mechanical energy. The plan defined a hazard zone, but it was not clear whether the zone was fixed or moving. There were no markings for the zone; the crew identified the boundaries by landmarks in the terrain. There was nothing to prevent the launch vehicle or targets from breaching the zone and nothing to indicate when the zone would be breached. If the zone were moving, there would be no practical way to use it as a barrier. If the zone were fixed, the size wasn’t sufficient to cover the actual hazard area.

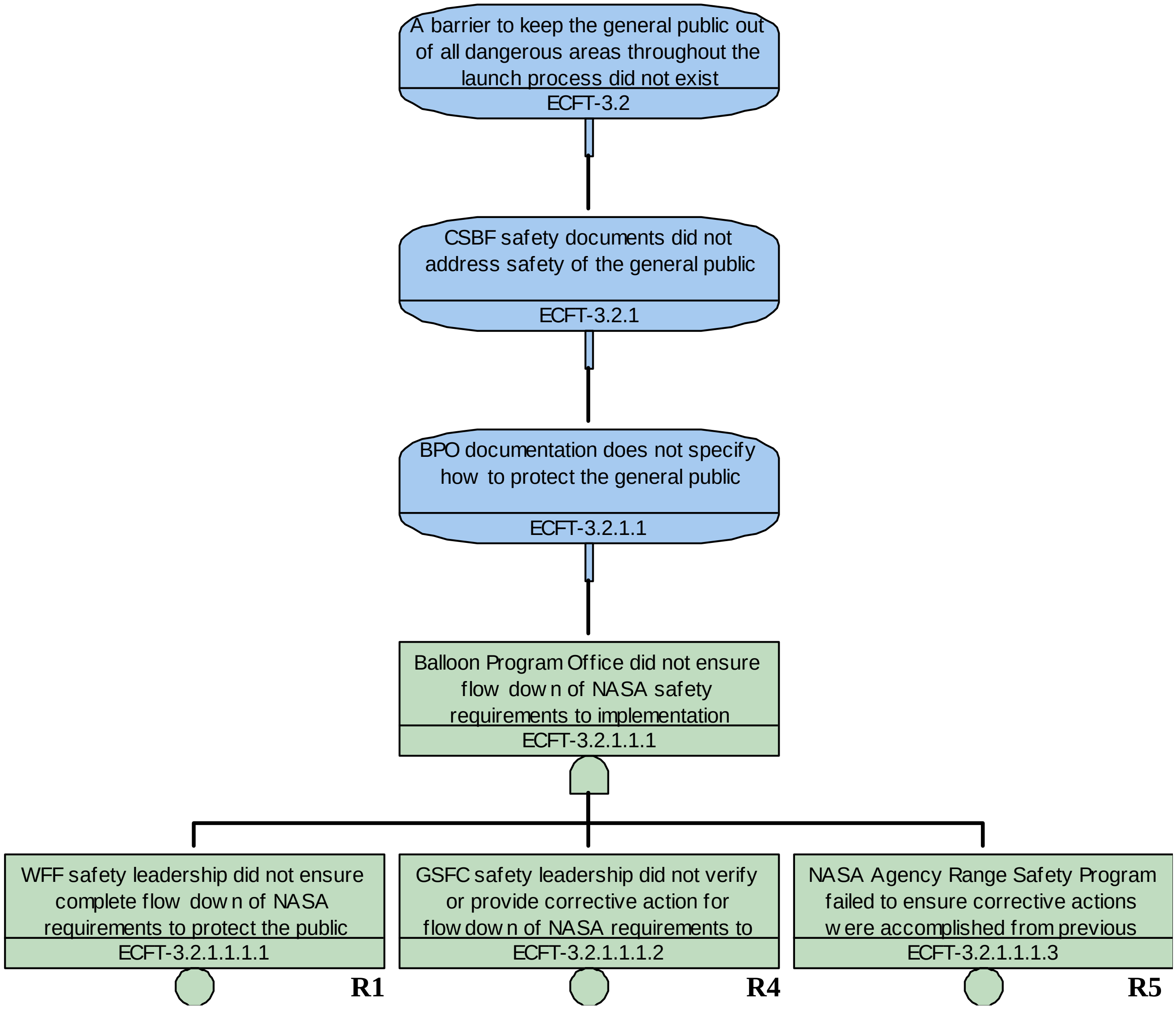


Figure 66. A Barrier to Keep the General Public Out of All Dangerous Areas Throughout the Launch Process Did Not Exist

A. Neither CSBF nor Balloon Program Office safety documents address safety of the general public. Safety documentation of CSBF and the BPO lacks any provision for dealing with spectators and passers-by during the launch process.

   1. BPO did not ensure flow down of NASA safety requirements to implementation. From RSM 2002 Rev B, BPO was delegated the responsibility to ensure safety requirements were implemented at the launch site, but lacking provisions for dealing with people appearing at the launch site indicates a failure to protect the general public due to the hazards associated with the launch process and the ability for people to gain proximity to the launch. This lack of adequate assurance of public safety amidst credible hazards contradicts the requirements in several NASA safety documents, to include NPR 8715.3 and NPR 8715.5.

a. WFF safety leadership did not ensure complete flow down of NASA requirements to protect the public. While the BPO is delegated the responsibility for implementation of safety requirements in balloon activities, WFF safety leadership, to include at a minimum the WFF Safety Office and Code 800 management was not aware that public safety was endangered during balloon activities. Such awareness would have likely prevented the undesired outcome. **(Root Cause R1)**

b. GSFC safety leadership did not verify or provide corrective action for flow down of requirements to protect the general public. GSFC safety leadership responsible for safety of activities conducted by WFF did not ensure that the appropriate safety practices were in place to protect the public in all such activities. **(Root Cause R4)**

c. NASA Agency Range Safety Program failed to ensure corrective actions were accomplished from previous agency audits. Several items from a 2002 audit had not been closed, but in particular one item found that "Balloon Program payloads are potentially hazardous to the public and should be managed consistent with other hazardous, uninhabited programs" and this item was still not closed. A finding that activities endanger the public did not prompt diligent follow-up and elevation to the highest level of NASA to prevent such activities from continuing without proper mitigations. **(Root Cause R5)**

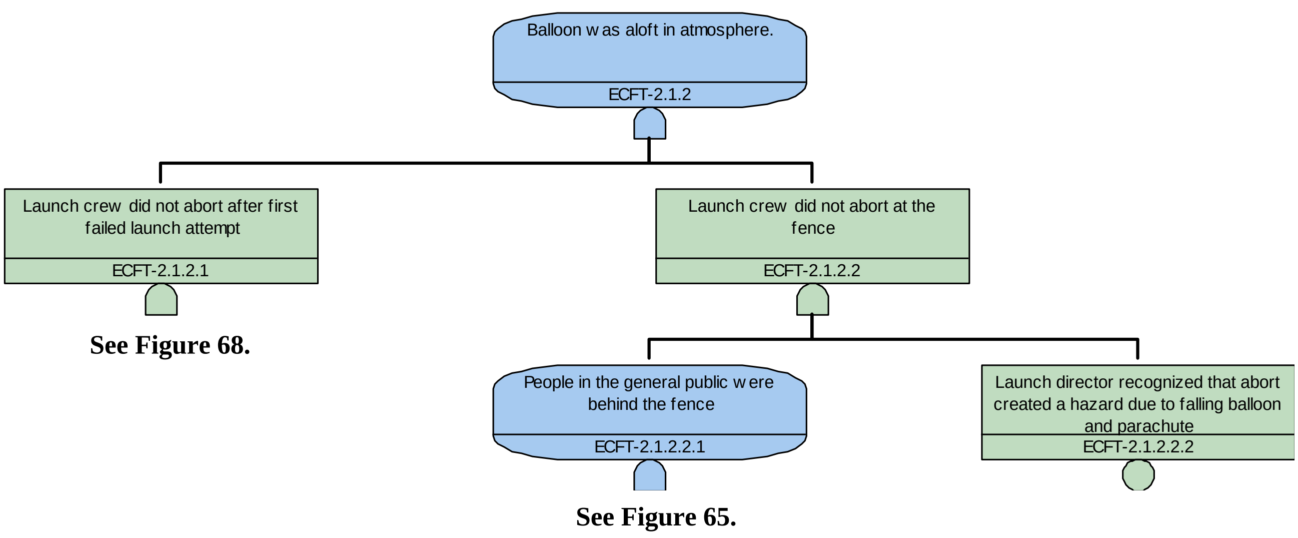


Figure 67. Balloon Was Aloft in the Atmosphere

A. The launch crew did not abort after the first failed launch attempt. When the launch director was unable to get the pin to release from pulling on the lanyard, he decided to chase the balloon for another attempt. Had they aborted after the first attempt, the undesired outcome would not have occurred. This was evident from video evidence and interview.

B. The launch crew did not abort at the fence. After the launch vehicle had breached any possible interpretation of the hazard zone, a physical limit was reached when it came to a fence. At this time, the launch director recognized that there was no further hope for a successful launch, but he did not abort the balloon. This was revealed from video evidence and interview.

1. People from the general public were located immediately behind the fence, as indicated in video evidence and interview. This leads to the same set of events in the branch shown in Figure 65.
2. The launch director recognized that abort created a hazard due to the falling balloon and parachute as indicated from interview and video evidence. This hazard was due to heavy components in the flight train, balloon, and the parachute and aborting would risk these components falling on anyone in the vicinity. Hence he realized that he needed to move to a different location to abort. However, had he remained in that position, if there were an individual with responsibility for protecting the public, the people could have been moved to a safe location in order to ensure a safe abort.

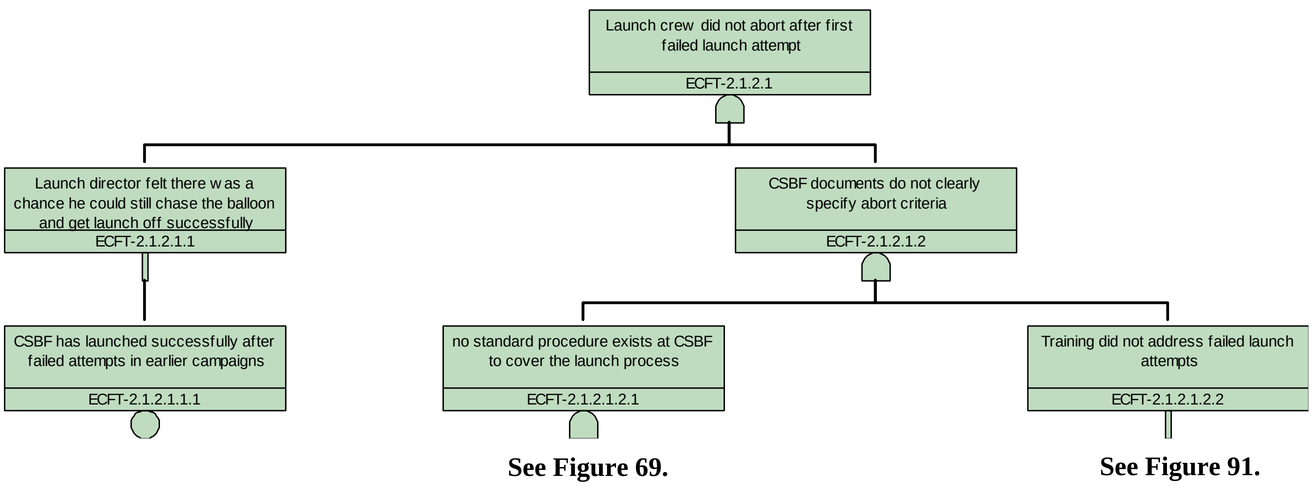


Figure 68. Launch Crew Did Not Abort After the First Failed Launch Attempt

A. The launch director felt there was a chance he could still chase the balloon and get the launch off successfully. Hence, he proceeded forward to get into a better position under the balloon. In fact, had there been no fence or people around, evidence indicates that he eventually would have caught the balloon. This was evident from interview and video evidence.

1. CSBF has launched successfully after failed attempts in earlier campaigns. Hence there was no expectation that they wouldn’t eventually get into a proper position to launch. This was indicated from interviews.

B. CSBF documents do not clearly specify abort criteria. Abort is performed only as an instinctual action and not based on clear guidance.

1. Based on interview and documentation review, it became clear that no standard procedure exists at CSBF to cover the launch process. It is entirely reliant on human observation and decision-making.
2. Training did not address failed launch attempts. In general, launch directors are not given clear direction for the possible range of contingency and anomalous situations.

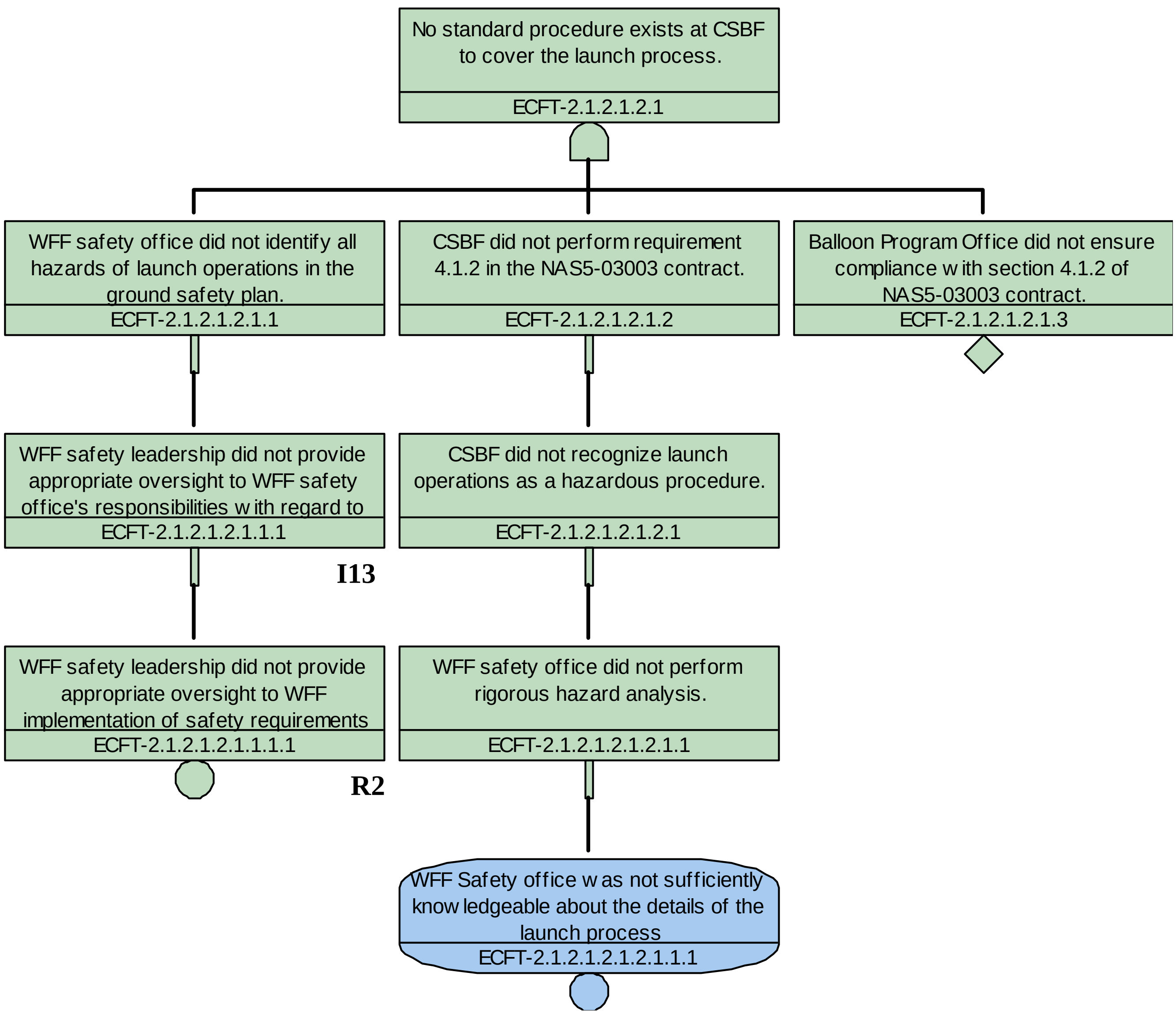


Figure 69. No Standard Procedure Exists at CSBF to Cover the Launch Process

A. WFF safety office did not identify all hazards of launch operations in the ground safety plan. In particular, the energy in the hanging payload was not identified as a hazard. Nor were the hardware in the balloon or parachute identified as hazards, although they were identified as hazards by the launch director when the vehicle approached the fence. This was evident from reviewing ground safety documentation, including the ground safety plan. Given that the hazards of launch operations were not identified, there was no recognition that a procedure would be required to cover the launch process.

1. WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program. WFF safety leadership did not pay particularly close attention to the broad set of safety practices within the balloon program, particularly anything outside of over flight casualty assessments. This is evident from interview, documentation, and video evidence. **Intermediate Cause I13**

    a. WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements. **Root Cause R2.**

B. CSBF did not perform requirement 4.1.2 in the NAS5-03003 contract, as evident from documentation and interviews. Requirement 4.1.2 states that written procedures are required for any hazardous procedure and given that the launch process involves many hazards, it requires written procedures.

1. CSBF did not recognize launch operations as a hazardous procedure. Generally, the hazards were identified within the unique payloads, in the pyrotechnics, and in over flight. The rest of the logic flows as in Figure 61, as the lack of a full hazard analysis by the WFF safety office (as required in RSM 2002 Rev B, where WFF safety office is responsible for writing the ground safety plan) allowed this key hazard to slip through the cracks. This is indicated by documentation, in particular within the Ground Safety Plan.

C. Balloon Program Office did not ensure compliance with section 4.1.2 of NAS5-03003 contract. BPO did not ensure that procedures were written to cover the launch process.

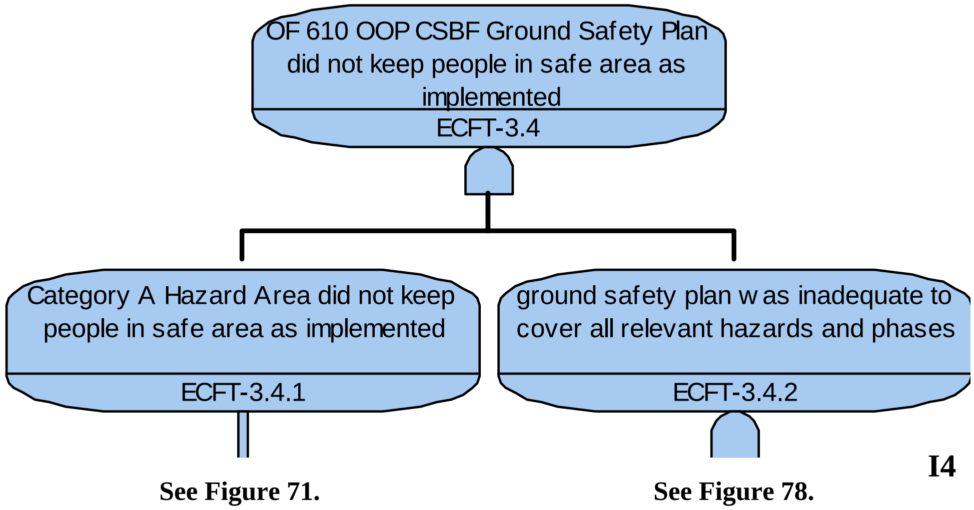
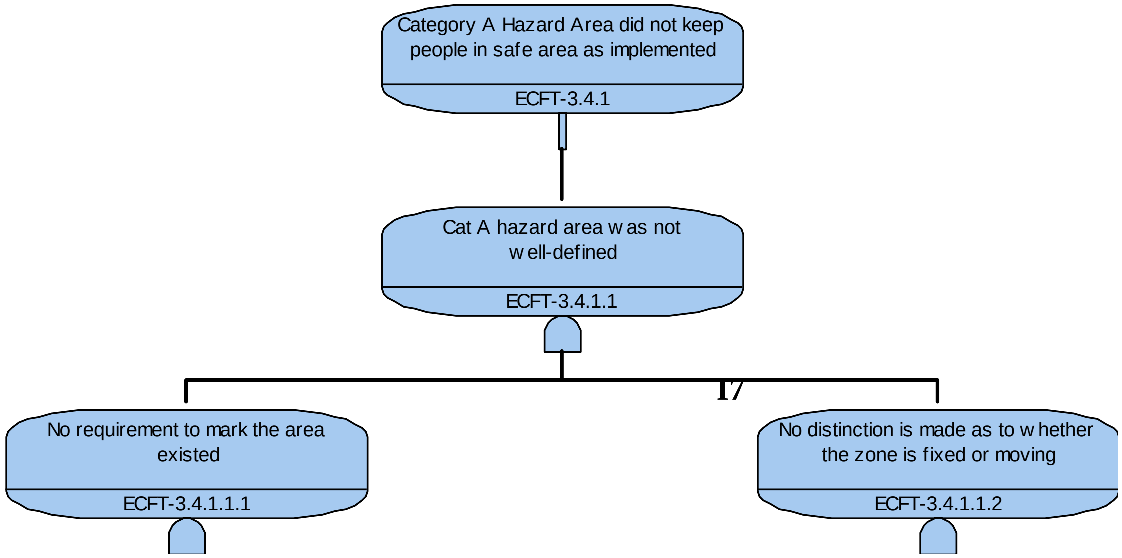


Figure 70. The OF 610 CSBF Ground Safety Plan Did Not Keep People in a Safe Area as Implemented

A. The Category A Hazard Area did not keep people in a safe area as implemented. Although generally the launch crew was aware of a hazard area, known by several different names, it was ineffective at keeping people out of harm's way. This was evident from video evidence and interview.

B. The ground safety plan was inadequate to cover all relevant hazards and phases according to documentation review. The plan did not cover the detailed actions generally performed in the launch phase and it failed to identify several hazards, including that of the stored energy in a hanging payload and the hardware present in the balloon and parachute that could land on people or property in the case of an abort. **Intermediate Cause I4**



See Figure 72. **See Figure 75.**

Figure 71. The Category a Hazard Area Did Not Keep People in a Safe Area as Implemented

A. The Category A Hazard Area was not well-defined. There are several different interpretations of the area within the BPO and CSBF. This was evident from review of documentation. **Intermediate Cause I7**

1. No requirement to mark the area existed, based on review of documentation. Henceforth, there was no way for anyone to tell when it was close to being breached.

2. No distinction is made as to whether the zone is fixed or moving, as indicated from documentation. The definition of the zone would tend to lean towards it being a moving area, but a moving area would not be implementable. A fixed area would be insufficient to cover the most relevant hazards during launch. The BPO believes the zone to be moving while CSBF believes the zone to be fixed.

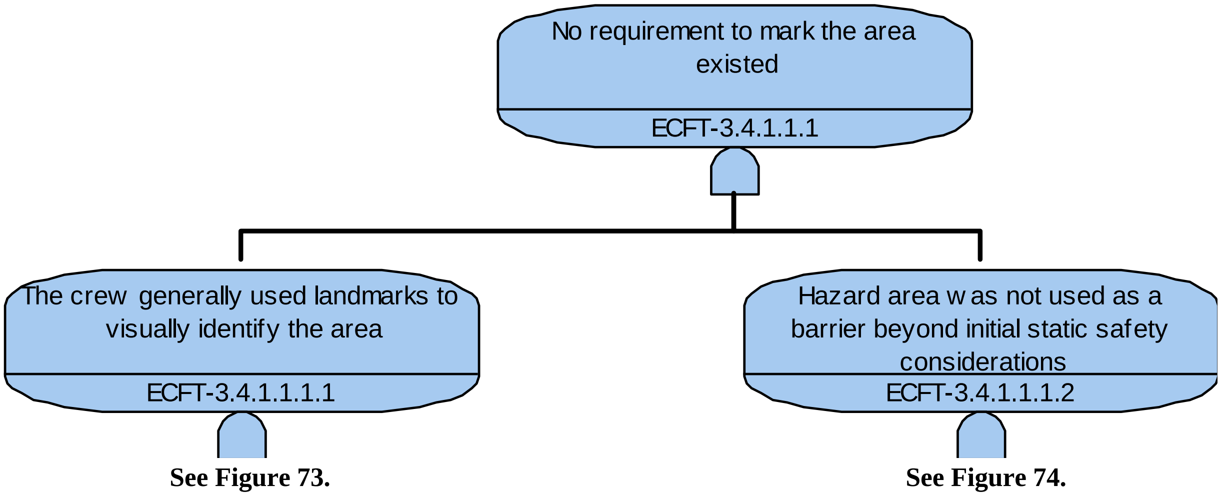


Figure 72. No Requirement to Mark the Area Existed

A. The crew generally used landmarks to visually identify the area. Interviews indicate that during set up for launch the crew would loosely walk off the hazard area and take mental note of identifying features at the edges of the zone.

B. The hazard area was not used as a barrier beyond initial static safety considerations. There is no evidence that there is any consideration of the Category A Hazard Area once the launch vehicle begins to move.

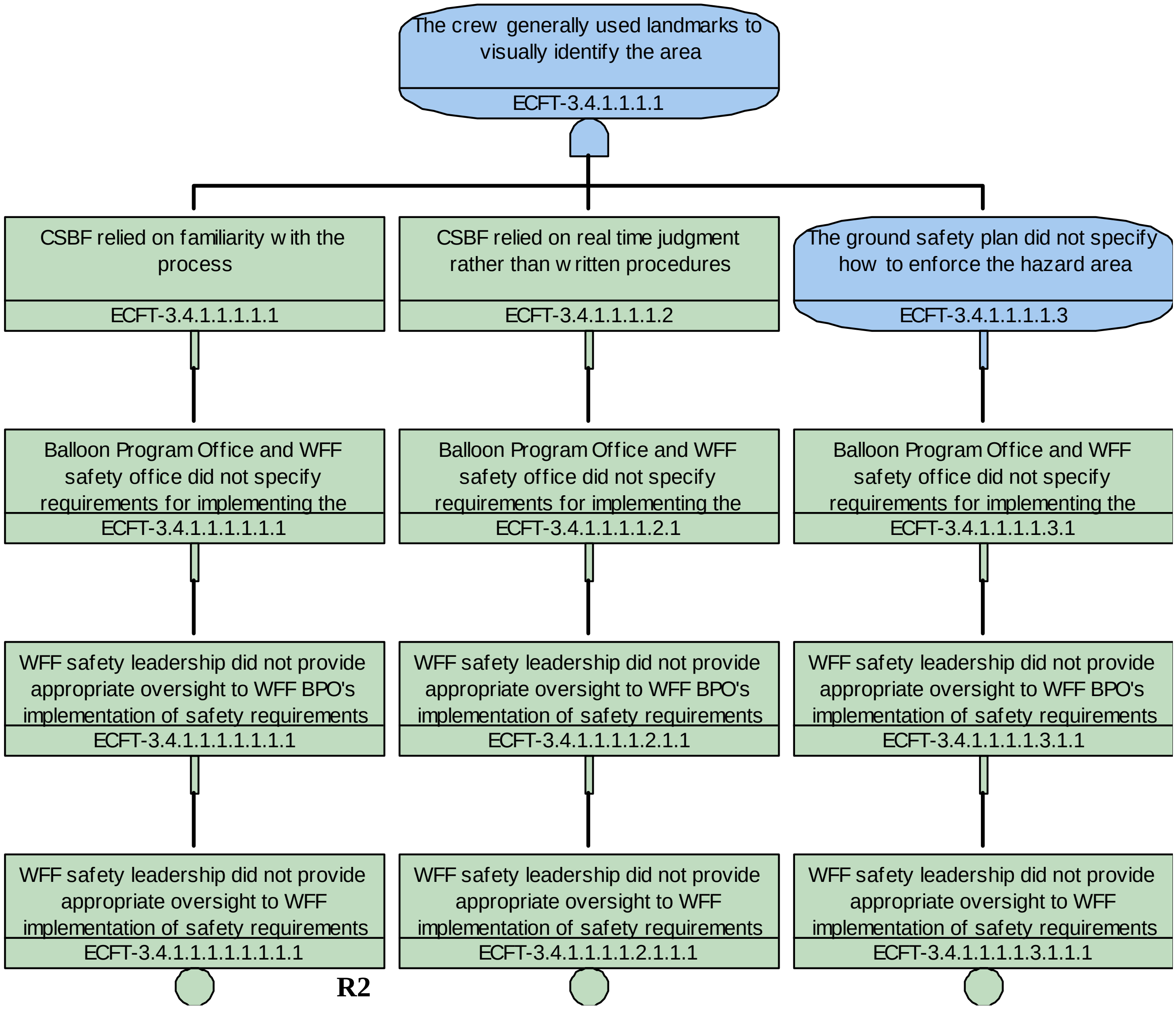


Figure 73. The Crew Generally Used Landmarks to Visually Identify the Area

A. CSBF relied on familiarity with the process. Rather than explicitly marking things off and writing down procedures, CSBF based successful operations on experience and training, which left much susceptible to human error or lack of understanding of what to do in contingency or anomalous situations. This was evident from interviews and documentation.

1. BPO and WFF safety office did not specify requirements for implementing the hazard area. This responsibility was fully contractually delegated to the CSBF but given the safety implications, both should have been knowledgeable about how this was being performed. This was evident from interviews and documentation.

   a. WFF safety leadership did not provide appropriate oversight to WFF BPO’s implementation of safety requirements. Interviews indicate that the balloon program has operated with minimal direct interaction from WFF safety leadership.

i. WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements. **Root Cause R2.**

B. CSBF relied on real-time judgment rather than written procedures. This is based on documentation and interview and the logic flow is the same as that in item A. above.

C. The ground safety plan did not specify how to enforce the hazard area. This is based on documentation and the logic flow is the same as that in item A. above.

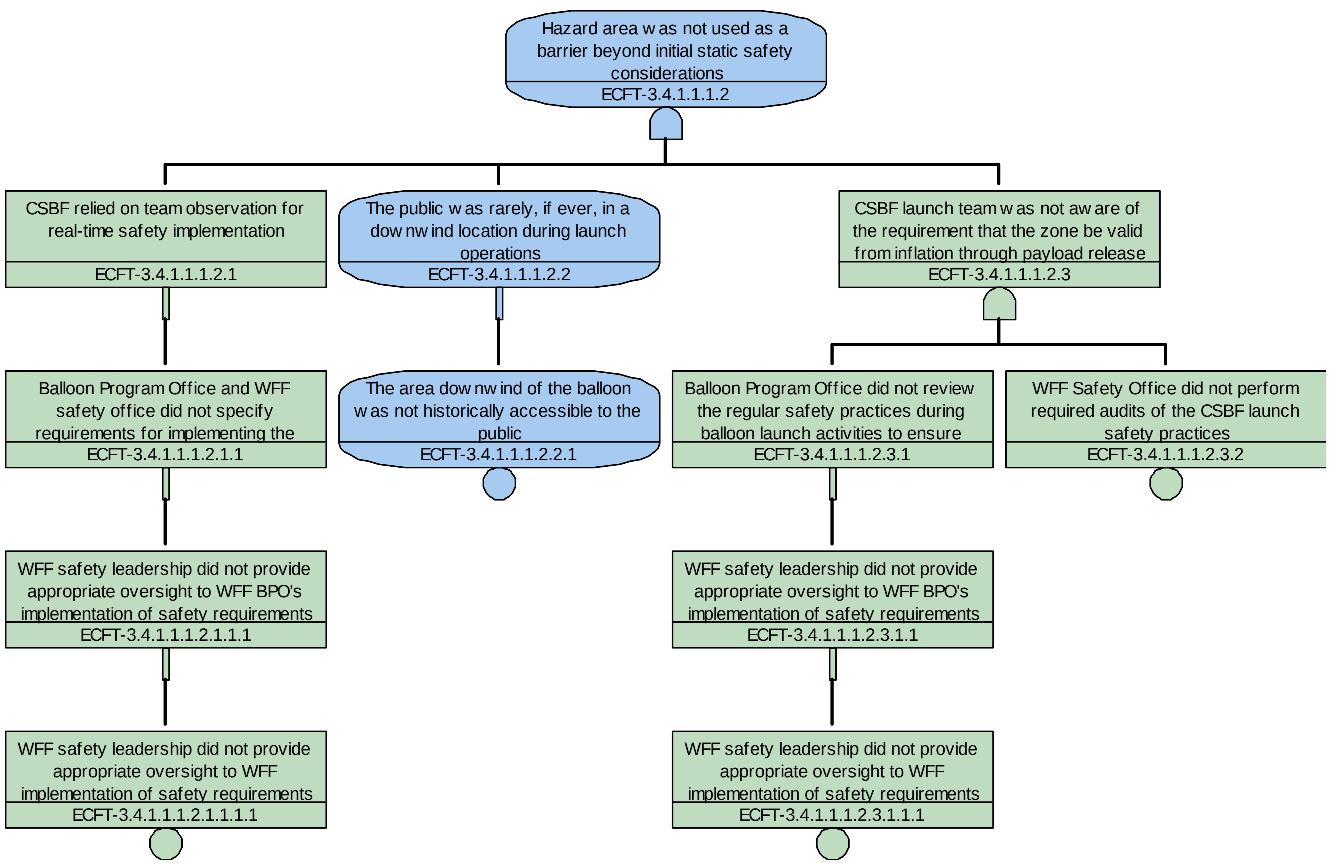


Figure 74. The Hazard Area Was Not Used as a Barrier Beyond Initial Static Safety Considerations

A. CSBF relied on team observation for real-time safety implementation. There was no coordinated effort or centralized responsibility for safety and this mode leaves much to having problems slip through the cracks. This was evident from interviews and documentation.

1. BPO and WFF Safety Office did not specify requirements for implementing the safety zone. Safety documentation written and approved by BPO and WFF defines the zone in general terms but does not indicate any requirements for implementation, as indicated in the Ground Safety Plan.

   a. WFF safety management did not provide appropriate oversight to WFF BPO's implementation of safety. The extent of oversight does not go beyond knowledge of the safety documentation, primarily the ground safety plan and the balloon risk analysis. This was evident from interviews. The logic flow continues as in Figure 73.

B. The public was rarely, if ever, in a downwind location during launch operations. This was not a situation that the team had experienced, according to interviews.

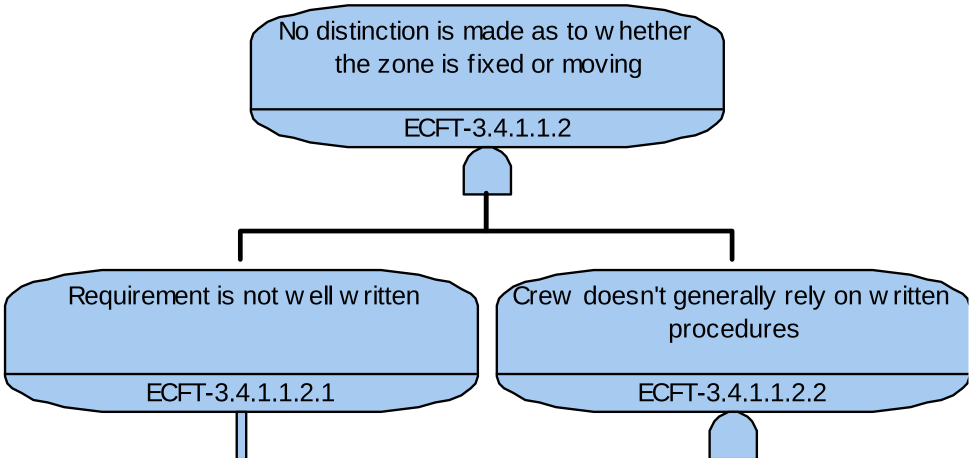
   1. The area downwind of the balloon was not historically accessible to the public. It just so happened that the layout of the balloon on this day was such that publicly accessible points were in the proximity downwind. This was indicated in interviews.

C. CSBF launch team was not aware of the requirement that the zone be valid from inflation through payload release. There was no evidence that any attention was paid to the zone during the process of chasing the balloon and trying to launch.

   1. BPO did not review the regular safety practices during balloon launch activities to ensure compliance with existing requirements. BPO's primary awareness of safety practices was in knowledge of the ground safety plan and Balloon Risk Analysis, but little knowledge of what was actually being practiced in the field.

      a. WFF Safety leadership did not provide appropriate oversight to WFF BPO's implementation of safety. WFF BPO's implementation of the safety during balloon launches was "out-of-sight, out-of-mind" to WFF safety leadership. The logic flow continues as in Figure 73.

   2. According to interviews, WFF Safety Office did not perform required audits of the CSBF launch safety practices. These audits were to be in response to the 2002 audit by NASA HQ OSMA. However, they were never performed.



See Figure 76. **See Figure 77.**

Figure 75. No Distinction Is Made as to Whether the Zone Is Fixed or Moving

A. The requirement is not well-written. There is no specific discussion about what happens when the vehicle moves or how one would determine whether the zone is breached in practice. This is evident from review of the Ground Safety Plan.

B. The crew doesn’t generally rely on written procedures, according to documentation and interviews. Training and experience are the primary means to successfully launch balloons.

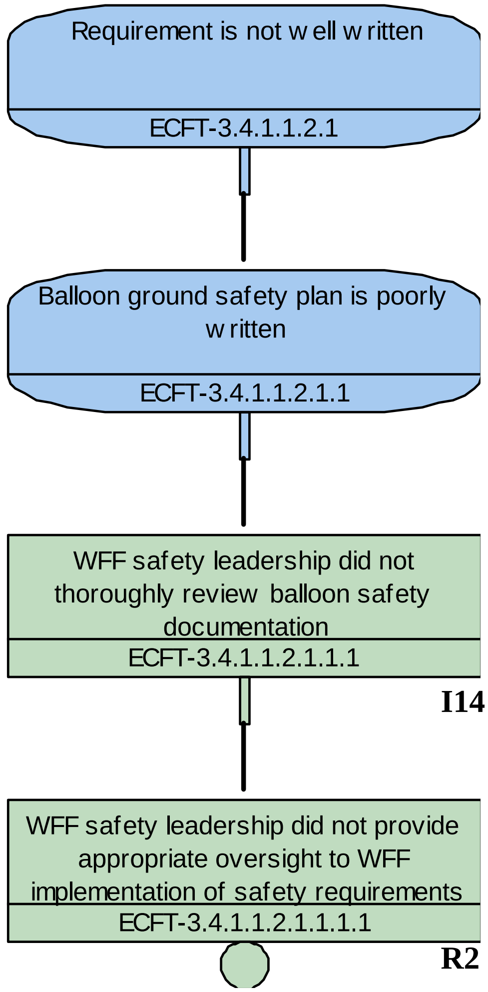


Figure 76. Requirement Is Not Well Written

A. The balloon ground safety plan is poorly written. It leaves out many of the details during the launch process and does not address all hazards.

   1. WFF safety leadership did not thoroughly review balloon safety documentation. There is much ambiguous language in the documentation, hazards are not covered completely, there is no provision to protect the public except in the over flight phase, and it does not completely cover all phases of balloon operations. **Intermediate Cause I14**

      a. WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements. **Root Cause R2**.

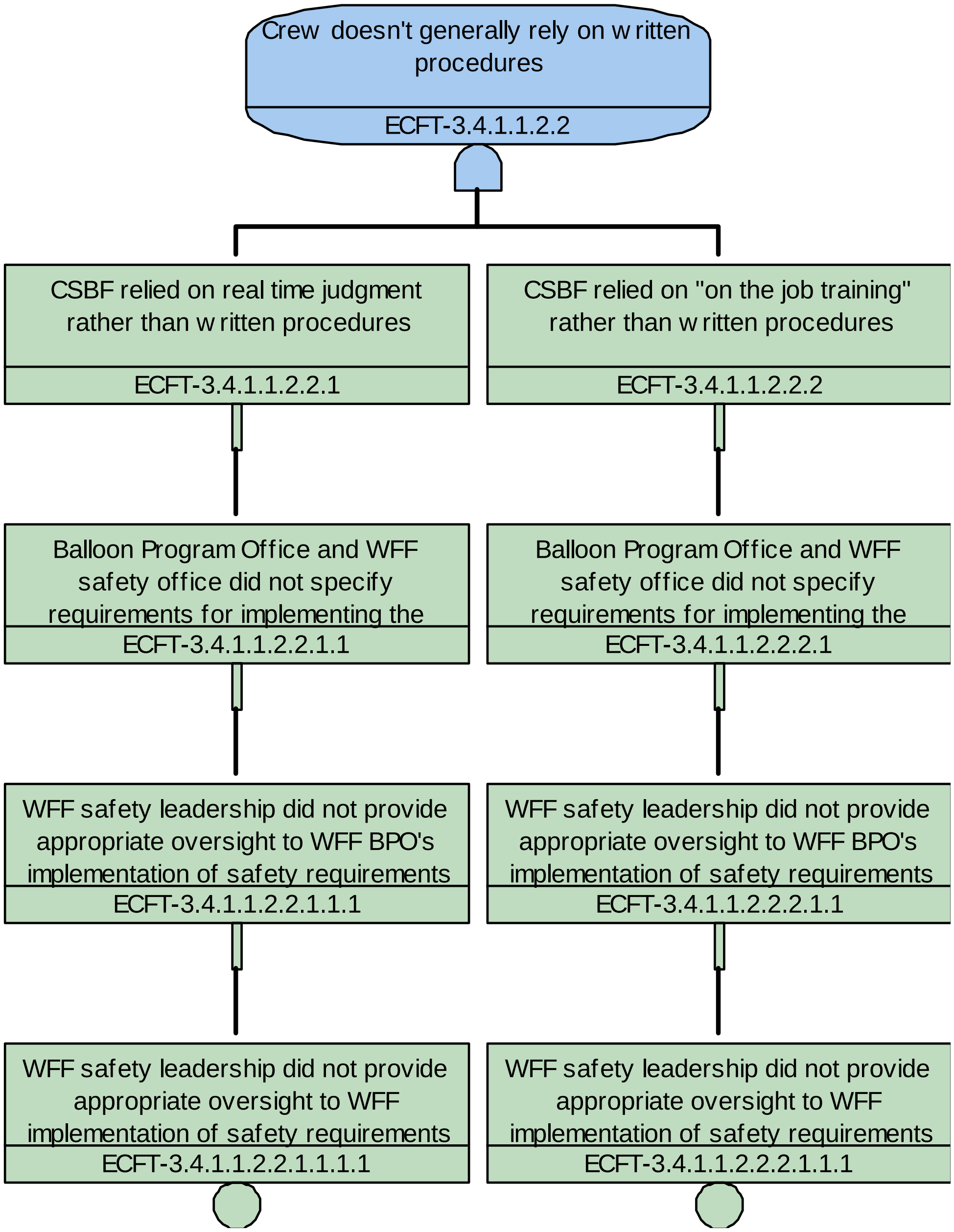


Figure 77. Crew Does Not Generally Rely on Written Procedures

Both of the following items lead through the same path as in branch “A” of Figure 74.

A. CSBF relied on real-time judgment rather than written procedures. The general approach is to train the launch crew in a general sense and have them respond to the events with good judgment. This is according to interviews and documentation.

B. CSBF relied on “on-the-job training” rather than written procedures. On-the-job training is used in place of explicit rules and procedures. This is according to interviews and documentation.

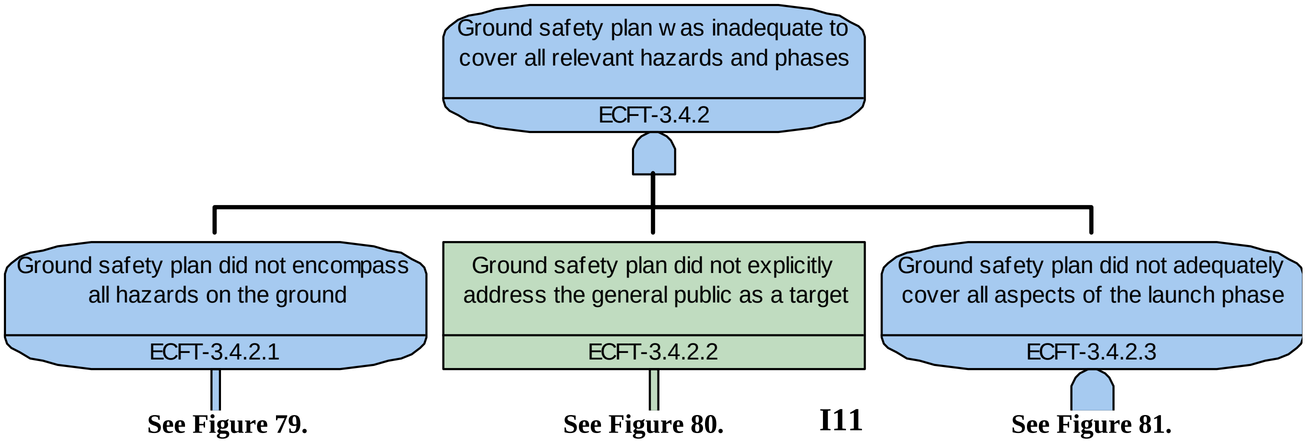


Figure 78. The Ground Safety Plan Was Inadequate to Cover All Relevant Hazards and Phases

A. The ground safety plan did not encompass all hazards on the ground. For example, neither the hazard of a hanging heavy payload, nor those of the balloon or parachute and associated hardware falling due to an abort were acknowledged.

B. The ground safety plan did not explicitly address the general public as a target. The plan only focused on personnel and keeping unauthorized personnel out of a hazard zone, but did nothing to address hazards to spectators or passers-by. **Intermediate Cause I11**

C. The ground safety plan did not adequately cover all aspects of the launch phase. The process of moving the crane around to chase the balloon, attempting launch, and the process and requirements for abort are not thoroughly covered.

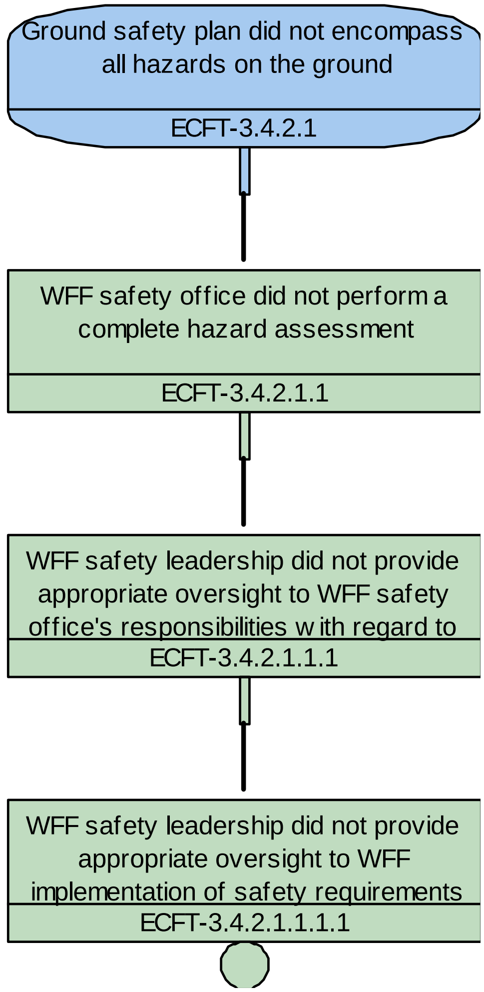


Figure 79. The Ground Safety Plan Did Not Encompass All Hazards on the Ground

A. WFF Safety Office did not perform a complete hazard assessment. The WFF Safety Office is responsible, according to RSM 2002 Rev B, for developing the ground safety plan. This plan includes the only reference in the balloon safety documentation to hazards during ground operations. Only a subset of the actual hazards during ground operations is indicated and no full hazard analysis exists.

   1. WFF safety leadership did not provide appropriate oversight to WFF Safety Office's responsibilities with regard to the balloon program. The safety leadership at WFF fully delegated responsibilities that had full bearing on safety of the public to the WFF Safety Office without any indication of audit or review of all aspects of safety. The remainder of the logic flow is as in several previously-described branches.

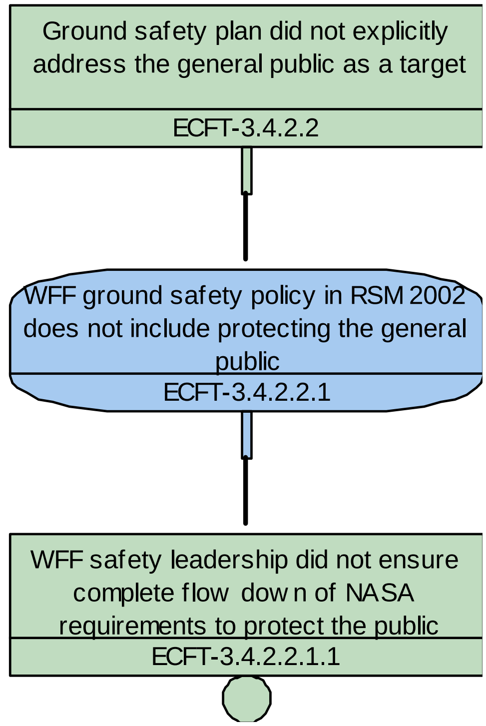


Figure 80. The Ground Safety Plan Did Not Explicitly Address the General Public as a Target

A. WFF ground safety policy in RSM 2002 (Rev B) does not include protecting the general public. Dangers to the general public during ground operations were not understood or acknowledged.

   1. WFF safety leadership did not ensure complete flow down of NASA requirements to protect the public. RSM 2002 does not account for hazards to the general public during ground operations and protection of the public is not addressed in the CSBF documentation.

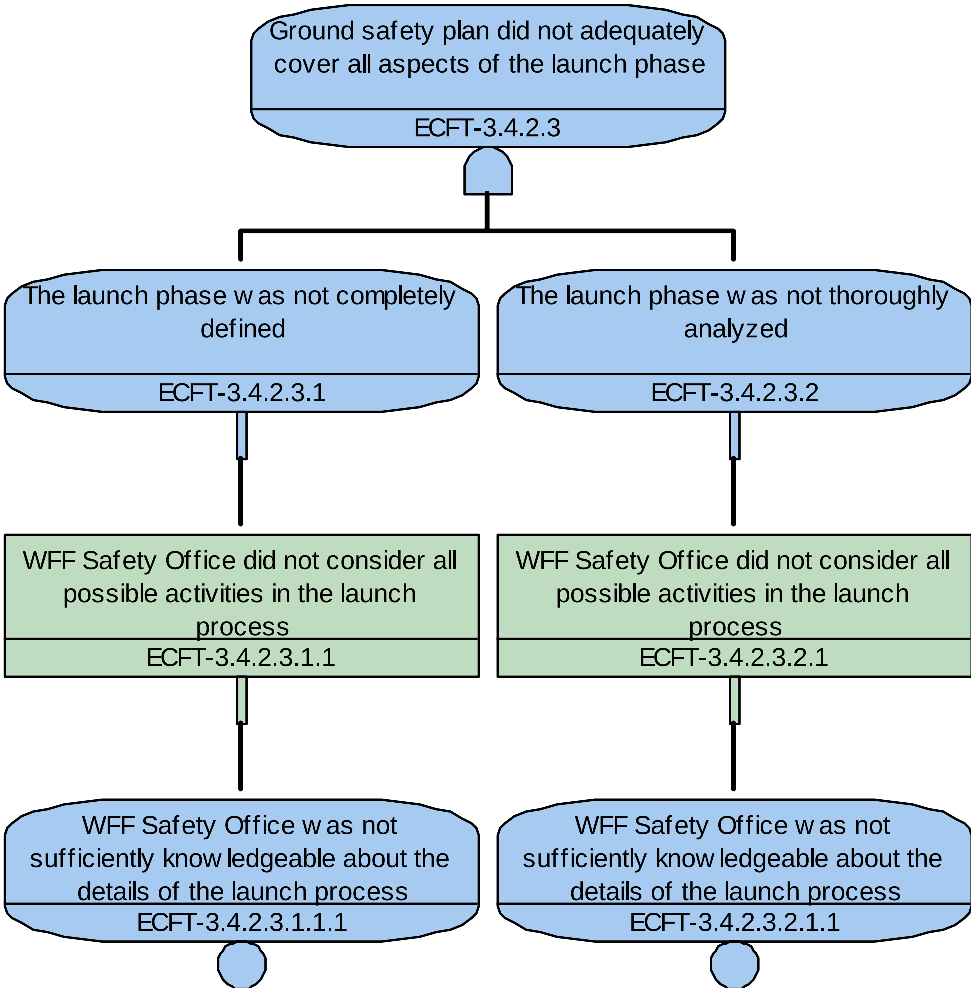


Figure 81. The Ground Safety Plan Did Not Adequately Cover All Aspects of the Launch Phase

A. The launch phase was not completely defined. The process of moving the launch vehicle to chase the balloon, aligning the launch vehicle with the balloon, and attempting launch is not expressed in the Ground Safety Plan's description of the launch phase. This is indicated in documentation.

  1. WFF Safety Office did not consider all possible activities in the launch process. There is very little about the launch process specified in the ground safety plan.
     a. WFF Safety Office was not sufficiently knowledgeable about the details of the launch process. In particular, hazards to the public were not identified in the ground safety plan.

B. The launch phase was not thoroughly analyzed. Key hazardous elements of launch operations were not addressed for the process of chasing the balloon to attempt launch. This was evident from review of the Ground Safety Plan. The remainder of the logic follows as in item A.

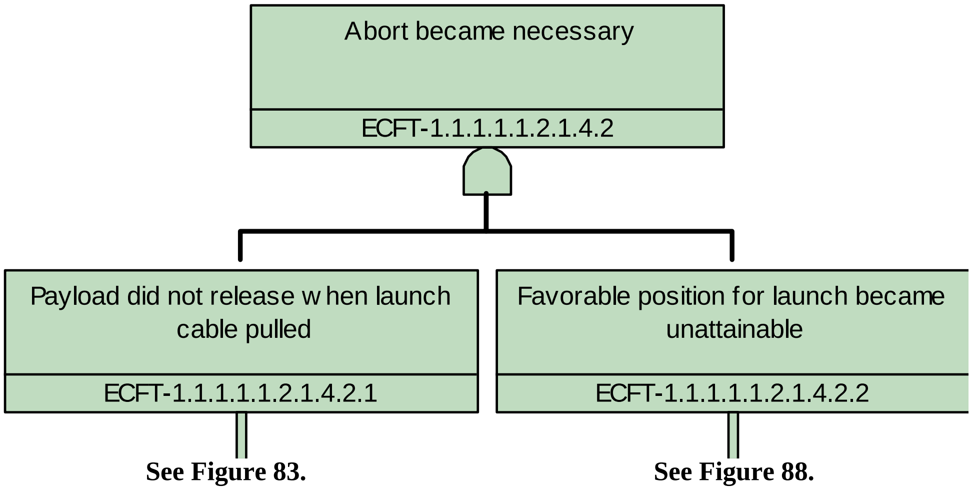


Figure 82. Abort Became Necessary

A. Payload did not release when launch cable pulled. The pull force was insufficient to move the pin back from the pear ring and hence the payload remained attached to the launch vehicle. This was evident from video, test, and analysis.

B. Favorable position for launch became unattainable. With limited space based on the fence and the spectators, the balloon became too far offset from an appropriate position above the launch vehicle to ever be able to reach a position where launch would be feasible. This was evident from video and analysis.

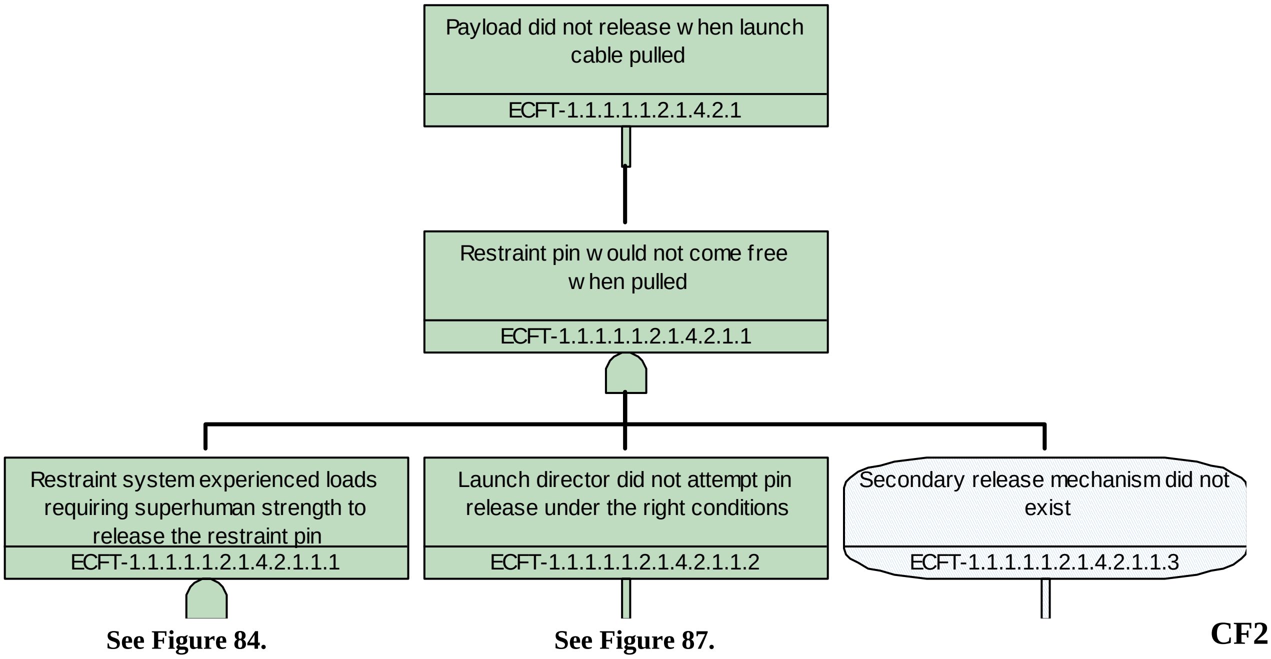


Figure 83. Payload Did Not Release When Launch Cable Was Pulled

A. Restraint pin would not come free when pulled. The combined friction and spring force was higher than the force resolved at the pin from pulling the lanyard, according to video, analysis, and test.

1. Restraint system experienced loads requiring superhuman forces to enable release. Analysis shows that over 200 lb was required to free the pin in the configuration during the launch attempt. Normal human capability would be no greater than 100 lb pulling force.

2. Launch director did not attempt pin release under the right conditions. The angle of the balloon relative to the vertical from above the launch vehicle was too great, causing a significant shear force on the pin, resulting in a significant friction force, preventing its release. This was indicated from analysis.

3. A secondary release mechanism did not exist. Had there been a secondary mechanism that was not subject to the shear and friction force combination that limited the launch director's ability to release the pin, the payload may have released successfully. Analysis shows that the catenary angle, while large, would not likely have caused the payload to pendulum down and hit the ground upon launch. **Contributing Factor 2.** This leads to root cause R6 in the next block and is not shown again here.

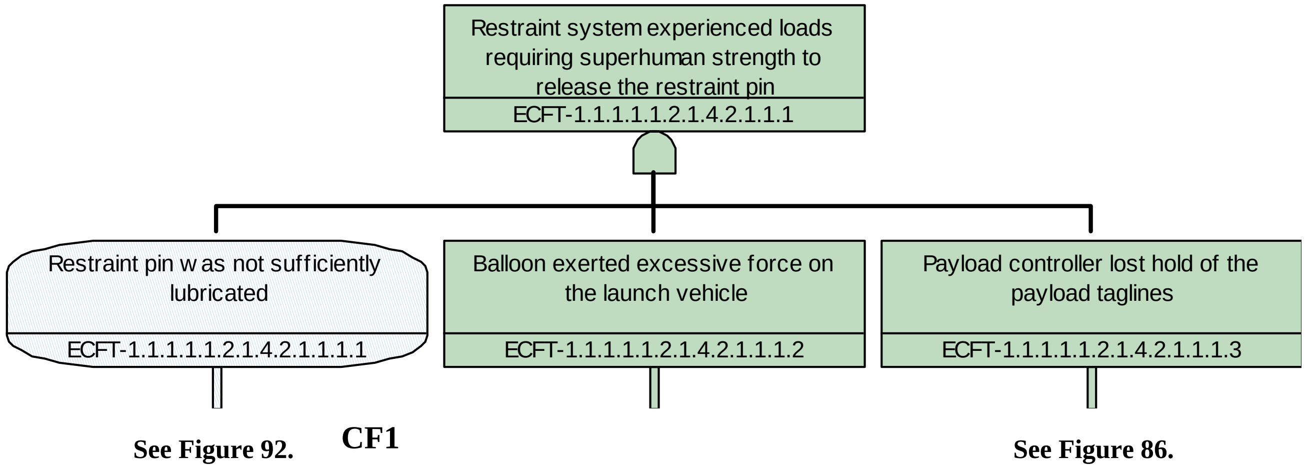


Figure 84. Release Mechanism Experienced Loads Requiring Superhuman Forces to Enable Release

A. Restraint pin was not sufficiently lubricated. While there is no evidence of requirements to lubricate the pin, without lubricant, the amount of friction force due to shear force imparted by horizontal motion or pull of the balloon can be arbitrary, and require a tremendous force to overcome. This was evident from analysis. **Contributing Factor 1.**

B. Balloon exerted excessive force on the launch vehicle. The balloon being significantly ahead of the vehicle caused a large horizontal force on the launch vehicle. This was evident from video and analysis. The logic continues the flow in the middle branch of Figure 54.

C. Payload controller (aka the payload launch assistant) lost hold of the taglines. When the straps used to stabilize the payload during launch were lost, it created a dynamic load on the launch mechanism adding to the force on the pin that the launch director would have to overcome for successful launch. This was evident from video and analysis.

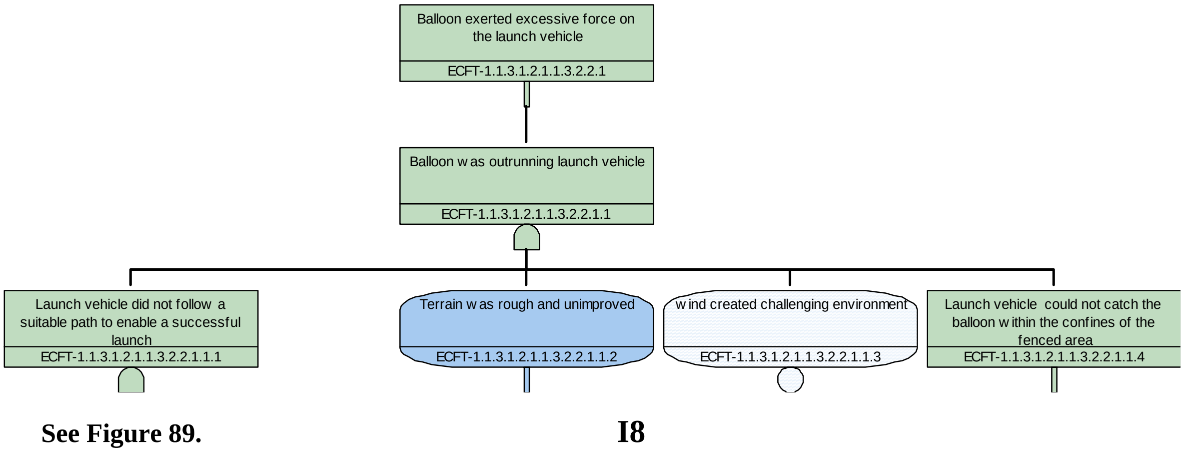


Figure 85. Balloon Exerted Excessive Force on the Launch Vehicle

A. The balloon was outrunning the launch vehicle. The balloon was ahead and getting further ahead and more and more challenging to catch.

1. Launch vehicle did not follow a suitable path to enable a successful launch. Some of the turns taken by the launch vehicle caused the vehicle to lose ground on catching the balloon. This is evident from interviews and video.
2. Terrain was rough and unimproved. Logic in Figure 63 follows and is not repeated here. **Intermediate Cause I8.**
3. The launch vehicle could not catch the balloon within the confines of the fenced area. The combination of speed limitations of the crane and the limited travel range of the vehicle due to the layout of the flight train and limited area prevented the launch vehicle from being able to catch the balloon (block not shown). This is evident from videos and documentation.

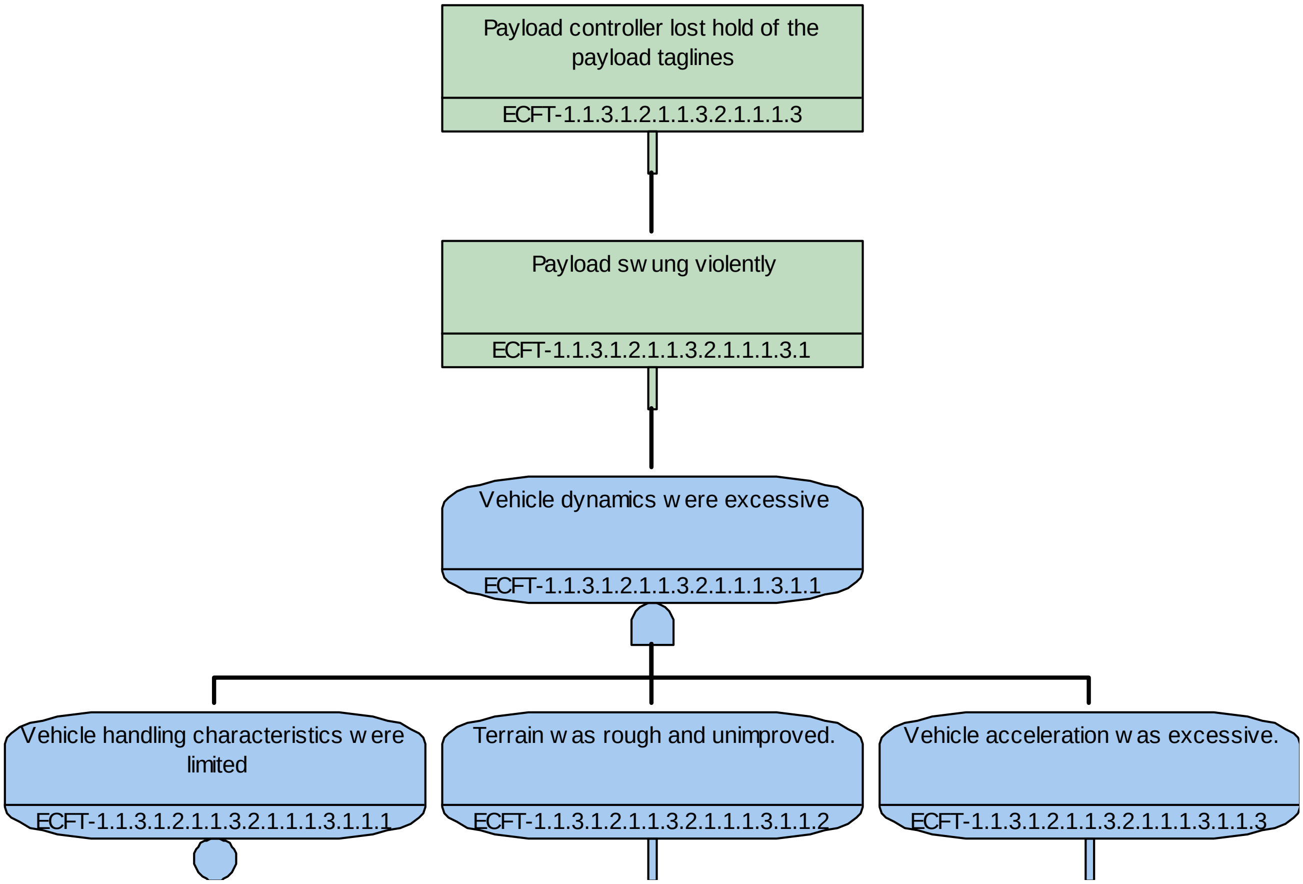


Figure 86. Payload Controller Lost Hold of the Taglines

A. The payload swung violently, as observed in video evidence. This caused additional stresses on the hardware and made it more difficult to successfully release the payload from the vehicle.

1. Vehicle dynamics were excessive. Motions of the vehicle were imparting into the payload, as apparent from video evidence.

   a. Vehicle handling characteristics were limited. There was, expectedly, a finite amount of speed, shock absorption, and lateral control capability.

   b. Terrain was rough and unimproved. (See Figure 63.)

   c. Vehicle acceleration was excessive. Specifically the deceleration due to a sudden stop caused a jolt, as evident from the video. The sudden stop was in order to make a launch attempt (block not shown).

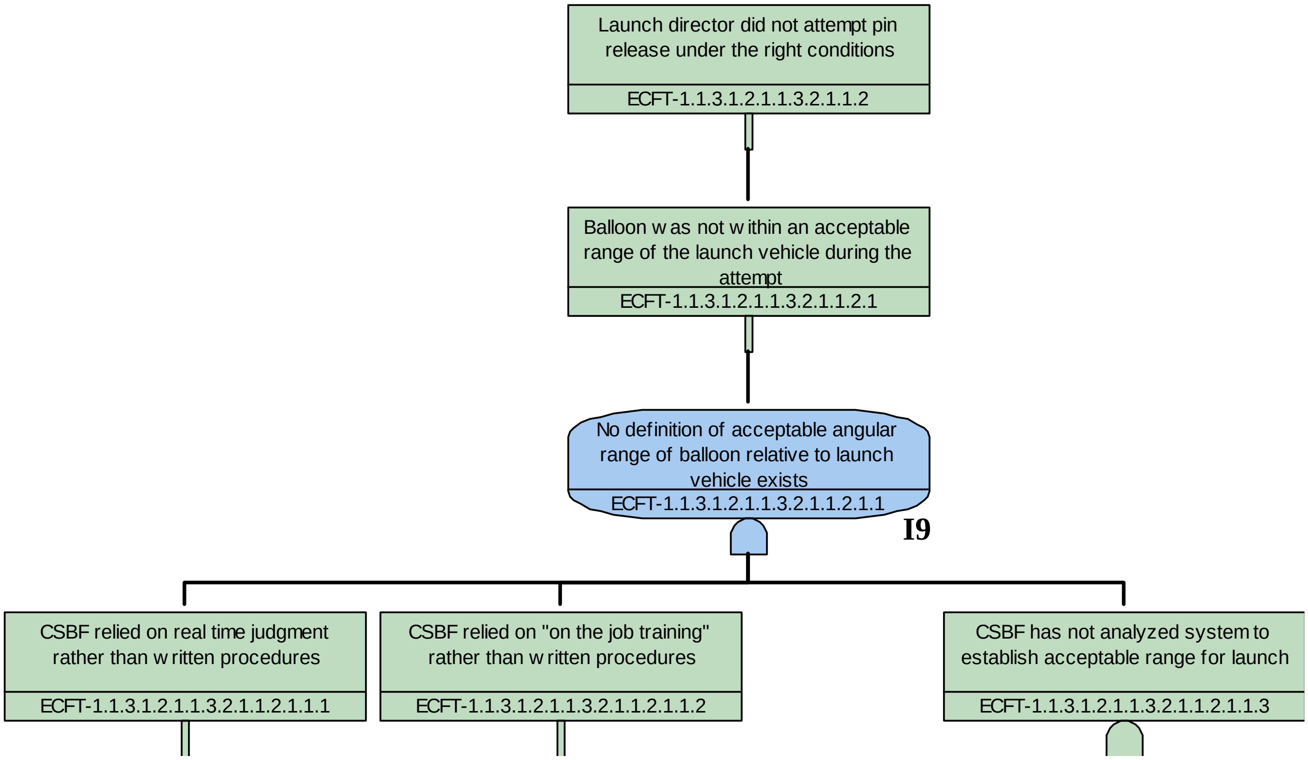


Figure 87. Launch Director Did Not Attempt Release Under the Right Conditions

A. Balloon was not within an acceptable range of the launch vehicle during the attempt. Analysis and test showed that the large angle with the vertical caused a significant shear force and hence friction force, which ultimately prevented the pin from releasing.

1. No definition of acceptable angular range of balloon relative to launch vehicle exists. **Intermediate Cause I9**

a. CSBF relied on real-time judgment rather than written procedures. The general approach has been to train the launch crew in a general sense and have them respond to the events with good judgment. This is evident from documentation and interview. The rest of this branch follows with the logic in Figure 60.

b. CSBF relied on “on-the-job training” rather than written procedures. On-the-job training is used in place of explicit rules and procedures. This is evident from documentation and interview. The rest of this branch follows with the logic in Figure 60.

c. CSBF has not analyzed the system to establish the acceptable range for launch. There is no evidence that anything but training and visual determination is used to decide when launch can take place. The rest of this branch leads to the same cause as determined from Figure 60.

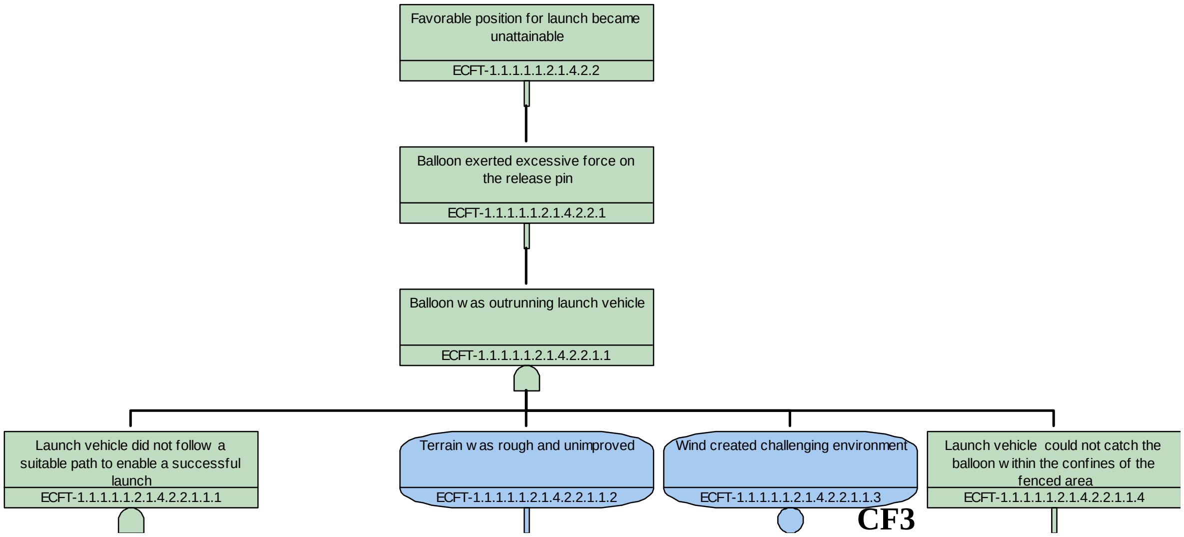


Figure 88. A Favorable Position for Launch Became Unattainable

A. Balloon exerted excessive force on the launch vehicle. This branch follows essentially the same logic path as that in Figure 84, with the addition of the "wind created challenging environment" block. Although the wind was not greater than allowable specifications, according to interview, it was strong enough to make the process of catching the balloon more challenging (**Contributing Factor 3**).

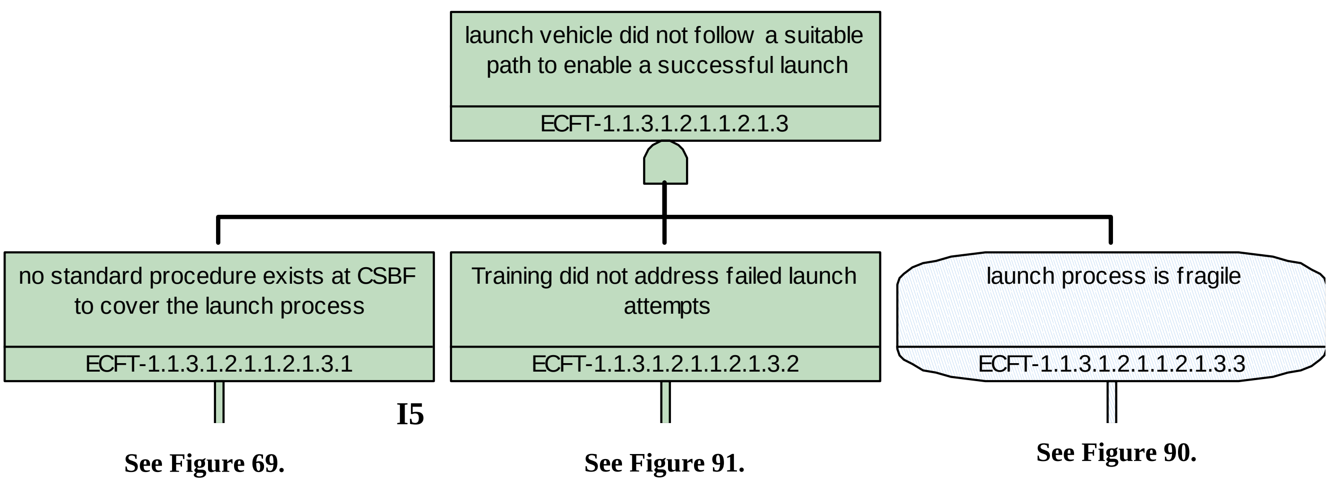


Figure 89. Launch Vehicle Did Not Follow a Suitable Path to Enable a Successful Launch

A. No standard procedure exists at CSBF to cover the launch process. Given that the launch process is a hazardous operation, the contract with CSBF requires written procedures. This is evident from interview and documentation. **Intermediate Cause I5**

B. Training did not address failed launch attempts. In particular, there is insufficient guidance for dealing with any anomalous or contingency situations. This is evident from interview and documentation. **Intermediate Cause I6**

C. The launch process is fragile. Without explicit procedures and due to the dependency on visual assessment and good judgment, the launch process is highly sensitive to errors in judgment, perception, and visualization. This is evident from interview and documentation. **Contributing Factor 4**

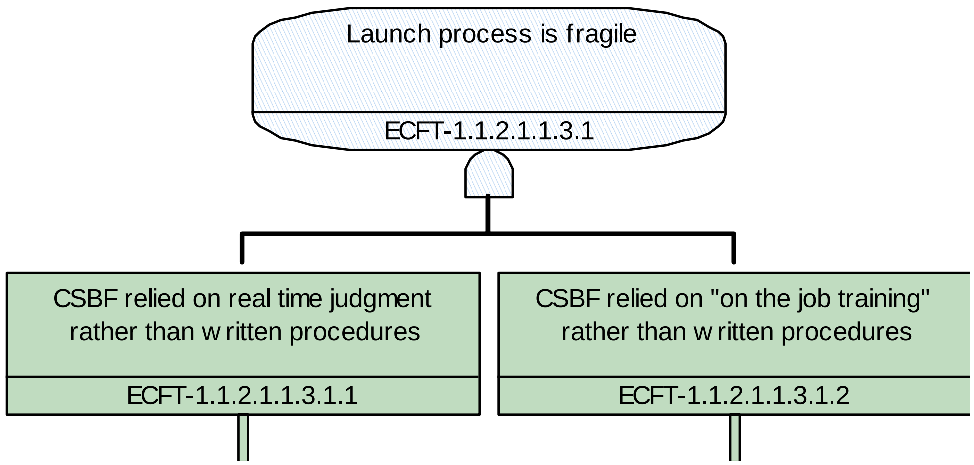


Figure 90. The Launch Process Is Fragile

A. CSBF relied on real-time judgment rather than written procedures. Interview and documentation review indicate that the process of launching the balloon is not something that is written down, but rather is something of an art based on the observation of the surroundings and some general, unwritten guidelines. This block next leads to Root Cause R6: Reliance on past success has become a substitute for good engineering and safety practices.

B. CSBF relied on "on-the-job training" rather than written procedures. Interview and documentation review indicate that on-the-job training is the means for conveying the process of launching the balloon, rather than writing down a procedure. This block next leads to Root Cause R6 as well.

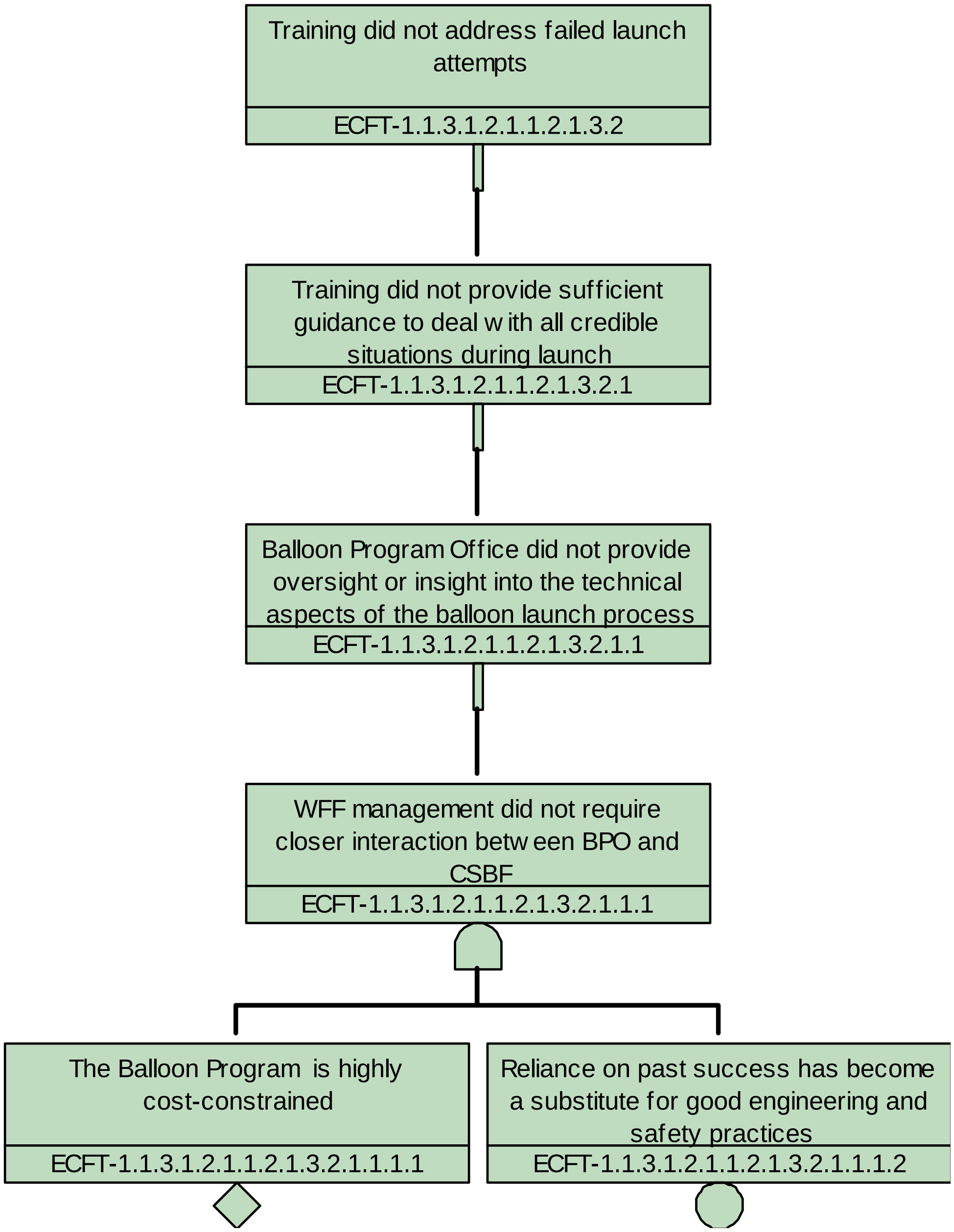


Figure 91. Training Did Not Address Failed Launch Attempts

A. Training did not provide sufficient guidance to deal with all credible situations during launch. Interviews indicated that there is no specific training element to deal with anomalies or unexpected occurrences. The rest of the branch follows Figure 60.

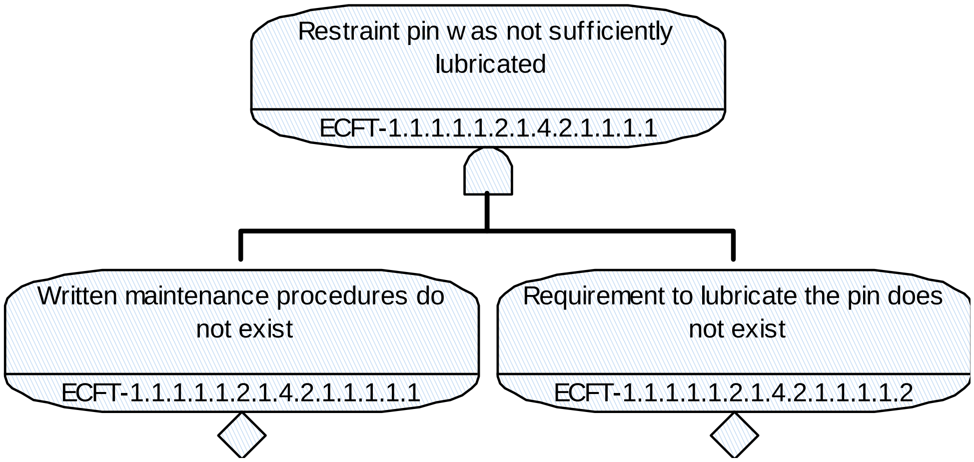


Figure 92. Restraint Pin Was Not Sufficiently Lubricated

A. Written maintenance procedures do not exist. No evidence of maintenance was provided upon request to the MIB.

B. A requirement to lubricate the pin does not exist. There was no information provided nor that provided from interviews to indicate lubrication requirements.

3.6.4 Secondary Undesired Outcome

In response to the direct language of the appointment letter, the MIB considered the real threat to lives of the public and their associated property as the primary undesired outcome of the mishap. During the course of the investigation, the MIB identified two additional undesired outcomes. This section addresses these undesired outcomes. For both secondary undesired outcomes (SUOs) the MIB used the work completed for the PUO, rather than complete additional, independent exhaustive analysis on each SUO.

The first secondary undesired outcome (SUO1) for this mishap was the **significant loss of assets including the scientific payload, the airport fence, and the costs associated with the failed launch attempt**.

The second secondary undesired outcome (SUO2) for the mishap was that **contractor personnel were endangered when the payload inadvertently released from the launch head**.

3.6.4.1 ECF Analysis for SUO1 NASA incurred significant loss of assets including the scientific payload, the airport fence, and the costs associated with the failed launch attempt.

The MIB used the work products created in the analysis of the causes for the PUO as a starting point for analysis of the SUO1. Of the three PUO proximate causes (P), which included P1) payload separated from the launch vehicle, P2) released payload was dragged downwind by the balloon and P3) people in the general public were in the projected flight path, only causes P1 and P2 are necessary and sufficient to cause the asset loss that occurred during this mishap. These two proximate causes were then traced down the Event and Causal Factor Tree (E&CFT) to determine if the intermediate causes for the PUO were necessary and sufficient for the SUO1.

Analysis of the E&CFT reveals that all causes and conditions are identical for SUO1 except for the following:

Cause: E&CFT-2.1.2.1.2.1 No Standard procedure exists at CSBF to cover the launch process. This branch of the E&CFT for the PUO is reproduced in Figure 93.

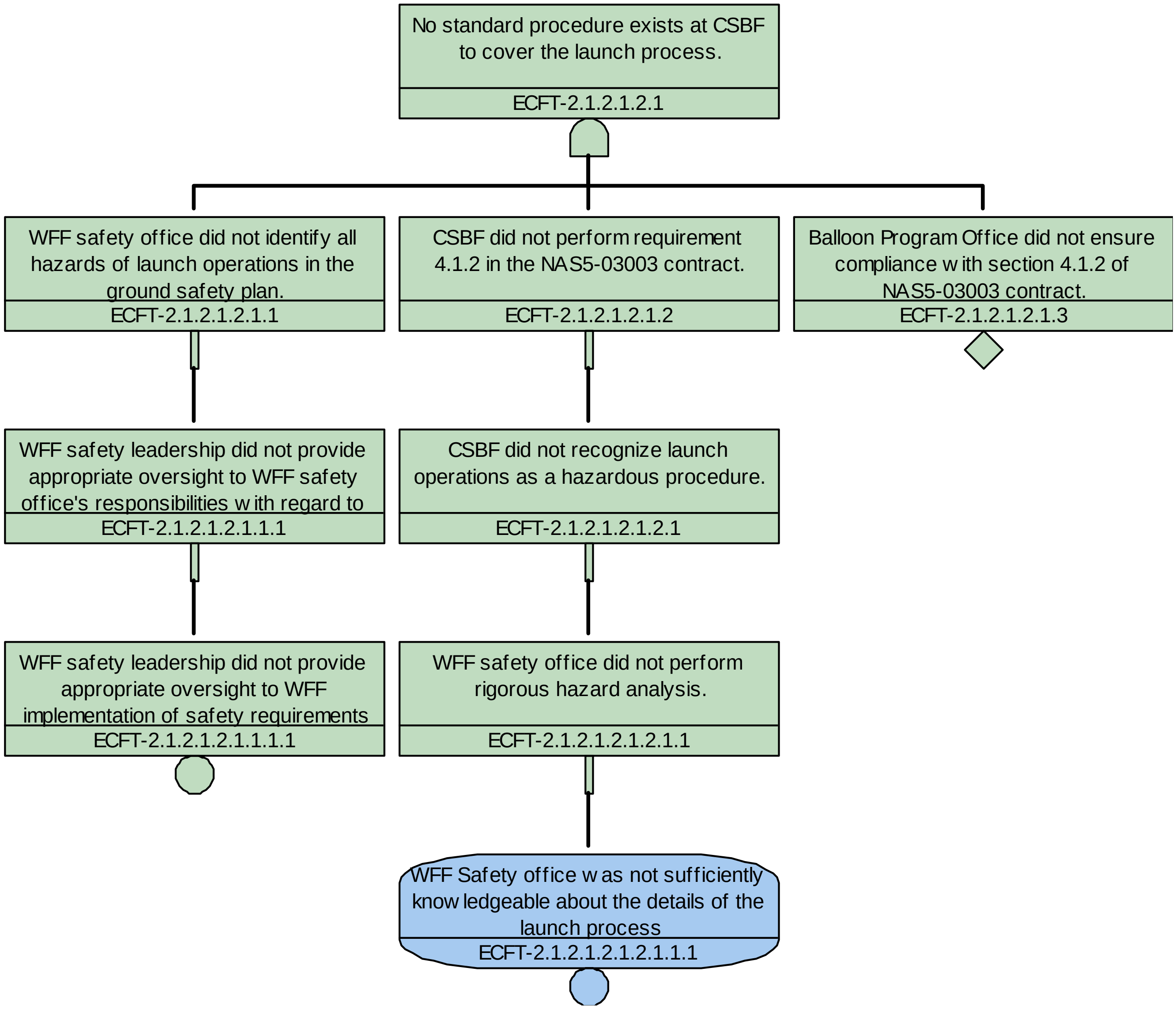


Figure 93. Repeated From PUO—No Standard Procedure Exists at CSBF to Cover the Launch Process

Discussion:

This cause traces down to three causes including 1) WFF Safety Office not identifying all hazards, 2) CSBF not establishing written procedures for hazardous operations and the 3)BPO not ensuring compliance with the NAS-03003 contract (which requires written procedures for hazardous operations).

The focus of these three intermediate causes for the PUO is to address the hazards and hazardous operations that target humans, specifically the public. For SUO1, the interpretation of these three intermediate cause and all causes that flow down from them must be expanded to include the assets as targets for the hazards. Likewise, causes associated with safety oversight must include safety of the assets.

That branch would be modified in the following manner to address the SUO1. The modified portions are discussed below.

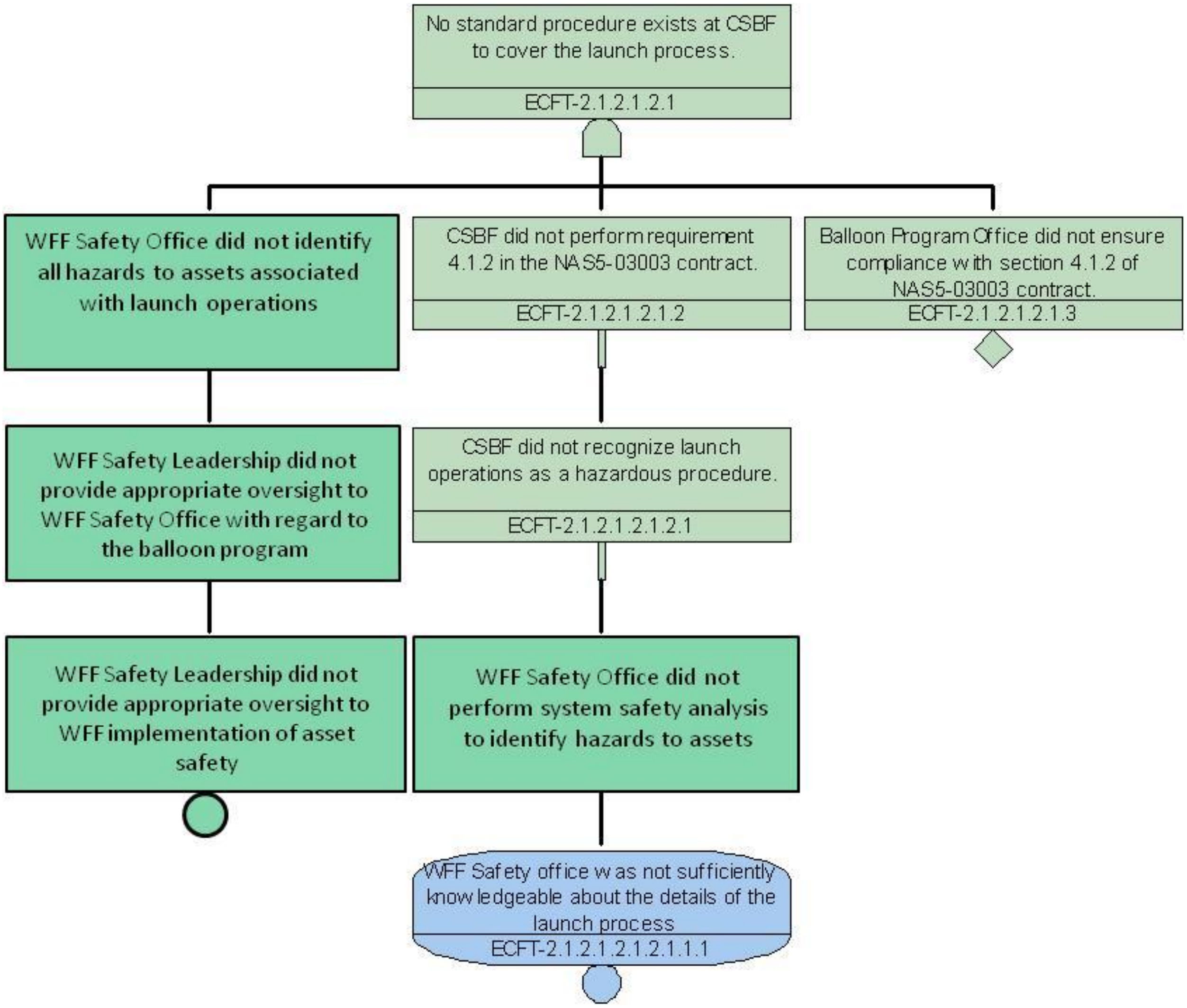


Figure 94. SUO1 - No Standard Procedure Exists at CSBF to Cover the Launch Process

It is evident from the documentation review that the value of the science payload was considered as part of the mission planning (820-CMPP-1002 “NCT Mission Project Plan). However, the protection for this significant asset (as well as for assets such as the balloon, helium, and other facility assets) is not well addressed in any process documentation.

A. **WFF Safety Leadership did not provide appropriate oversight to WFF SMA with regard to the balloon program.** There is no evidence that the leadership of the WFF Safety Office or Facility management required the consideration of hazards to assets in documentation, including procedures.

1. **WFF Safety Leadership did not provide appropriate oversight to WFF asset safety. <u>Root Cause SR1</u>**

Recommendation: WFF safety leadership should review and become knowledgeable about all safety requirements and plans implemented for the balloon program and ensure the proper flow-down of all safety requirements, including but not limited to NPR 8715.3 and NPR 8715.5 in order to protect the public, NASA workforce, high-value equipment and property and the environment.

This recommendation is identical to Recommendation A-3.

B. **WFF SMA did not perform systems safety analysis to identify hazards to assets. <u>Intermediate Cause SI1</u>**Through the interview process, it was communicated that in general the launch operation is a hazardous operation for both humans and assets. This is also evident from the review of launch videos, including the NCT mishap data. The board found no documentation to show that the hazards to the assets were identified or analyzed as part of the system safety process for this mission.

Recommendation: WFF Safety Office should perform a complete hazard analysis, in accordance with NPR 8715.5, section 3.2 Range Safety Analysis. All phases of the balloon launch process should be considered. This hazard analysis should be validated by independent review.

This recommendation is identical to Recommendation I1-1. Note that the proper execution of NPR 8715.3 and 8715.5 will encompass the analysis of hazards to the assets and the development of procedures required for mitigation.

3.6.4.2 ECF Analysis for SUO2—Contractor personnel were endangered when the payload inadvertently released from the launch head.

The MIB used the work products created in the analysis of the causes for the PUO as a starting point for analysis of the SUO2. Of the three PUO proximate causes (P), which included P1) payload separated from the launch vehicle, P2) released payload was dragged downwind by the balloon and P3) people in the general public were in the projected flight path, all causes are necessary and sufficient to cause the danger to the personnel that occurred during this mishap. These three proximate causes were then traced down the E&CFT to determine if the intermediate causes for the PUO were necessary and sufficient for the SUO2.

Analysis of the E&CFT reveals that all causes and conditions for POU are identical for SUO2.

The MIB feels that the recommendations produced from the PUO address the personnel safety issues for this secondary undesired outcome. No additional recommendations are required.

3.6.5 Items Ruled Out

The “Items Ruled Out” were initially considered during the construction of the mishap FT as either potential causes or potential contributing factors to the balloon launch mishap. Refuting evidence or the lack of substantiating evidence gathered during the investigation has subsequently allowed these items to be ruled out as either causes or contributors. The following items were eliminated from further consideration and do not appear on the Event and Causal Factor Tree (E&CFT). They are listed in this section for the sake of completeness.

3.6.5.1 Potential Causes—Ruled Out

PCRO-1: Eye bolt was faulty. A visual inspection of the eyebolt and a favorable comparison of the manufacturer's ultimate load rating (7015 lbs) with the predicted load at time of failure provided evidence to rule out a faulty eyebolt as a potential cause.

PCRO-2: CSBF launch team ignored the requirement that the Category A zone is valid from inflation through payload release. Interview evidence substantiated that the launch team did consider the Category A zone valid throughout payload release. The zone was not closely monitored and breaching of the zone yielded no consequence; however evidence suggests that the zone was neither fully understood, clearly marked, nor closely monitored and that no procedures were in place to prescribe actions for breaching the zone. These factors were causes and contributors to the incident. There is a lack of evidence to suggest that the requirement was intentionally ignored; therefore this was ruled out as a potential cause

PCRO-3: Launch mechanism broke. Field Test 1 determined that the mechanism functioned nominally under no-load and showed that there were no mechanical or configuration-dependent conditions that prevented proper operation of the release mechanism; therefore, the launch mechanism broke was ruled out as a potential cause.

PCRO-4: Cables were tangled, jamming release. Visual inspection, a series of field tests and substantial photographic evidence provided the refuting evidence to rule out tangled cables jamming the release as a potential cause.

PCRO-5: Launch mechanism was not properly assembled and/or maintained. Visual inspection, a series of field tests, maintenance record review and photographic evidence provided the refuting evidence to rule out improper assembly and improper maintenance of the launch mechanism as potential causes. Note that the insufficient lubrication of the restraint pin was carried forward as a contributing factor. (Reference CF1)

PCRO-6: Eyebolt was destroyed due to sabotage. There is no evidence to support or even to raise suspicion that sabotage played a role in the incident; therefore eyebolt destroyed by sabotage was ruled out as a potential cause.

PCRO-7: Eyebolt was destroyed due to horseplay. There is no evidence to support or even to raise suspicion that horseplay played a role in the incident; therefore eyebolt destroyed by horseplay was ruled out as a potential cause.

PCRO-8: Cables were frayed. Visual inspection and photographic evidence ruled out that the cables were frayed; therefore frayed cables were ruled out as a potential cause.

PCRO-9: Cables were destroyed due to sabotage. There is no evidence to support or even to raise suspicion that sabotage played a role in the incident; therefore cables destroyed by sabotage was ruled out as a potential cause.

PCRO-10: Cables were destroyed due to horseplay. There is no evidence to support or even to raise suspicion that horseplay played a role in the incident; therefore cables destroyed by horseplay was ruled out as a potential cause.

3.6.5.2 Potential Contributing Factor—Ruled Out

PCFRO-1: Wind exceeded safe limits. Refuting evidence provided by the Balloon Program Office showed that the winds at the time of launch were in family with historical wind conditions for previous NASA balloon launches. Winds exceeded safe limits was ruled out as a potential cause.

PCFRO-2: Crane was in high-traction mode. Evidence provided by interview was refuting evidence that the crane was in high-traction mode; therefore crane in high-traction mode was ruled out as a potential cause.

4.0 Findings

This MIB found the following issues that contributed to this incident. Major causes, proximate and intermediate causes are discussed in this section.

4.1 Proximate Causes

A Proximate Cause is the event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in the occurrence of the undesired outcome and, if eliminated or modified, would have prevented the undesired outcome.

Based on this definition the MIB noted three (3) proximate causes for this mishap.

P1 Proximate Cause: The NCT payload separated from the launch vehicle.

P2 Proximate Cause: The released payload was dragged downwind by the balloon.

P3 Proximate Cause: People in the general public were in the projected flight path.

4.2 Intermediate Causes

An Intermediate Cause is an event or condition that created the proximate cause that, if eliminated or modified, would have prevented the proximate cause from occurring.

Based on this definition the MIB noted 14 significant intermediate causes. The following were the significant intermediate causes:

I1 Intermediate Cause: WFF Safety Office did not perform rigorous hazard analysis.

I2 Intermediate Cause: A barrier to keep the general public out of all dangerous areas throughout the launch process did not exist.

I3 Intermediate Cause: No trained individual was in place to ensure public safety.

I4 Intermediate Cause: The ground safety plan did not cover all relevant hazards and

phases.

I5 Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process.

I6 Intermediate Cause: Launch crew training did not address failed launch attempts.

I7 Intermediate Cause: Category A hazard area during launch phase was not well-defined.

I8 Intermediate Cause: Terrain was rough and unimproved.

I9 Intermediate Cause: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt.

I10 Intermediate Cause: CSBF was not aware of hardware limitations that might give rise to a failure during a launch vehicle maneuver.

I11 Intermediate Cause: The ground safety plan did not explicitly address the protection of the general public.

I12 Intermediate Cause: The BPO did not have sufficient insight or oversight into the technical aspects of CSBF's balloon launch process.

I13 Intermediate Cause: WFF safety leadership did not provide appropriate oversight to WFF Safety Office's responsibilities with regard to the balloon program.

I14 Intermediate Cause: WFF safety leadership did not thoroughly review balloon safety documentation.

4.3 Contributing Factors

A Contributing Factor is an event or condition that may have contributed to the occurrence of an undesired outcome but, if eliminated or modified, would not by itself have prevented the occurrence.

Based on this definition the MIB noted the following contributing factors:

CF1 Contributing Factor: Restraint pin was not sufficiently lubricated.

CF2 Contributing Factor: Secondary release mechanism did not exist.

CF3 Contributing Factor: Wind created a challenging environment.

CF4 Contributing Factor: The launch process is fragile.

4.4 Root Causes

A Root Cause is one of multiple factors (events, conditions, that are organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated or modified, would have prevented the undesired outcome.

Based on this definition, the MIB identified six (6) NASA Root Causes for this mishap.

R1 Root Cause: WFF safety leadership did not ensure complete flow down of agency requirements to protect the public.

R2 Root Cause: WFF safety leadership did not provide appropriate oversight to WFF

implementation of safety requirements (WFF Safety Office and BPO as implementing organizations).

R3 Root Cause: WFF Safety Office was not sufficiently knowledgeable about the details of the balloon launch process.

R4 Root Cause: GSFC safety leadership did not verify or provide corrective action for flow-down of NASA requirements to protect the public.

R5 Root Cause: NASA Agency Range Safety Program failed to ensure corrective actions were accomplished from previous agency audits.

R6 Root Cause: Reliance on past success has become a substitute for good engineering and safety practices in the balloon program.

4.5 Observations

Several Observations were noted during this investigation. Although these observations were not direct contributors to the mishap, the board determined that they would be beneficial in improving awareness and/or preventing other potential types of safety issues.

O1 Observation: The hanging heavy payload was not identified as a hazard.

O2 Observation: The Launch Director was not wearing protective equipment for his hands while pulling the launch lanyard.

O3 Observation: The audits conducted of WFF safety in 2002 resulted in recommendations that, if properly implemented, would have made the undesired outcome extremely unlikely.

O4 Observation: Leaving the BPO and the CSBF responsible for classifying mishaps gives rise to sidestepping the requirements of a NASA incident response team.

O5 Observation: The Balloon Ground Safety Plan (BGSP) identifies an institutional RSQA, but it's not clear whether this is a person, organization, or a virtual entity.

O6 Observation: During the course of the investigation, the MIB obtained copies of two operating permits that were issued by Australia's Civil Aviation and Safety Authority (CASA): WOA 7058 dated 8 February 2010 and WOA 8064 dated 30 April 2010. The launch attempt of the NCT payload fell under the authority of WOA 7058. WOA 8064 was issued by CASA after the mishap. The "Approval" section of WOA 7058 states "I approve the area of Alice Springs Airport S23^{O} 48.4; E133^{O} 54.1 as an approved area for the operation of a heavy balloon." The MIB found the language to be ambiguous in that an area could not be defined by a single latitude/longitude point. The MIB observed that a revised permit (WOA 8064), accomplished after the mishap, contained a drawing that shows shaded "patrolled" area and one "closed" gate. Copies of these permits are shown in Appendix J. The MIB notes that both CASA operating permits contain ambiguous language regarding the approved area and that the shaded area in the revised permit is not adequate to cover all possible launch layout possibilities.

O7 Observation: Documented mishap response and recovery (contingency action plans) do not meet the requirements of NPR 8621.1B. There are no documented IRT processes in place. This was evident in all post mishap video and photos that depicted the general public within the vicinity of unexpended pyros, smoking chemical batteries, and dangerously sharp pieces of wreckage. Additionally, the CSBF team was observed with the science team handling the wreckage without any PPE. Interviews indicated that the personnel had no idea of what the recovery requirements were (if any). This lack of post mishap recovery requirements also led to the discard of damaged payload material to a scrap yard for recycling and the shipment of other payload material back to a university in California instead of being impounded. This was all done without the approval of the Investigating Authority (MIB). This was in violation of the NPR 8621.1.B requirements.

O8 Observation: BPO Mishap investigation and reporting is being conducted under 820-PG-8621.1.1B. The requirements in 820-PG-8621.1.1B do not meet the Agency's requirements documented in NPR 8621.1B.

O9 Observation: The safety organization at GSFC's WFF is not independent from projects and lacks the direct SMA reporting path that exists at GSFC's Greenbelt facility.

O10 Observation: CSBF personnel seemed unaware of a number of operational hazards and constraints.

O11 Observation: Members of the CSBF launch crew were not wearing hard hats during the launch operation as required by Section 4.1 of the Ground Safety Data Package.

O12 Observation: The Corrective Action from a previous balloon close call was not implemented for this program despite their apparent applicability. The Corrective Action was to require additional PPE and a protective structure for the launch crew. The incident (reference IRIS 2000-231-00012) involved a payload swinging out of control and nearly hitting crew members on the launch platform.

5.0 Recommendations

This section is a compilation of the recommendations that were derived from the findings identified by this investigation. Each one has been identified by the number used in the report and is traceable to the exact finding that it represents.

Table 4—Recommendations

Recommendation		Root Cause, Intermediate Cause, Contributing Factor, Observation
A-1	WFF safety leadership should verify that all elements of the public (people in nearby populated areas, spectators, and passers-by) as well as NASA workforce, high-value equipment and property and the environment are protected from all credible hazards, identified by thorough, formal, hazard analysis, covering all phases of balloon operations from set-up through termination and recovery.	**R1, R2**
A-2	WFF safety leadership should regularly verify, through a minimum annual audit, BPO's oversight of safety at balloon launches and the WFF Safety Office's activities to ensure safety at balloon launches.	**R2**
A-3	WFF safety leadership should review and become knowledgeable about all safety requirements and plans implemented for the balloon program and ensure the proper flow-down of safety requirements, including but not limited to NPR 8715.3 and NPR 8715.5 in order to protect the public, NASA workforce, high-value equipment, property and the environment.	**R1, R2**
B-1	WFF Safety Office should obtain expertise in the precise details of the balloon launch process through training and direct interaction to ensure their own capability to produce balloon ground safety documentation	**R3**
C-1	GSFC safety leadership should provide oversight to ensure that exhaustive measures are taken to safeguard the public in the balloon program with no less fervor than is imparted to other activities and programs at GSFC. The GSFC safety leadership should also provide oversight to ensure protection of the NASA workforce, high-value equipment, property, and the environment.	**R4**
D-1	NASA Agency Range Safety Program should exhaustively follow up on audit recommendations and elevate any conditions of inaction for safety-related concerns to prevent unsafe activities from continuing.	**R5**
D-2	NASA Range Safety audit functions should be added to the NASA Safety Center Audits and Assessments responsibilities.	**R5**
E-1	The BPO, WFF, GSFC, and SMD should avoid considering a particular mission success rate or lack of safety incidents to be a sign that activities have been or are currently safe.	**R6**
E-2	NASA Safety Center (NSC) should generate a Case Study based on the common problem that the reliance on past success becomes a substitute for good engineering and safety practices.	**R6**

Recommendation		Root Cause, Intermediate Cause, Contributing Factor, Observation
SUO R1-1	WFF safety leadership should review and become knowledgeable about all safety requirements and plans implemented for the balloon program and ensure the proper flow-down of all safety requirements, including but not limited to NPR 8715.3 and NPR 8715.5 in order to protect the public, NASA workforce, high-value equipment and property and the environment. This recommendation is identical to Recommendation A-3.	**R1, R2**
I1-1	WFF Safety Office should perform a complete hazard analysis in accordance with the NPR 8715.5 section 3.2 Range Safety Analysis. All phases of the balloon launch process should be considered. This hazard analysis should be validated by independent review.	**I1**
I2-1	In each launch location, the BPO should ensure that dedicated safety personnel thoroughly examine(s) the potential for spectators or passers-by entering hazardous areas and implement barriers or controls to prevent entry during the launch process.	**I2**
I3-1	WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring mission success.	**I3**
I4-1	The WFF Safety Office should revise the BGSP to cover all phases, from inflation through recovery, identify all hazards from the Hazard Analysis, and resulting restrictions and implementation of operational requirements.	**I4**
I5-1	The BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3, Section 3.8 Hazardous Operations.	**I5**
I5-2	BPO should establish Launch Commit Criteria and flight rules.	**I5**
I5-3	BPO should establish and document firm and unambiguous criteria for aborts during the launch phase.	**I5**
I6-1	BPO should ensure that training for the launch crew covers the widest possible set of anomalous occurrences in the launch process including, but not limited to, failed launch attempts, breaches and near-breaches of the Hazard Zone, loss of payload control straps, loss of communication, and scenarios that would lead to an abort.	**I6**
I7-1	WFF Safety Office should clearly and unambiguously define the Category A hazard area and should require that it be implementable in practice with visible markings.	**I7**
I8-1	BPO should perform a cost, utility, and feasibility assessment for improving the terrain at Alice Springs Airport.	**I8**
I9-1	BPO should require in the contract that CSBF perform a thorough analysis of the payload restraint and release system to establish an acceptable angular range of balloon relative to crane for launch attempt.	**I9**

Recommendation		Root Cause, Intermediate Cause, Contributing Factor, Observation
I10-1	BPO should evaluate balloon launch hardware mechanisms through testing and review of documentation and specifications to determine proper operating conditions and ranges. The results of this evaluation should then be used to define operating limits of launch hardware and specify abort criteria.	**I10**
I11-1	WFF Safety Office should specifically address how to deal with the general public in the ground safety plan.	**I11**
I12-1	The BPO should become knowledgeable about the technical aspects of the launch process and gain an understanding of the hardware capabilities, limitations, operating bounds, and failure modes.	**I12**
I13-1	WFF safety leadership should ensure that WFF Safety Office is implementing an effective safety program that is applicable and consistent across the facility and for all contracts.	**I13**
I14-1	WFF safety leadership should review WFF balloon safety documentation for clarity and accuracy through a formal review process on at least an annual basis.	**I14**
CF1-1	BPO should perform analysis and/or test to determine the relationship between pin lubrication and lanyard pull force to establish lubrication guidelines for proper operation.	**CF1**
CF2-1	BPO should analyze, evaluate, and test the hardware to understand its capabilities and operating range, as well as to determine failures and associated sensitivities.	**CF2**
CF3-1	The BPO should establish firm, written criteria for wind limits and factor these into all go/no-go and abort criteria and any specific restrictions on a particular launch.	**CF3**
CF4-1	A. The BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3, Section 3.8 Hazardous Operations. B. BPO should ensure that training for the launch crew covers the widest possible set of anomalous occurrences in the launch process including, but not limited to, failed launch attempts, breaches and near-breaches of the Hazard Zone, loss of payload control straps, loss of communication, and scenarios that would lead to an abort.	**CF4**
O1-1	WFF Safety Office should identify the hanging payload as a hazard and follow relevant standards and requirements for hanging payloads to ensure protection of personnel and the general public.	**O1**
O2-1	WFF Safety Office should determine whether gloves or other PPE should be required for pulling the launch lanyard.	**O2**
O3-1	WFF Safety Office should ensure that all actions from the 2002 independent	**O3**

Recommendation		Root Cause, Intermediate Cause, Contributing Factor, Observation
	assessment are closed out thoroughly and completely, in particular, Items 5, 6, 9, and 21 referenced from the document "WFF range safety independent assessment response." GSFC safety management and the NSC should verify compliance with these recommendations.	
O4-1	WFF safety leadership should ensure that the mishap and contingency plan along with contracts associated with balloon campaigns adhere to requirements for an Incident Response Team (IRT) put forth in NPR 8621.1B.	**O4**
O5-1	The RSQA for CSBF should be an approving authority and knowledgeable about the BGSP and should be responsible for ensuring its completeness and proper implementation in the field.	**O5**
O6-1	The BPO should determine the full intention of CASA operating permits issued by the Australian government and be sure that they are properly implemented by CSBF and UNSW, along with stand-alone NASA range requirements.	**O6**
O7-1	WFF safety leadership should develop a mishap preparedness and contingency plan for BPO that adheres to the requirements put forth in NPR 8621.1B.	**O7**
O8-1	WFF needs to ensure that mishaps are appropriately classified and investigations are accomplished in accordance with NPR 8621.1B. Any program level procedures for mishap investigation and reporting should be coordinated with Code 300 and if necessary with OSMA to ensure they meet the agency level requirements.	**O8**
O9-1	GSFC should establish an organizational structure for safety that is consistent across Goddard’s Greenbelt and Wallops facilities, where the entire chain of the safety organization below the GSFC Center Director is independent of the projects, as is currently in place for the Code 300 organization at Goddard’s Greenbelt facility.	**O9**
O12-1	The BPO and the WFF Safety Office should ensure that all applicable lessons learned relating to balloon launches, including IRIS reports are examined and if applicable, that the corrective actions are implemented across the balloon program.	**O12**

National Aeronautics and Space Administration

Nuclear Compton Telescope Balloon Launch in Alice Springs, Northern Territory, Australia

High Visibility Type B Mishap

IRIS Case Number S–2010–119–00007

List of Appendices

Volume II of II

Date of Mishap: April 29, 2010

Date of Report: August 27, 2010

6.0 LIST OF APPENDICES

APPENDIX A: Event & Causal Factor Tree Diagram

<u>Event and Causal Factor Tree</u>

The event and causal factor tree is a graphical representation of only those events and conditions that have occurred and have caused or contributed to the undesired outcome. This is accomplished by the MIB evaluating the evidence and verifying that there are facts to demonstrate that each event or condition on the tree occurred. Events or conditions on the tree that the MIB were unable to find evidence that supported the event occurrence or the condition existed were eliminated from the tree.

APPENDIX B: Fault Tree

FAULT TREE

The NASA Nuclear Compton Telescope (NCT) Balloon Launch Mishap Investigation Board investigated the mishap using a "fault tree," a common organizational tool in systems engineering. Fault trees are graphical representations of every conceivable sequence of events that could cause a system to fail. The fault tree's uppermost level illustrates the events that could have directly caused the inadvertent release of the payload from the launch vehicle resulting in the damage to 2 POVs and the near catastrophic events to spectators watching the balloon launch. Subsequent levels comprise all individual elements or factors that could cause the failure described immediately above it. In this way, all potential chains of causation that lead to the mishap can be diagrammed, and the behavior of every subsystem that was not a precipitating cause can be eliminated from consideration.

The fault tree in itself is very large (over 620 elements) and intricate and was not able to be included in this report. The fault tree is stored with the final report in the NSC IRIS data base system under the RCA tool in which the tree was developed.

APPENDIX C: Test & Analysis

C1 – Tests

C2 - Analysis

C1 – Tests

Field Tests 1 and 2 of the Launch Head Truck Plate Restraint Cable Release Mechanism

With and Without Applied Pear Ring Loads

Summary: On May 13, 2010 from approximately 9 am to 10 am local time, a simple test was performed aimed at discovering the approximate forces required to pull the lanyard cable and retract the restraint cable release pin under a variety of loading conditions. The pear ring hanging from the *release* pin was subjected to a range of loading from zero to 1400 lbs in order to determine the relationship between the release pin shear loading and the load required to pull the release lanyard. The resulting lanyard forces ranged from approximately 50 lbs at zero load to 300 lbs at 1400 lbs load.

Background: Some evidence indicated that there was an attempt to pull the lanyard cable that retracts the release pin during the launch attempt, but the lanyard did not release the pin as expected. The test was designed to determine the approximate lanyard force required to release the pin under several conditions. Since the release pin can be loaded through a ring via the restraint cables, a variety of loads was applied to a flight type ring using suspended loads.

Mechanism description: The release mechanism uses a spring loaded pin through a pillow block to retain a ring connected to the restraint cables. The pin is actuated through a 3/16 inch metal cable attached to the base of the pin and travels through a 90 degree pulley to a fulcrum arm that pivots on the launch head frame. A cable continues back from the outer end of the fulcrum arm through a metal ring back toward the personnel platform on the front of the launch vehicle. The fulcrum measurements of interest are 13.5 inches and 4.5 inches, providing a 3:1 mechanical advantage. The pin is held in the engaged position with a preload spring which reacts against the launch head frame and the base of the pin. The pin is 1 inch in diameter and engages the far pillow block by approximately 3/8 inch. (See Figures C1-1 through C1-3).

The truck plate is retained on the main *launch* pin by two ¼ inch steel cables that attach to the bottom of the truck plate via eyebolts and swaged cable ends. This cable pair terminates in the direction of the launch vehicle in a pear shaped ring. It is this pear ring that is captured by the engaged restraint pin in the pillow block. (See figure C1-4).

It was noted during pre-test observations that the restraint pin was not well lubricated and felt relatively ‘dry’ to the touch. This was also true of the pulley used to redirect the cable from the release pin to the fulcrum.

Significance of the test: During the launch process, the launch director is required to release the truck plate from the launch pin via the release lanyard. If the restraint pin is loaded through the pear ring, the lanyard pull force increases with increase pin loading. Forces are created through friction with the pear ring and with the pillow block. The test is intended to determine the relationship of pear ring loading to the required lanyard pulling force.

Test Set Up and Procedure (As Run): The crane and launch head were used in their unchanged flight conditions. The crane boom was positioned in the transportation position (horizontal) rather than in the raised launch condition. This configuration is shown below.

Figure C1-1. Launch Head Mounted to Crane

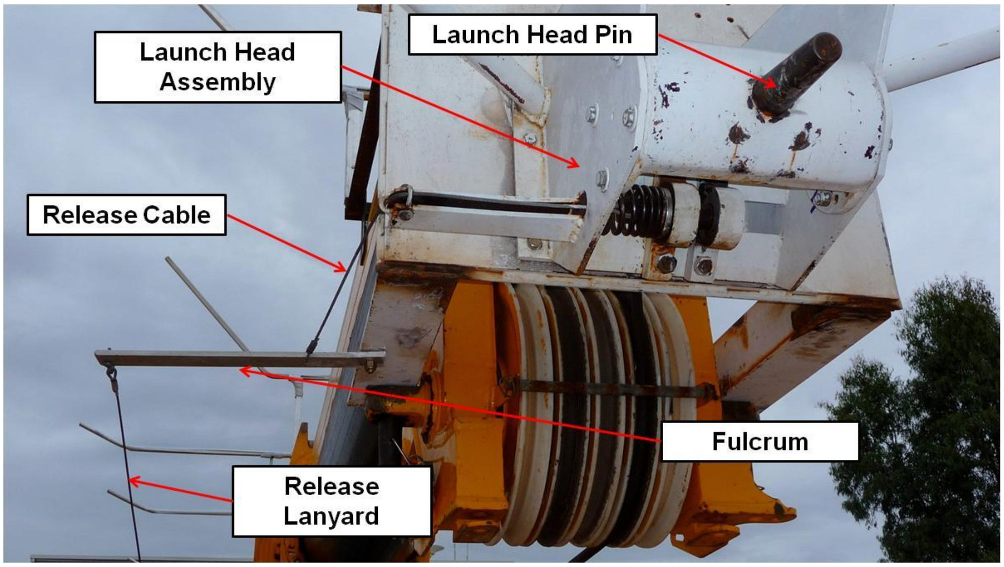


Figure C1–2. Launch Head Mounted to Crane

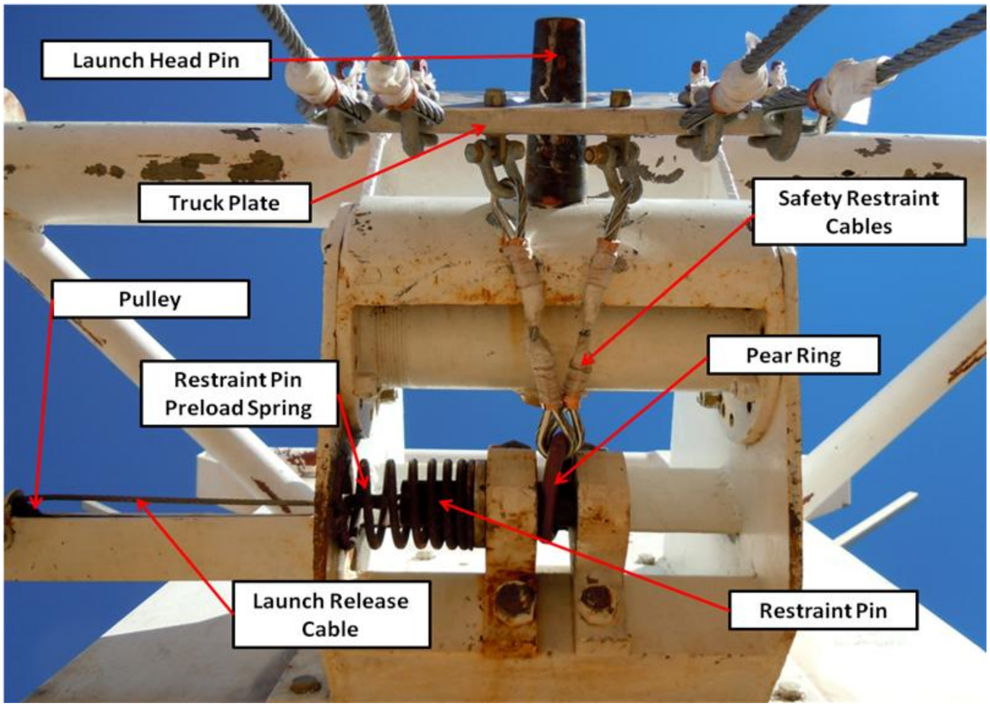


Figure C1–3. Annotated View From Under Launch Head

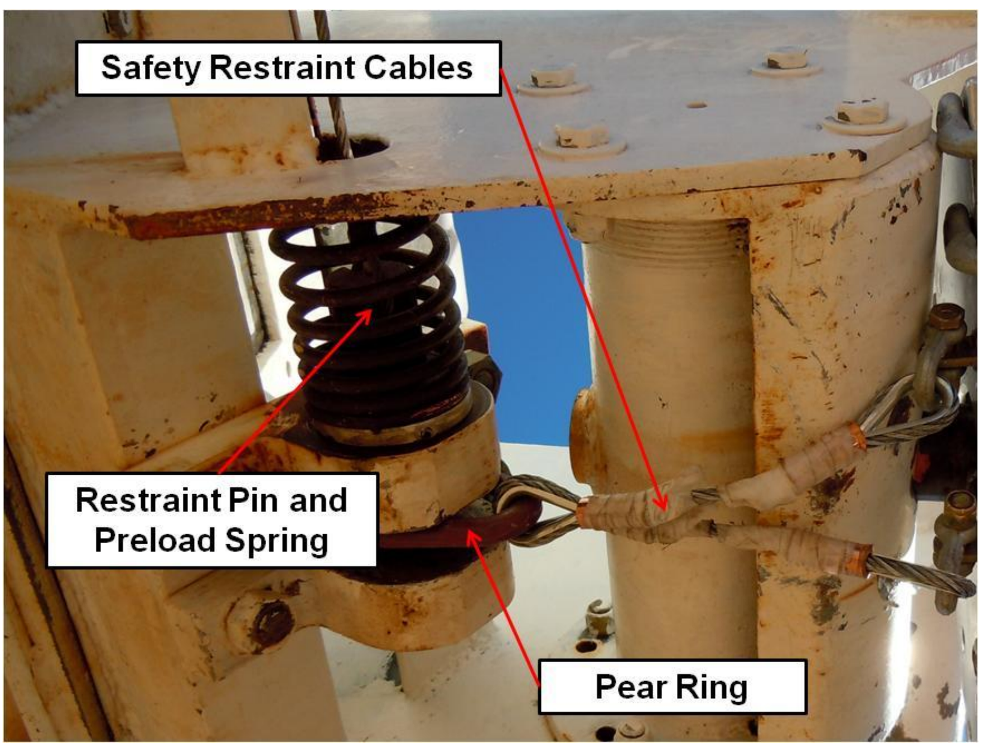


Figure C1–4. Another View of the Launch Head Assembly

A new pear ring with a lift strap was placed in the restraint mechanism over the pin within the pin block in the same way as the pear ring is captured during operations. (See Figures C1-5 and C1-6). Premeasured loads of 300, 600 and 1400 pounds were suspended. The 300 and 600 pound loads were hook and pulley blocks and the 1400 pound load was a concrete block.

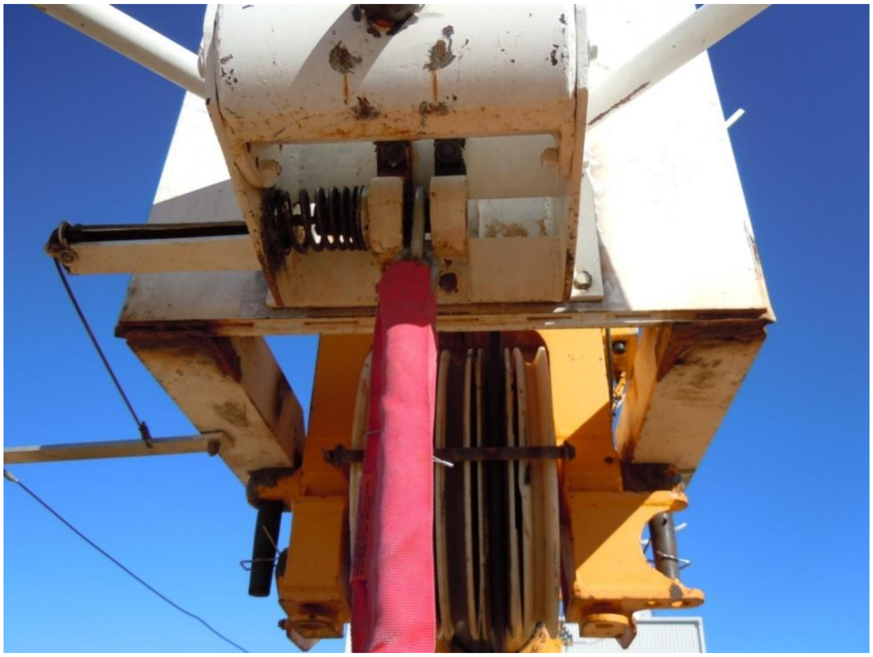


Figure C1–5. Test Configuration with Loading Hardware

Figure C1–6. Full Test Configuration with Load

A scale was used to determine the pull force required to retract the pin and release the load from the restraint pin. For loads up to 50 lbs, a digital "fish scale" (Figure C1-7) was selected and for loads in excess of 50 lbs, an in-line digital readout load scale (Figure C1-8) was used.

Figure C1–7. Spring Type Hand Scale

Figure C1–8. Load Cell Type Digital Scale

The 3/16" steel cable lanyard was fed back through the eyebolt (Figure C1-9) that is used to redirect the lanyard down to the flight director who is located in the personnel basket on the front of the crane. The eyebolt with lanyard is shown below.

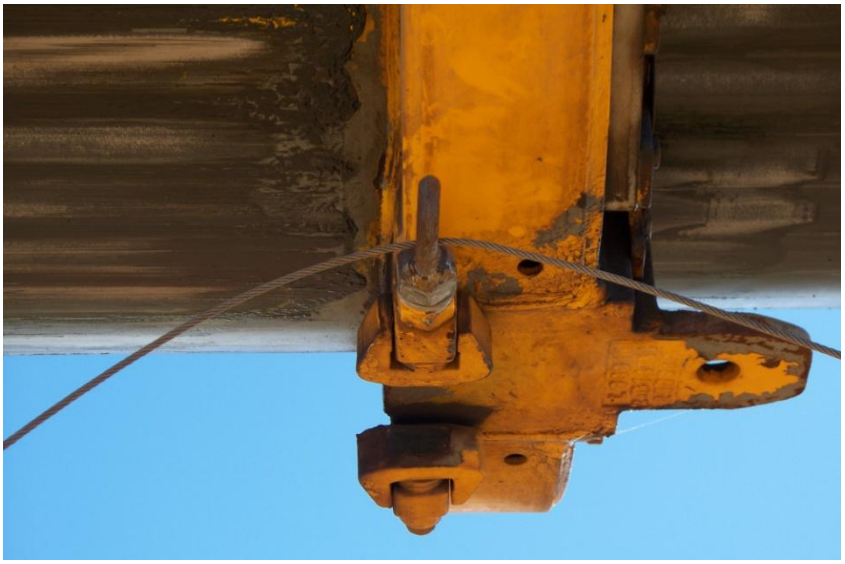


Figure C1–9. Steel Release Lanyard through Eye on Crane Boom

The lanyard force measurements were taken by applying pulling force by hand and reading real time from the scale display (Figure C1-10). The lanyard pulling force measurements were estimated to be within +/- 10 lbs using this technique. Multiple people were used to apply the force when necessary.

Figure C1-10. Side view of Crain

Test Results:

Table C1-11 below shows the raw results for Field Test 1 & 2. Field Test 1 was conducted to determine the "no load" force required to release just the pear ring. This was repeated several times and the results are shown below.

In Field Test 2 convenient objects were used to increase the shear loading on the restraint pin. As stated above, this test was accomplished in a very short period of time and only one measurement was made for each suspended load. A quick look at the data shows, as expected, the lanyard pull force increased as the suspended load was increased. Figure C1-12 depicts the results graphically.

Suspended Load	Units	Lanyard Force Required	Units	Uncertainty
0	lb	47	lb	+/- 5 lbs
0	lb	54	lb	+/- 5 lbs
0	lb	50	lb	+/- 5 lbs
300	lb	110	lb	+/- 10 lbs
600	lb	200	lb	+/- 10 lbs
1400	lb	290	lb	+/- 10 lbs

Figure C1–11. Results of Field Tests 1 & 2 for Direct Loading of Restraint Pin

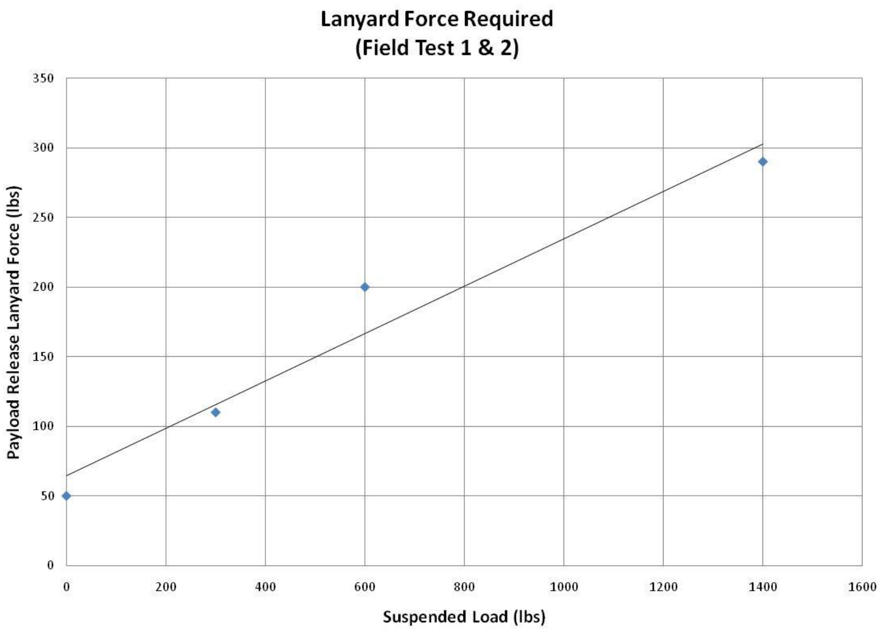


Figure C1–12. Field Tests 1 & 2 Results: Direct Loading of Restraint Pin with Least Squares Best Fit Line

Test Conclusions:

The results of this test were generally as expected, showing an increase of the required lanyard pull force with increasing load on the pear ring. The pull force without any pear ring load is about 50 lbs. While the determination is somewhat subjective, the pull force would become difficult for the average person in the 80 to 125 lb range, which is reached between 200 and 350 pounds of suspended weight.

A simple analysis of the force transfer appears to be consistent with the test results. Figure C1–13 repeats the test data with the addition of predicted lanyard forces assuming that the fulcrum advantage is 3:1 and that the effective coefficient of friction between the pear ring and the restraint pin is 0.60. This coefficient of friction is consistent with kinetic friction between two non-lubricated pieces of steel. In this system there are also some losses in the pulley and at the eyebolt that also is proportional to the total load.

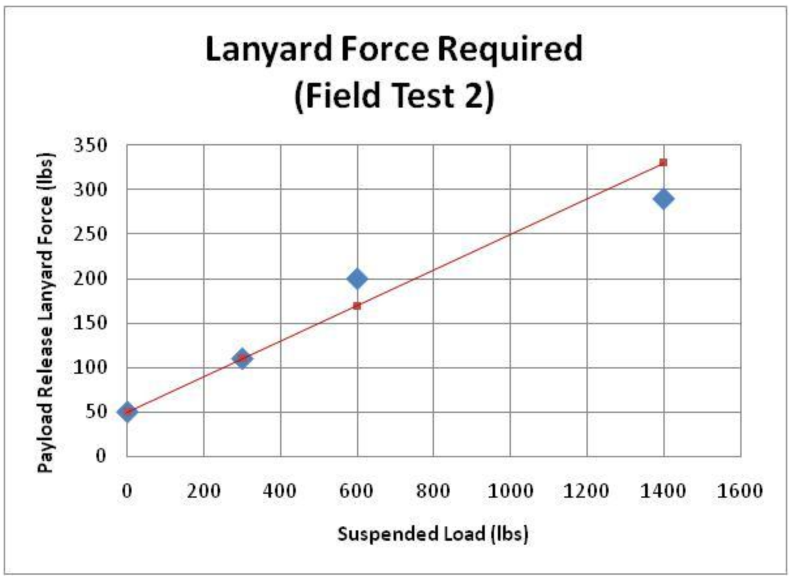


Figure C1–13. Modeled (in red) and Measured (blue diamonds) Lanyard Force vs Pear Ring Load

Field Test of the Launch Head Truck Plate Restraint Cable Release Mechanism with Applied Truck Plate Loads

Summary: On May 14, 2010 from approximately 1 pm to 4 pm local time, a simple test was performed aimed at discovering the approximate forces required to pull the lanyard cable and retract the restraint cable release pin as a result of applied loads to the truck plate. This test differed from the previous day's test in that the loads were applied to the truck plate instead of directly to the pear ring. The purpose of the test was to determine if loads applied to the truck plate through the flight train during launch operations would be translated into loads on the pear ring sufficient to make release difficult for personnel. The truck plate was loaded in several representative ways to simulate potential launch loads. (See Figure C1-14 for the basic setup). The applied loads were limited for two reasons: 1. To keep the crane and fitting loads many multiples below the ratings for safety, 2. To keep the required lanyard loads small enough for two people to be able to actuate the release – this simplified the test setup. The applied loads were approximately 1000 and 2000 lbs and were applied at forward and side angles of approximately 8 degrees and 15 degrees, including combinations of forward and side angles. The resulting lanyard forces ranged from approximately 100 lbs at 1000 lbs with zero forward and side angles to approximately 210 lbs at 2000 lbs with 15 degrees forward angle and zero degrees side angle.

Background: Some evidence indicated that there was an attempt to pull the lanyard cable that retracts the release pin during the launch attempt, but the lanyard did not release the pin as expected. The test was designed to determine the approximate lanyard force required to release the pin under several loading conditions.

Mechanism description: The release mechanism uses a spring loaded *restraint* pin through a pillow block to retain a ring connected to the restraint cables. The pin is actuated through a 3/16 inch metal cable attached the base of the pin and travels through a 90 degree pulley to a fulcrum arm that pivots on the launch head frame. A cable continues back from the outer end of the fulcrum arm through a metal ring back toward the personnel platform on the front of the launch vehicle. The fulcrum measurements of interest are 13.5 inches and 4.5 inches, providing a 3:1 mechanical advantage. The pin is held in the engaged position with a spring which reacts against the launch head frame and the base of the pin. The pin is approximately 1 inch in diameter and engages the far pillow block by approximately 3/8 inch.

The truck plate is retained on the main launch pin by two ¼ inch steel cables that attach to the bottom of the truck plate via eyebolts and swaged cable ends. This cable pair terminates in the direction of the launch vehicle in a pear shaped ring. It is this pear ring that is captured by the engaged restraint pin in the pillow block.

The *launch* pin is tapered and is typically adjusted in the launch head so that when the launch vehicle (crane) boom is raised in to launch position (about 27.5 degrees), the effective angle of the bottom of the pin relative to the horizontal is approximately 16.75 degrees above the horizon.

Please reference the "Field Test of the Launch Head Truck Plate Restraint Cable Release Mechanism with Applied Pear Ring Loads" for additional figures of the mechanism.

Significance of the test: During launch operations, if the net upwards force on the truck plate is applied at an angle forward of normal to the bottom of the launch pin, a component of that force will be carried by the restraint cables and pear ring into the restraint pin. The purpose of the restraint hardware is to prevent the truck plate from coming free from the launch pin before it is desired. A concomitant result is that normal (or shear) loading on the restraint pin is a factor of the various forces on the cable ladder introduced by the buoyant and aerodynamic forces on the balloon and by the gondola. A forward angle (balloon ahead of the launch vehicle) of the flight train loading tends to pull the truck plate away from the launch head and toward the end of the launch pin. (See Figure C1-15)

Figure C1–14. Basic Loading Set-Up for Forward Load Angle

This action extends the restraint cables and loads the restraint pin. Generally, the greater the forward angle, the greater part of the force is reacted at the restraint pin.

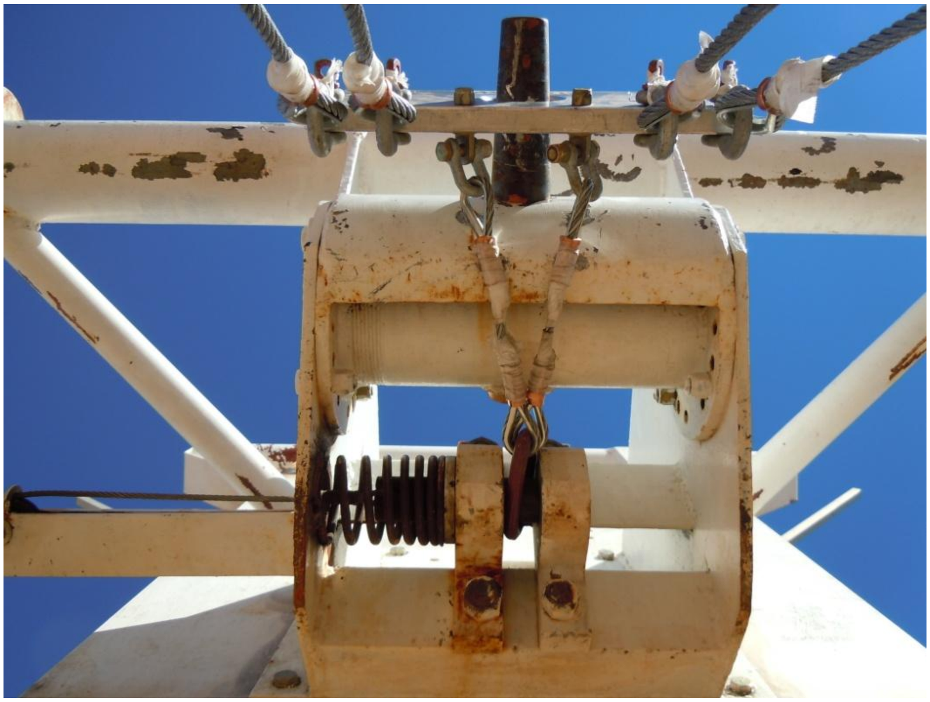


Figure C1–15. Position of the Truck Plate and Restraint Cables When Pulled Forward

Note: Cables to Upper Crane for Test are not Shown Here

In addition, a sideward angle has the effect of lifting the nearer (to the direction of the load) corner of the track plate and twisting the truck plate such that the nearer restraint cable is loaded due to the twisting action of the truck plate. (See Figure C1–16) The safety restrain cable on the low end of the truck plate is unloaded. The test was intended to quickly assess the possible individual and combined effects of these two loading conditions.

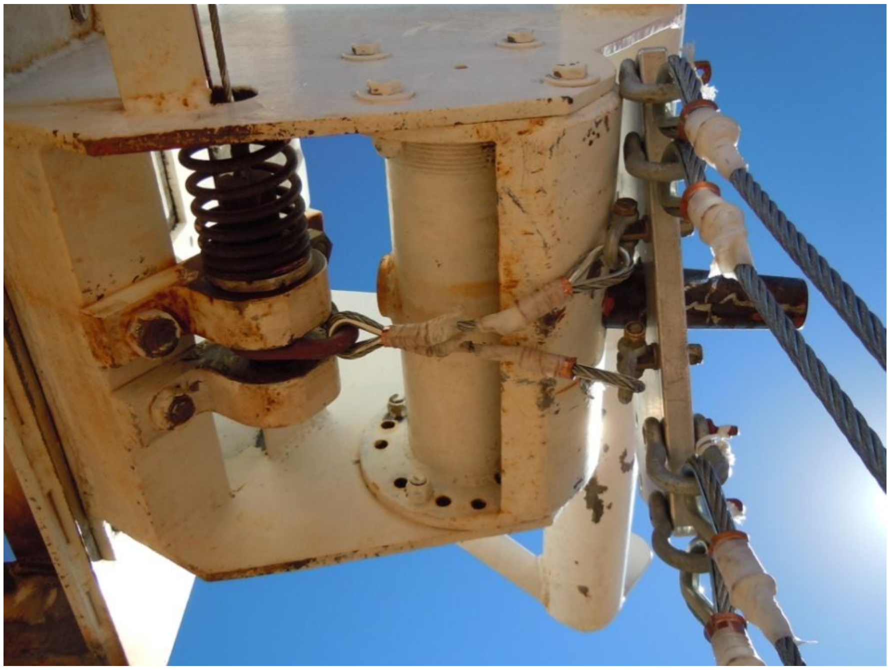


Figure C1–16. Truck Plate Twisted by a Manually Applied Force

Test Procedure (As Run):

The crane and launch head were used in their unchanged flight condition. Unlike the first tests, the boom was raised to the launch angle of approximately 27.5 degrees. This boom launch angle was repeatable due to steel chain restraints on the boom that had not been altered from the launch attempt.

A truck plate prepared for the next flight was used in the test. It was installed on the launch head with the restraint cables in normal flight configuration. The four cables that normally would carry the load of the gondola were attached to the top of the truck plate to simulate introducing loads through the flight train. No gondola load was applied.

A second yard crane was rented and used to apply an upward load to the truck plate through a load cell. The load cell had a mechanical dial readout and was rated to 5000 lbs. The yard crane also had a load readout.

For each loading condition, photographs were taken to record the approximate forward and side load angle of the test. The applied load was measured by sight through a pair of binoculars and confirmed with the yard crane operator. It should be noted that due to time constraints, the field tests were limited to a few test combinations and the applied angles were approximated when loading and determined after the tests were complete.

Test Results:

The table below C1-17 shows the raw test results. A quick look at the data shows that the lanyard pull force varies as the forward and side loads change magnitude and direction. Generally, as the forward angle increases and the load increases, the lanyard force increases. Side angle without forward angle also results in increased required lanyard force, but the relationship isn't as strong as for the forward load angle. (See Figures C1-18 through C1-20)

Note that for combined forward and side load test cases L and M, the resulting lanyard force dropped as the side load increased from 12 to 22 degrees with a roughly constant forward angle (18 to 16 degrees). This test was repeated in test N because the result was not necessarily expected.

Lanyard Pull Force vs Truck Plate Load

Test	Associated Photos	Upward Load	Units	Uncertainty	Forward Load Angle	Sideward Load Angle	Lanyard Force Required	Units	Uncertainty
							Incl ~ 20 lbs Load Cell Weight		
A	100_1902	850	lb	+/- 50 lbs	0	0	88	lb	+/- 10 lbs
B	100_1903	1000	lb	+/- 50 lbs	0	0	75	lb	+/- 10 lbs
C	100_1905	1900	lb	+/- 50 lbs	0	0	110	lb	+/- 10 lbs
D	100_1908	1000	lb	+/- 50 lbs	9.9	0	110	lb	+/- 10 lbs
E	100_1911	1810	lb	+/- 50 lbs	12.6	0	165	lb	+/- 10 lbs
F	100_1913	1000	lb	+/- 50 lbs	23	0	180	lb	+/- 10 lbs
G	100_1916	1950	lb	+/- 50 lbs	17	0	210	lb	+/- 10 lbs
H	100_1919	1000	lb	+/- 50 lbs	0	18.3	90	lb	+/- 10 lbs
I	100_1923	2000	lb	+/- 50 lbs	0	9.25	90	lb	+/- 10 lbs
J	100_1925	1000	lb	+/- 50 lbs	0	17	100	lb	+/- 10 lbs
K	100_1926	2000	lb	+/- 50 lbs	0	15.3	150	lb	+/- 10 lbs
L	100_1927, 1928	1000	lb	+/- 50 lbs	18	12.4	210	lb	+/- 10 lbs
M	100_1929, 1930	1000	lb	+/- 50 lbs	15.75	22	115	lb	+/- 10 lbs
N	100_1931, 1932	1000	lb	+/- 50 lbs	17.5	22.8	115	lb	+/- 10 lbs

Figure C1–17. Field Test 3 Tabulated Measured Data

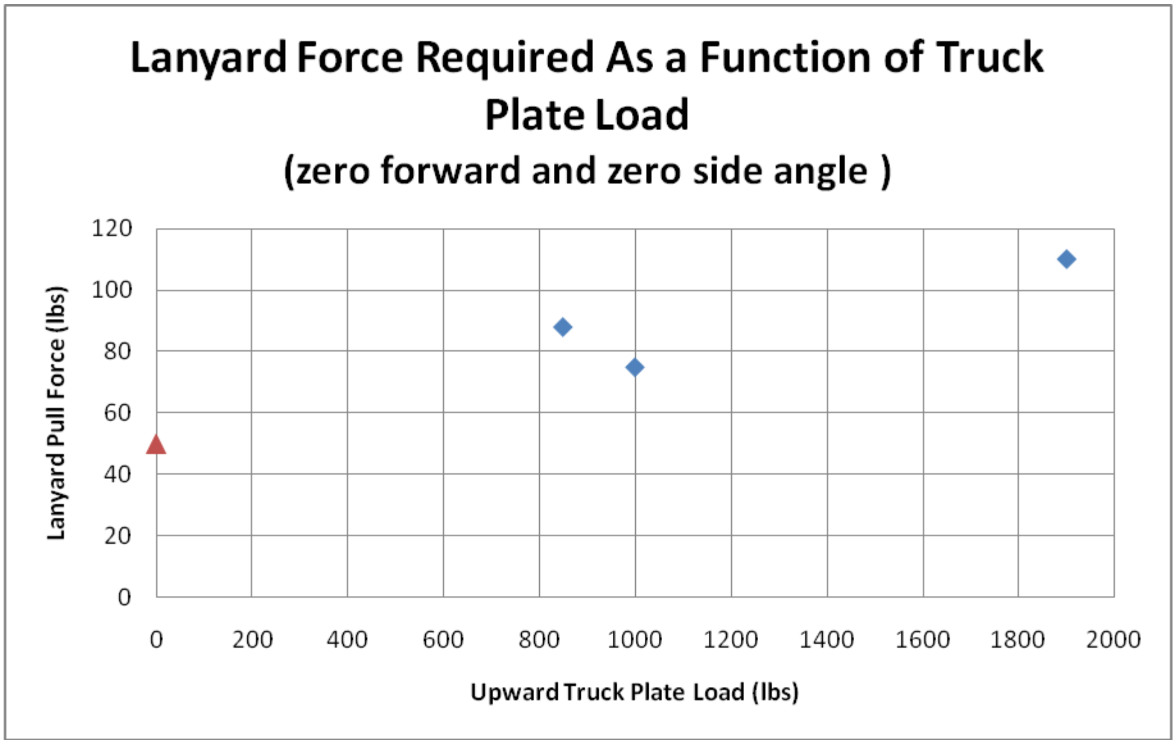


Figure C1–18. Lanyard Force vs Vertical Load (Data at zero load is taken from Test 1)

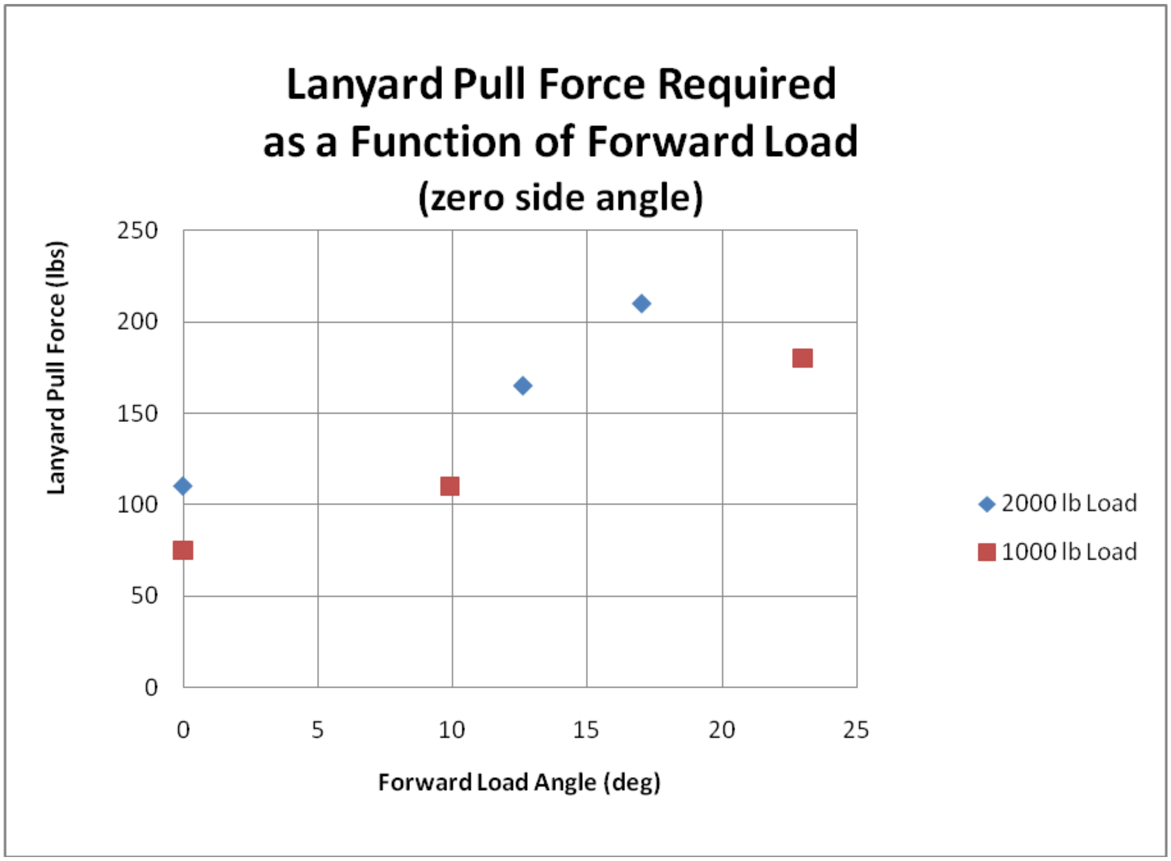


Figure C1–19. Lanyard Force vs Forward Load Angle and Load Magnitude

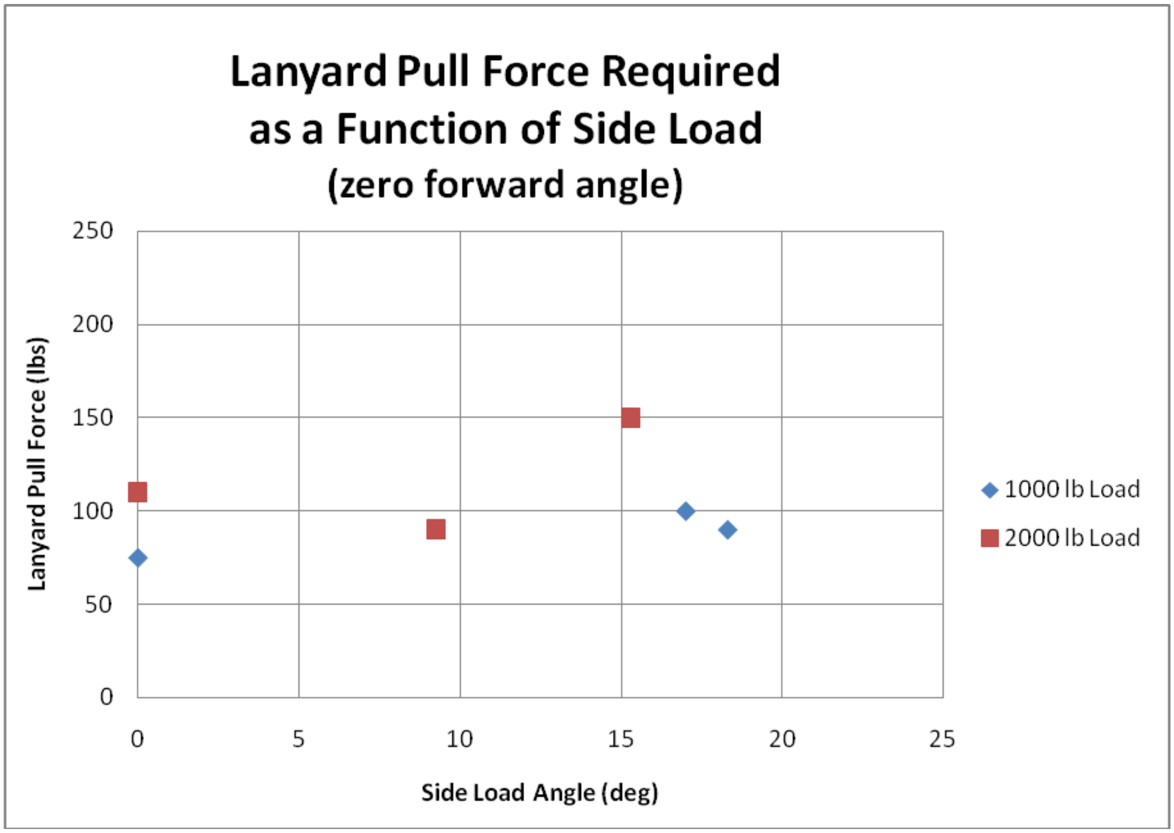


Figure C1-20. Chart 3 Lanyard Force vs Side Load Angle and Load Magnitude

Test Conclusions:

The results of this test were generally as anticipated. Increasing loads increased the lanyard pull force. Increasing forward load angle increased the lanyard pull force. Increasing side angle increased the lanyard force only mildly, except for some combine load conditions where the lanyard force appeared to decrease.

Considering that the designed free lift (net lifting force on the launch pin) is about 985 lbs, the lanyard force required for a balloon directly overhead would seem reasonable at about 80 pounds. However, the tests indicate that with relatively small forward angles of 10 to 15 degrees (balloon ahead of the launch crane), the lanyard force could rise to 125 to 150 pounds. Adding loads created by the wind on the balloon could easily take the lanyard loads to over 200 pounds.

C2 - Analysis

Estimates of Balloon and Flight Train Forces at Several Stages during the Attempted Launch and Abort Process

Summary:

Analysis was conducted to bound the potential forces that were extant in the balloon and flight train elements during the Nuclear Compton Telescope inadvertent payload release. The knowledge of these forces is important for the investigation. Analysis included approximations of the balloon and flight train distributed weights, the drag forces produced by the relative wind on all elements, and the lift forces generated by the buoyant forces on the contained helium. The system of structural elements and forces produces a complex catenary. The geometry is well represented by Figure C2-1 which shows the system near the time of the incident. This catenary system was modeled using two different methods, a multi-element equilibrium steady state shooting method and a dynamic model that solves the accelerations of lumped mass and spring system. The models show considerable forces at the truck plate at the moments of the launch attempt, the holding and backing at the fence, and at the time of the safety restraint cable rupture. The estimated forces and apparent geometries of the application of those forces are consistent with the inability to actuate the lanyard pull successfully during the launch attempts. The estimated forces and apparent geometries of the application of those forces are also consistent with the rupture of the restraint cable assemblies at the time of the unplanned payload release.

There is also evidence that the payload, while supported by the launch vehicle, experienced pendulous motion. This motion also produced forces on the truck plate that were transmitted to the restraint system and may have added to the difficulties with payload release and loads that caused rupture at the time of the inadvertent release. While the horizontal forces on the bottom of the truck plate due to payload pendulous motion can be significant and sufficient to prevent a lanyard pull, it is difficult to confirm that the gondola was swinging in an unfavorable direction at the moment of lanyard pull attempts.

Figure C2-1. Image of the NCT Balloon System at the Airport Fence

Section 1 – Catenary Forces

System Description

Weight Distribution:

The flight train is made up of a number of different sections and the distribution of weight was determined using the mechanical description for the standard 120' chute system and the flight weight breakdown. The weight distribution of the balloon was estimated by proportioning the total weight of the manufactured balloon as a function of the approximate local radius of the design shape. In this case, the fully inflated balloon float shape was approximated as a sphere for the purpose of approximating the weight distribution.

Drag:

The balloon was modeled based on the geometry determined by photographs of the system during the times of interest. In all cases, the collar had already been released. The photographs were analyzed to approximate the projected area of the spherical top, the triangular "sail" section, and the remaining "rope section" (see figure 1). The parachute and risers were modeled as a cylinder and the cable ladder section was modeled as four 3/8 "cables. Coefficients of drag were estimated based on information from Hoerner and others. Drag coefficient estimates for the parachute and the various balloon sections are difficult to estimate because the sections are flexible, the material is very compliant and "flagging" occurs, and the overall boundary changes as a function of the applied force. For this analysis, the upper spherical "cap section" was assigned a Cd of 0.5, the "sail section" 1.5, and the "rope section" a Cd of 1.5. The parachute and risers section was assigned a Cd of 1.5 and the wire rope cables a Cd of 1.5. It would be reasonable to expect these Cd's and the corresponding drag forces to be within 25% to 30% of the actual.

The piball wind data before and after the attempted launch was used to establish a wind velocity for each altitude layer and drag was calculated for each section.

Steady State Equilibrium Analysis:

For the steady state analysis, the catenary system was modeled as a series of rods or chain links, each with external weight, lift and drag forces. The system was arbitrarily divided into 100 elements for analysis. A seed initial angle for the top balloon element is provided and the equilibrium solution is obtained. The initial angle and drag were adjusted until the shape of the modeled catenary matched closely with the photograph (see figure C2-2).

Dynamic Analysis:

For the dynamic analysis, the system was modeled as a lumped mass system connected by springs. The dynamics were integrated from spool release using a Runge Kutta method. As above, the forces were distributed to the representative nodes.

Drag Analysis Results:

The catenary Steady State Equilibrium (Static) analysis for the crane positioned at the Airport fence solution produced a reasonable geometric fit with the photographic evidence as is shown in figure C2-2. The necessary forces at the truck plate to support the system weight and drag through the catenary were calculated to be approximately 9280 lbs. at approximately 38 degrees from horizontal. Matching the observed catenary required a drag adjustment factor of about 0.65 resulting in a total horizontal drag force of about 7300 lbs.

At the fence condition, the results of the independent Dynamic Analysis confirm the estimated horizontal drag force to be about 7200 lbs and the flight train angle with the horizontal at the crane to approximately 38 degrees. The total load at the crane head for this analysis is 9300 lbs.

A simple check can be accomplished by resolving the net vertical force (lift – weight) in the system along the known ladder angle at the crane head. The angle is determined from the photo evidence to be about 38 degrees. Resolving the net 5745 lbs along this angle gives a necessary total reactive force of 9350 lbs.

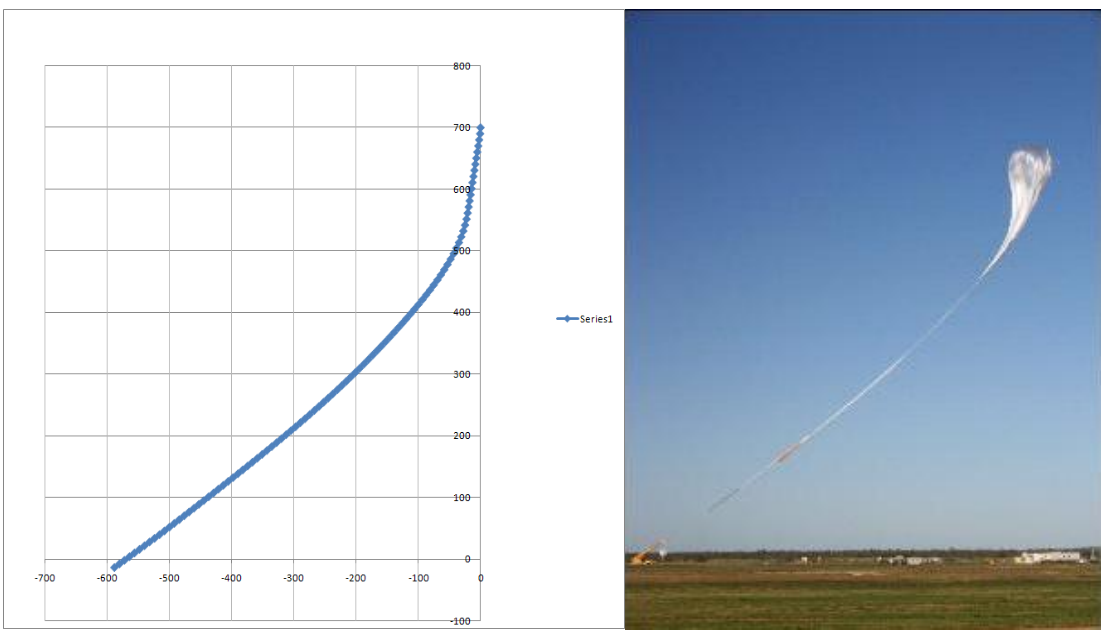


Figure C2-2. Catenary Analysis of the NCT Flight Train

Using the dynamic and static analysis techniques, additional considerations were made for the system at four key events: Attempted Launch, At the Fence, The Backing Maneuver, and The Inadvertent Release. It should be noted that the purpose of the analysis is to determine if the observed events are reasonably explained by estimates of the forces present and the capabilities of the operators and capacities of the hardware.

Some general time-dependent results are presented below in Figures C2-3 through C2-6. The time dependent position of the launch vehicle (crane) was taken from the science payload GPS information made available to the MIB. The GPS data frequency was 1/5 Hz. The time dependent position of the balloon and flight train were determined through the dynamic simulation using the wind data and time-dependent drag coefficient estimates backed out from the static conditions and from video evidence (for instance, for the spool lift-off period). Further video correlation with balloon/crane relative position and flight train shape was accomplished and is presented in Appendix G.

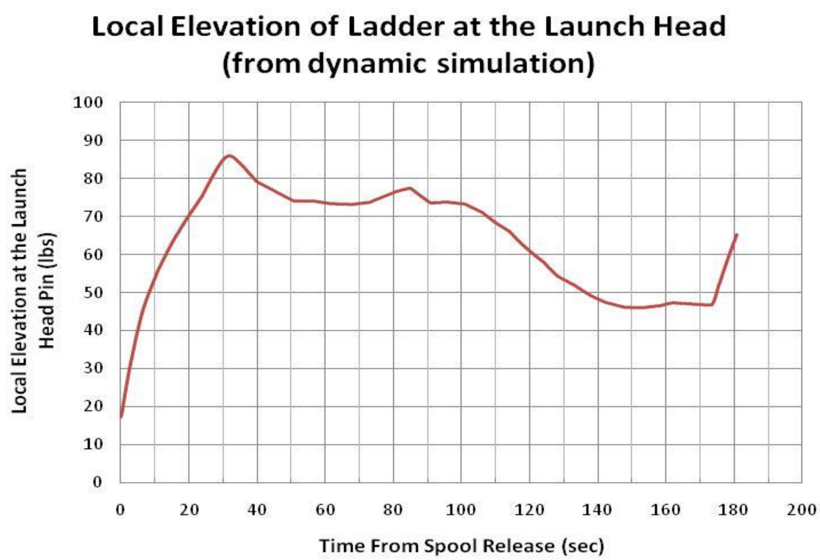


Figure C2-3. Ladder Elevation vs Time Estimate Gs from Dynamic Simulation

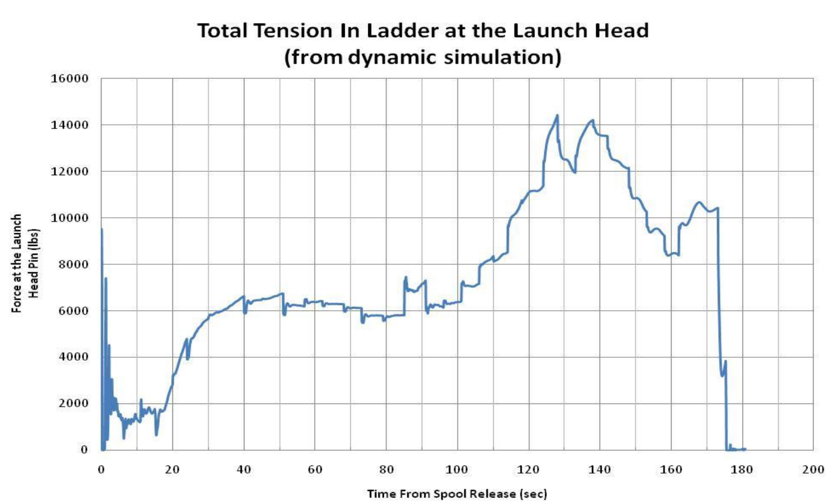


Figure C2-4. Ladder Tension at the Launch Head vs Time Estimates from Dynamic Simulation

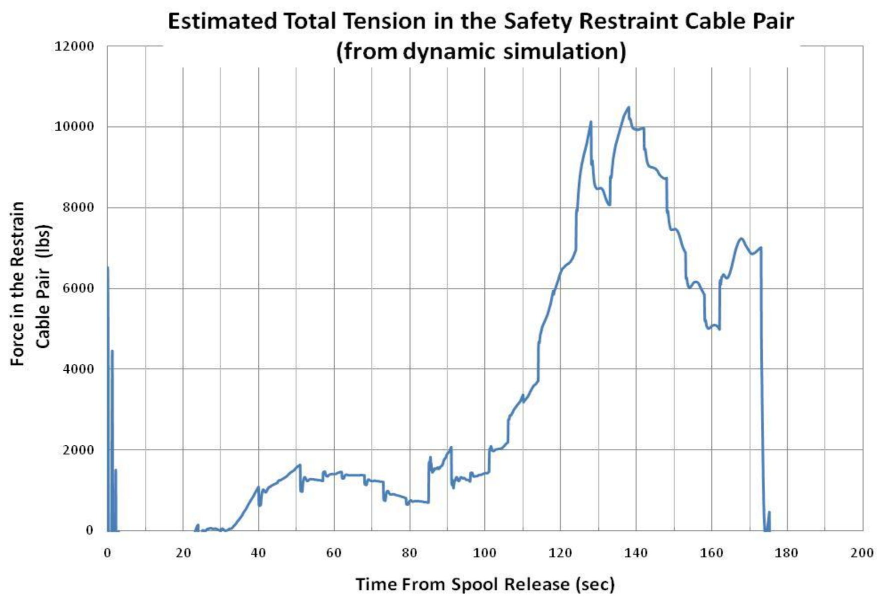


Figure C2-5. Safety Restraint Cable Forces (pair) vs Time Estimates from Dynamic Simulation

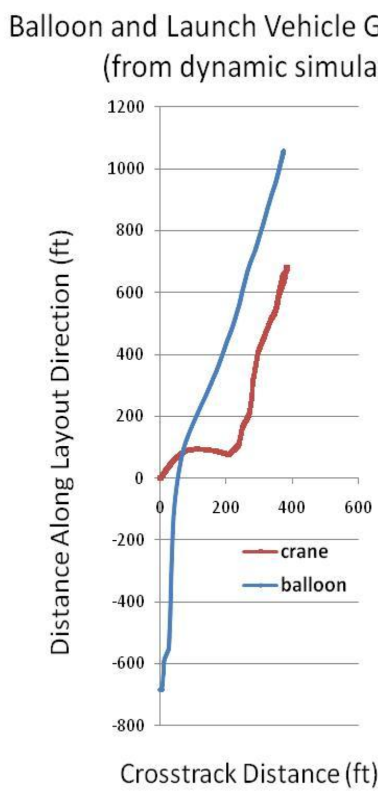


Figure C2-6. Ground Track Estimates vs Time Estimates From Dynamic Simulation

Attempted Launch –

For the launch attempt analysis, the important result is to estimate the pull force required on the release lanyard at the time of the launch attempt. Shear forces are applied to the release pin through the pear ring, the safety restraint cables, the truck plate, the flight train ladder, and eventually the balloon. The lanyard pull force is a function of the shear force on the release pin, therefore a function of the forces generated by the balloon and the relative geometry of the balloon and the launch vehicle.

From photographic evidence, the forward angle at the launch attempt appears to be about 10 to 12 degrees (78 - 80 degrees from horizontal). The effective angle of the launch head pin from the horizontal was a function of the crane boom angle, the launch head pin angle within the launch head assembly and the launch head pin taper. This effective angle is approximately 25 degrees from the horizontal, but is in practice dynamic, changing as the crane moves over the terrain. At this angle, the load in the safety restraint cables after resolving the force along the launch head pin is reduced to about 60% of the load in the flight train. (For reference see Figure C2-7 below) The analysis assumes no appreciable reduction due to friction. This is a reasonable approximation since the truck plate/launch head pin normal forces are relatively small since the truck plate sees the force difference between the payload weight and the upward flight train loads. Preliminary calculations showed force modifications on the safety restraint cables due to friction to be on the order of 200 lbs. The remainder of the ladder force on the truck plate is reacted in the pin in shear and bending. The static catenary analysis shows a total flight train force introduced into the truck plate of about 6000 lbs. The resulting total force in the safety restraint cable pair is then about 1500 lbs after allowing for the offset due to the payload weight (4787 lbs), reacted at the bottom of the truck plate. For comparison, the dynamic analysis shows a total force of about 6900 lbs and a slightly higher force on the restraint cable pair.

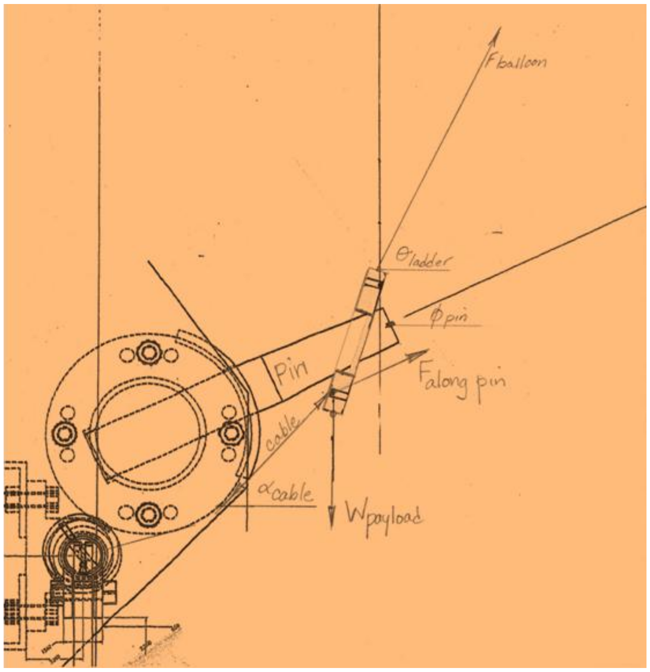


Figure C2-7. Launch Head Pin, Restraint Cable and Truck Plate Sketch

Using the data from Field Test 1 repeated below in Figure C2-8, the resulting lanyard pull force would be predicted to be about 320 lbs (test data only covered up to 1400 lbs applied load). The 300+ pounds of pull force required to release the payload exceeded the maximum reasonable human capability of about 100 lbs. Human factors research (Das and Wang, International Journal of Occupational Safety and Ergonomics, 2004, Vol. 10, No 1, 43-58 and Aghazadeh, Advances in Industrial Ergonomics VI, Taylor and Francis, 2010) suggests that realizable downward pull force for a male in standing position is in the range of 85 to 100 lbs.

Lanyard force models developed from the Field Test results were coupled with the dynamic model to estimate the pull force throughout the launch timeline. These results are presented in Figure C2-9. Note that pull force is predicted to change quite abruptly at about 86 seconds when the launch vehicle slows for the attempt. This is consistent with the inertial and increased drag loading of the balloon system as the launch vehicle slows. The implication is that an attempt just prior to slowing is predicted to take about 200 lbs, where just after it decelerates is increased to over 300 lbs. The dynamic analysis is consistent with the static analysis regarding the lanyard pull force.

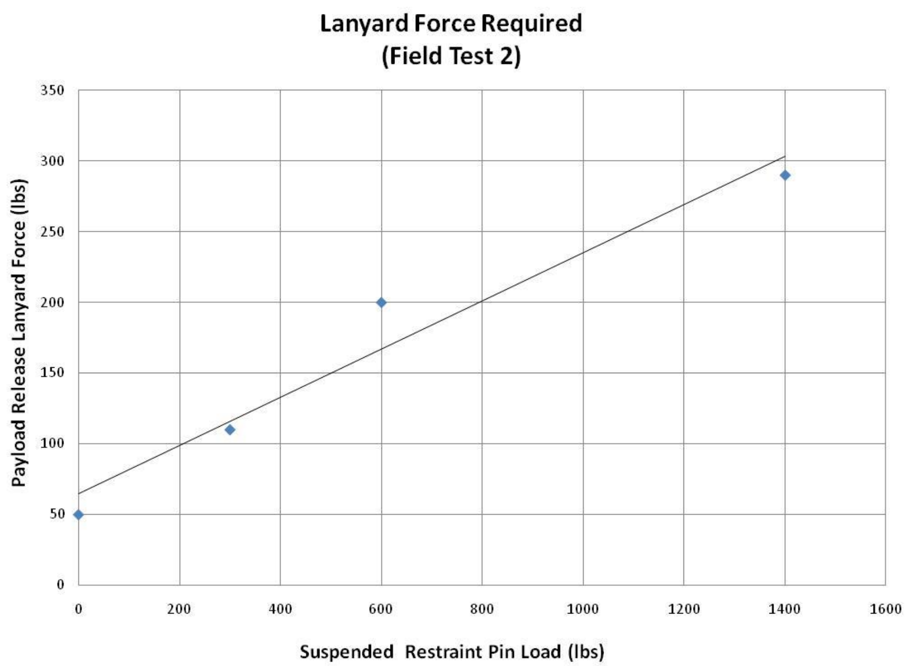


Figure C2-8. Release Lanyard Pull Force vs Pear Ring (equivalent total restraint cable) Loading

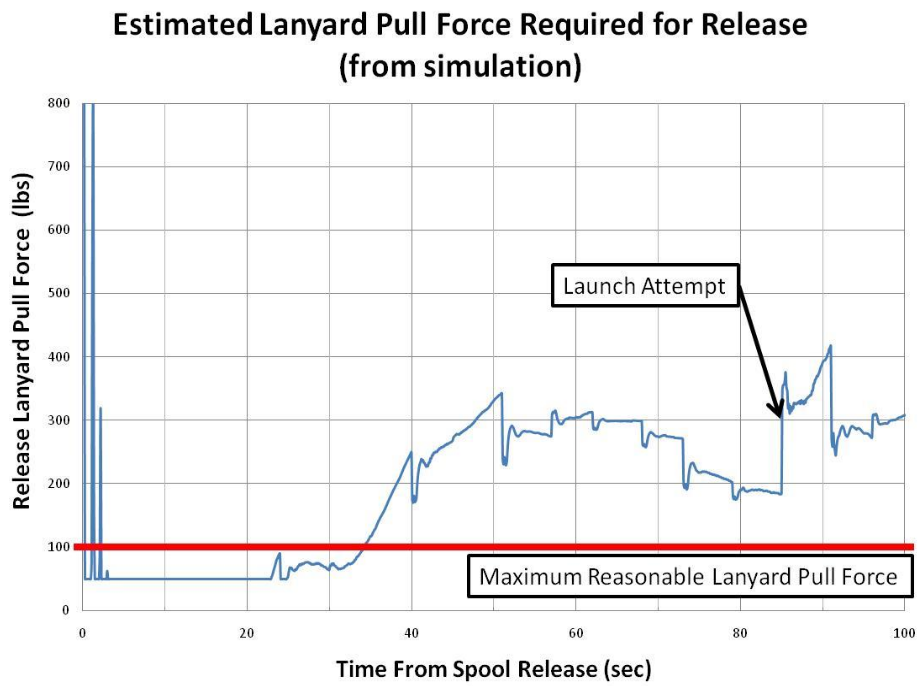


Figure C2-9. Estimated Release lanyard Pull Force vs Time Estimates from Dynamic Simulation

Conclusions:

These results suggest that the lanyard pull force due to the forces resulting from the balloon and flight train catenary was approximately 200 to 350 pounds during the first and second pull launch attempts. The required pull force during the launch attempts was clearly well in excess of typical human capabilities. Further, at no time after the crane was aligned with the wind direction was there a time that the launch attempt could have been completed successfully.

At The Fence –

At the time that the crane stopped at the Airport fence, the flight train was determined to be at 38 degrees from the horizontal at a total force of about 9350 lbs. Resolving these forces along the launch head pin gives a force along the pin direction of about 9200 lbs. This resultant force is then reacted by the payload weight and the tension in the restraint cables. The truck plate is constrained to move along the launch head pin, which also constrains the cables to react the load at an angle not aligned with the launch head pin. The cables with no payload weight would react with 9500 lbs. This restraint cable force is then corrected by the component of payload weight along the restraint cable direction. This correction is approximately 3200 lbs, yielding reactive force in the *cable pair* of about 6300 lbs. This compares to the specified ultimate load of the restraint cables of 7,000 lb *each* CSBF document OM-200-18-D, ("Aircraft Cable Approved Load Rating").

The 5/16" Crosby chain shackles and the AN46 38" – 24 UNF eyebolts are rated at 9,000 lb ultimate and 7015 lb according to documents OM-200-19-D and an email from CSBF.

Conclusions:

If the total force from the balloon and flight train catenary system estimate is reasonable, it speaks to why the restraint cables did not rupture while the crane was at the fence.

During the Backing Maneuver –

During the backing maneuver, the drag forces were increased by the added relative wind velocity due to the backing speed of the crane. The backing speed of the crane was approximately 4 to 9 feet per second with the winds at about 21 ft/s. This produces a factor of 1.2 to 1.4 relative velocity and a resulting drag component factor of 1.4 to 2.0. The result would be a total force in the ladder between 11,800 and 15,000 lbs, pushing the cable pair loading to between 8,600 and 11,800 lbs. The dynamic simulation results were consistent, showing restraint cable forces peaking just under 10,500 lbs. It should be noted that pendulous motions which were present during the period would add to the maximum forces seen by the restraint cables.

Conclusions:

The estimates of the cable forces during the backing maneuver are consistent with the restraint cables not breaking during this maneuver. However, when used in this manner, the estimated safety factor based on the cable specification was only about 1.3 for this particular situation. The loading due to pendulous motion or wind gusts may have taken the system to a near failure condition.

At Inadvertent Release –

At the time of the unintended release from the launch head pin, the crane was headed generally in an anti-wind direction at several feet per second which would have generated ladder forces greater than 10,000 lbs and less than 12,000 lbs. This results in restraint cable forces (in the pair) of 7,000 to 8,000 lbs. In addition, loads produced by the pendulous motion of the payload would add to these forces to produce the maximum forces at the time. The process of turning the launch vehicle away from the downwind direction also changed the way the loads were introduced into the truck plate. Ground testing after the incident showed that side loads introduced through the flight train caused the truck plate to rotate about the launch head pin. This rotation of the truck plate in turn prevents the load from being carried symmetrically by the restraint cables. (See Figure C2-10)

Figure C2-10. Illustration of Twisted Truck Plate

For extensive rotation which would be produced by the configuration at cable rupture, one cable is essentially relieved of force and the entire load is carried by a single cable. Therefore, there was enough load reacted at the truck plate to rupture the single loaded cable assembly carrying the predominance of the load. The second cable assembly would then be subjected to the total local load and would also rupture. The ultimate ratings of the eyebolt that ruptured (after considering the bending loads produced as it was employed) and the cable that ruptured are both less than the predicted load.

Conclusions:

The estimated forces produced at the time of the inadvertent release are entirely consistent with the rupture of the restraint cables. The cables likely rupture one at a time as the load was carried first by one, then the next cable. (See Figure C2-11 below)

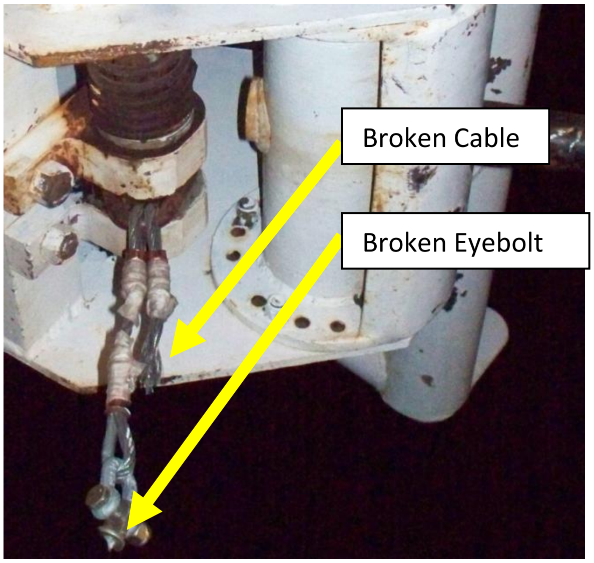


Figure C2-11. Illustration of Broken Cable and Broken Eyebolt

Section 2 - Pendulous Forces

System Description:

The payload is supported as a simple pendulum from the launch head pin. While the flexible cables used in the suspension make it possible to have a "wristing" action under certain circumstances, those effects are neglected here. The suspended weight is 4787 lbs with the center of mass at approximately 15 feet from the suspension point.

Analysis:

The forces of interest in this pendulum system are produced by two accelerations. One is from the acceleration of gravity, producing the weight component, and the produced other from the acceleration due to the circular motion, producing the centrifugal force component. Both the weight and centrifugal force components are maximum at the bottom of the swing, but at that location produce no horizontal (fore and aft) component to be transmitted into the bottom of the truck plate. The horizontal force magnitude varies as a function of maximum displacement angle (imparted energy) and the instantaneous angle of the payload center of mass. For small total displacements, under 10 to 15 degrees, the combined horizontal force is maximum at the maximum angle, is due completely to the horizontal component of the tension due to weight, and is practically linear with angle. For larger total angular displacements, over about 30 degrees, the horizontal force is maximum at intermediate angles due to the contribution from the velocity of the swinging mass. From 10 to 30 degrees total displacement the horizontal forces are nonlinear over the range and are maximum at the maximum angle.

For the launch conditions here, peak angular amplitudes were observed to 20 degrees, which can produce horizontal forces up to 1400 lbs. (See Figure C2-12 below) It is extremely challenging to determine the angular position of the gondola at the times of attempted lanyard pull.

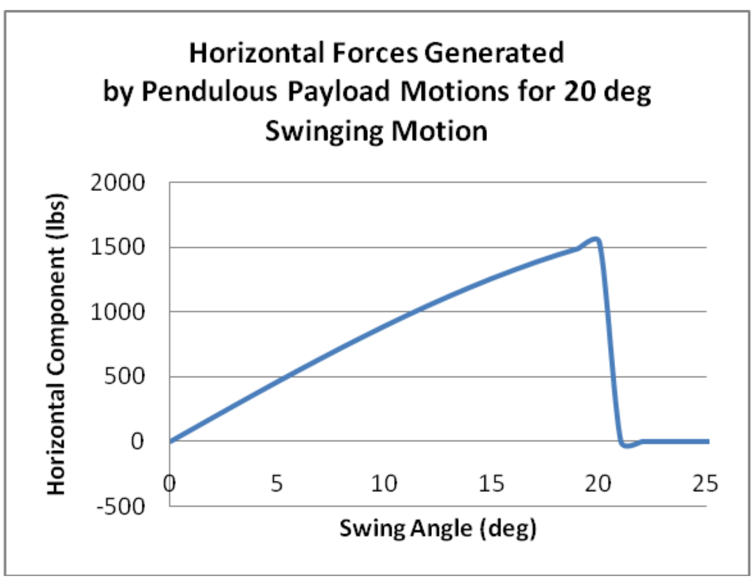


Figure C2-12. Potential Horizontal Forces Produced by Payload Pendulous Motions

Conclusions:

It is sufficient to say that pendulous motions have the potential for generating sufficient forces to prevent the lanyard pull, as well as add to the forces already present in the restraint cables due to the forces in the flight train from the balloon. At the same time, the pendulous forces, when acting in a favorable direction (payload swing toward the crane) have the potential to overcome some of the 1500 lbs of restraint pin loading generated by the balloon and flight train at the time of the launch attempt.

Section 3 - Forces at the Crane Launch Head for a Hypothetical No-Collar Release Condition

A brief analysis was accomplished to determine the likely level of forces at the crane launch head mechanism at the time of inadvertent release for a condition where the reefing collar had not been released prior to release from the launch pin. This question arose out of consideration of the launch process that generally includes instances both where the collar is released prior to the pin release and post pin release.

Analysis Approach:

The drag areas were determined based on photographic evidence of the balloon just prior to the collar release. (See Figure C2-13) In this condition, the drag area is somewhat less than that observed after the collar release. The new drag area was used with the same effective drag coefficient that was shown to cause analysis agreement with both the overall catenary shape and terminal angle at the launch head.

Results:

Application of the same static analytical technique yielded an ultimate force at the launch head of approximately 8000 lbs with the collar compared to 10000 lbs without the collar. The resulting angle with the horizontal is calculated to be closer to 50 degrees with the collar as compared to about 47 degrees without it. Applying an approximate 80% reduction would put the safety restraint cable forces between 5500 and 6500 lbs.

C2-13. Balloon with Collar

Conclusions:

Maintaining the collar until after pin release would have reduced the cable load on the safety restraint cables. The loads are predicted to be reduced to a point where, if one neglects potential pendulous payload dynamics loads or wind gust loads, the restraint cables may not have ruptured at the time. However, consideration of these additional loads creates a situation that may still have led to cable rupture

Section 3 – Predicted Release Lanyard Forces for the Hypothetical Case of no Traction Loss at PET = 62 Seconds

A brief analysis was accomplished to determine the predicted release lanyard pull force required at the time of launch attempt under the hypothetical condition that the launch vehicle (crane) did not lose traction at PET = 62 seconds. The dynamic simulation was used by modifying the launch vehicle (crane) velocity profile to allow a constant acceleration through the period around 62 s. In addition, the vehicle path was modified to better intersect the balloon by steering along the layout azimuth.

Again, it should be noted that the simulation uses PiBal information prior to and after the launch attempt to estimate the wind velocities as a function of altitude and use drag estimates that produced similar catenary shapes during static conditions (e.g., at the fence). The balloon position ground track position is influenced in simulation by both the aerodynamic drag forces and by the forces imparted by the launch vehicle (crane). Therefore, the Balloon Ground tracks are estimates only and do not represent any measured positions.

Results:

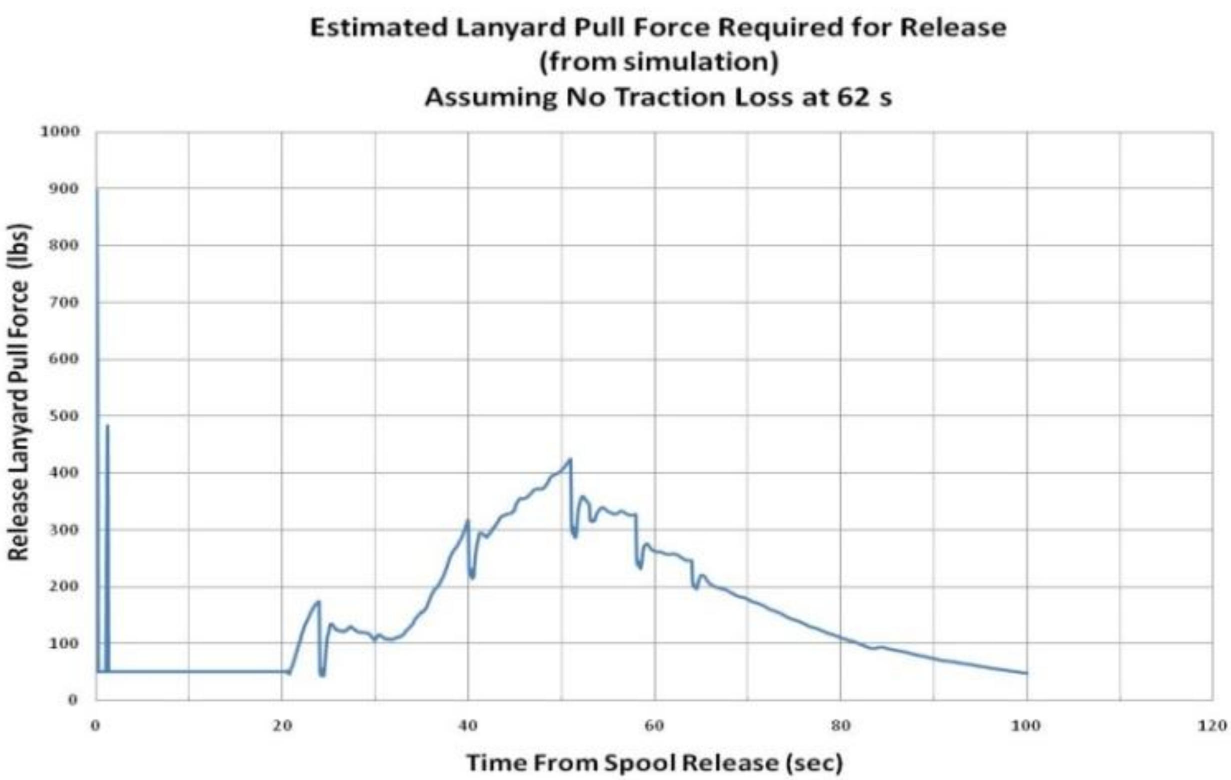


Figure C2-14. Estimated Lanyard Release Force for Hypothetical Case of No Traction Loss and Improved Driving Direction

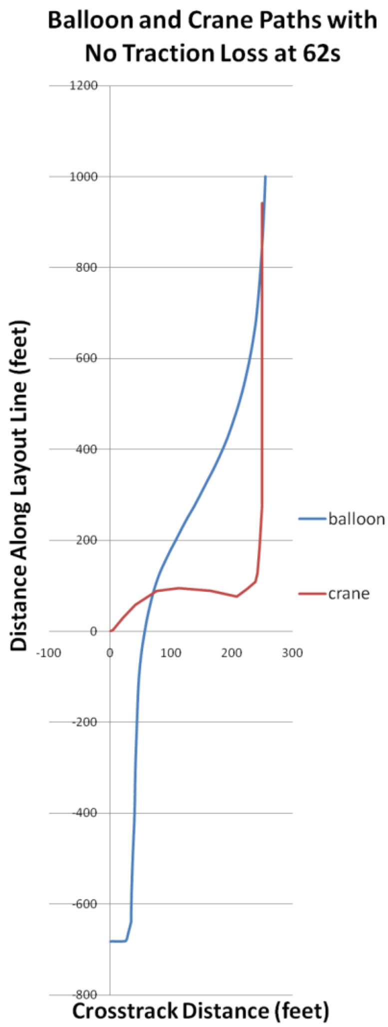


Figure C2-15. Balloon and Crane Ground Tracks for Hypothetical Case of No Traction Loss and Improved Driving Direction

The simulation presented shows that at the time of the actual launch attempts at about 86 seconds, the lanyard pull forces are predicted to be within the range of the operator (less than 100 lbs) if the traction loss had not been a factor and a slightly better driving azimuth had been followed.

Conclusions:

Given slightly different conditions, even with the wide right turn that was executed, it is predicted that the NCT launch was possible with the vehicle and hardware compliment that existed. It should be noted that the launch vehicle would have been out of the Category A Hazard Area.

APPENDIX D: SAFETY ANALYSIS

D1 – Safety Requirements Assessment

D2 – Safety Assessment Results

D3 – Human Error Assessment

D1 – Safety Requirements Assessment

Safety Requirements Assessment

The MIB conducted a Safety Requirements Assessment to determine areas where the applicable safety requirements were either overlooked (constituting non-compliance) or implemented poorly (constituting nonconformance with intent of the requirement). The requirements documentation examined for compliance included, but were not limited to: NASA Policy Directives; NASA Procedural Requirements; NASA Standards; NASA Range Safety Manuals; GSFC/Wallops Procedural Requirements; Suborbital and Special Orbital Project Balloon Procedures and Guidelines; Program Office Procedures and Guidelines; WFF Safety Office Procedures and Guidelines; WFF Safety Office work instructions; and the CSBF Contract documentation.

These requirements were compared with the information gathered through review of GSFC/WFF and CSBF program and activity documentation and records, witness statements, witness interviews, video documentation, and still photography.

The findings of the requirements assessment are provided within this section. Matrices mapping the results of this assessment to the root cause and interim cause findings of this MIB report, along with listings of the referenced safety requirements and excerpts of referenced requirements, are located in Appendix D-2.

D1.1 Protection of the Public

"It is NASA policy to protect the public… from potential harm as a result of NASA activities and operations by factoring safety as an integral feature of programs, projects, technologies, operations, and facilities." (NPR 8700.1)

The NASA General Safety Program Requirements, NPR 8715.3C, and the NASA Range Safety Program Procedural Requirements, NPR 8715.5, both function to provide requirements for implementation of the policy to protect the public.

These general Agency-level requirements should flow to each program, including the BPO (cite NPR). The implementing document for the BPO is the WFF RSM 2002. The WFF Range Safety Manual, RSM 2002 fails to flow the policy down into WFF Range Ground Safety requirements. Public safety is only addressed in the context of Flight Safety requirements (section 6 of RSM 2002). In addition, the CSBF Ground Safety Plan (OF-610-00-P) does not address the need for public safety in its scope or practice. The CSBF Contract NAS5-03003, Attachment D, Safety and Health Plan policy statement, also does not include safety of the public. The only reference to “public safety” that can be found in the CSBF contract is if one traces the referenced NASA FAR supplemental (NFS) clause 1852.223-70, Safety and Health to its source.

It is worth noting that neither the CSBF contract NAS5-03003 Statement of Work (SOW) nor the Safety and Health Plan mandate implementation of specific, applicable NASA public safety requirements.

The Balloon Program also failed to implement standard protective controls for personnel that would have also benefited public safety. Hazardous operating procedures were not instituted for launch activities as required by NPR 8715.3; NPR 8715.5; NASA FAR supplemental 1852.223-70; and the Contract NAS5-03003 Health and Safety Plan. WFF Procedures and Guidelines for control of public safety, such as those found in 800-PG-8715.1.1 and 800-PG-8715.0.3, including roadblocks and dedicated viewing areas, were not implemented for the Balloon Program nor were dedicated safety professionals (e.g., RSO, MRSO and OSS) assigned to oversee the launch process as required by NPR 8715.5 and RSM 2002.

D1.2 Protection of Personnel

RSM 2002 Ground Safety, Section 5.1.1, states that “the ground safety goal of GSFC’s WFF is to minimize the risks to personnel and property involved in conducting operations at GSFC’s WFF and to prevent mishaps that would result in embarrassment to NASA or the United States Government.” Section 5.1.2 also requires **“**that all systems be designed such that it will take a minimum of two independent, unlikely failures occurring in order for personnel to be exposed to a hazard” and that (Section 5.2.4) the CSBF Ground Safety Plan (OF-610-00-P) identify “the potential hazards and describe the system design and methods employed to control the hazards.”

The CSBF Ground Safety Plan (OF-610-00-P) echoes these goals; it too states that CSBF’s ground safety goal is to minimize risks to personnel. However, the Plan does not adequately address the requirements to identify potential hazards, to describe the design of hazardous systems, and to provide methods of hazard control for each identified hazard in order ensure personnel safety.

D1.3 Hazard Analysis

The Balloon Program’s lack of stringent hazard analysis left them vulnerable to non-compliances with Agency and WFF Range Safety Requirements.

NPR 8715.5, Range Safety Program under Range Safety Analysis (Section, 3.2.1), requires that “each range operation shall undergo a range safety analysis to establish any design or operational constraints needed to control risk to persons and property.” (Note: Range Operation is defined as the flight of a launch vehicle including payload at a range, to or from a range, or to or from launch sites or landing sites.) The BPO and the WFF Safety Office failed to perform or to ensure that adequate analyses were performed for the preflight phase of the balloon launch process. As a result of this omission, the balloon program operated without properly identified hazards and without adequate hazard controls.

The Range Safety Manual (RSM) states that the ground safety plan must also include a description and technical evaluation of the hazardous system's compliance with the design requirements of section 5.1.2, which stipulates "that all systems are designed such that it will take a minimum of two independent, unlikely failures occurring in order for personnel to be exposed to a hazard." Further section 5.3 (Specific Policies and Criteria) provides specific requirements for potentially hazardous systems including safety critical Ground Support Equipment (GSE) (5.3.5.1), electrically operated GSE used on Category A systems (5.3.5.6), ground support pressure systems (5.3.5.12), RF systems (5.3.5.8), and lifting devices and equipment (5.3.5.5).

The CSBF Ground Safety Plan, OF-610-00-P, does not include the required design descriptions and assessments nor does it identify all known hazards and controls associated with the launch pre-inflation, inflation, and launch phases. Examples of hazards not adequately addressed within the current Ground Safety Plan include the following:

1. Structural failure of launch equipment
2. Collision of moving/swinging payload with personnel or property (suspended loads)
3. Collision or tipping of mobile crane with personnel or property
4. Over pressurization or rupture of the balloon inflation system
5. Inadvertent/premature release of the payload
6. Inadvertent/premature ignition of pyrotechnics
7. Inadvertent/premature abort
8. Collision with aborted/released parachute train equipment

There is no evidence to suggest that a comprehensive safety analysis was performed for the balloon program for either the hardware or the operations associated with the launch process. Adequate documentation was not found in the Ground Safety Plan nor any other documentation reviewed. Operational constraints, hardware failure mechanisms, and limits were not identified.

RSM 2002 prescribes the methodology for analysis and control implementation in the Ground Safety Hazard Control (Section 5.2). The RSM requires that the following hazard control methods to be used to "protect personnel and property and minimize risk when conducting potentially hazardous operations":

A. Identify all known hazards associated with the program
B. Implement safety design criteria

C. Minimize exposure of personnel to hazardous systems
D. Establish safe operating procedures
E. Plan for contingencies

The typical ground plan will contain a list of all procedures (non-hazardous, hazardous, and safety critical), procedure descriptions, task summary details including hazards and precautions, and list of required PPE, identification of emergency and abort/back-out actions and a list of personnel training, certification and experience requirements for each type of hazardous operation such as ordnance, radiation and crane operations, and description of test performed on hazardous and safety critical systems. In addition a hazard analysis is included for each hazardous system and an Operating and Support Hazard Analysis (O&SHA) is provided for each hazardous operation. The O&SHA worksheets typically provide the following information: general hazard group, specific hazard condition, effect of hazard if not controlled, hazard control hardware, hazard control procedure, hazard control personnel. The plan also provides a mechanism for verifying that all hazard controls are in place prior to the beginning of the launch operation.

Individual hazard reports would have helped to ensure that the hazards, their causes, consequences, and controls were accounted for appropriately through the review and update of the reports prior to each mission.

D1.4 Hazardous Operating Procedures

The CSBF launch operations took place without the benefit of hazardous operating procedures. Lack of written hazardous procedures constitutes non-compliance with both Agency safety requirements and the WFF/CSBF contract.

NPR 8715.3, NASA General Safety Program Requirements, (section 1.4.3.j) states that the Center Director shall "ensure that for hazardous NASA operations, procedures are developed for the following circumstances: 1) to provide an organized and systematic approach to identify and control risks, 2) when equipment operations, planned or unplanned, are hazardous or constitute a potential launch, test, vehicle, or payload processing constraint, or 3) when an operation is detailed or complicated and there is reasonable doubt that it can be performed correctly without written procedures." NPR 8715.3, section 3.8. Hazardous Operations, also stipulates that Center Directors and project managers "shall ensure that all hazardous operations have a Hazardous Operating Procedure or a Hazardous Operating Permit (HOP), and that all procedures include sufficient detail to identify residual hazards and cautions to NASA personnel." "The Center SMA Director or designee shall review and approve the HOP."

NPR 8715.5, Range Safety Program (section 1.3.7.c) requires that "for each range operation, the vehicle program manager or NASA designee shall coordinate with the range safety organization to develop and implement …procedures" and the NASA FAR supplemental 1852.223-70, Safety and Health (j) as attached to the CSBF contract requires that "before hazardous operations commence, the Contractor shall submit for NASA concurrence (1) Written hazardous operating procedures for all hazardous operations; and/or (2) Qualification standards for personnel involved in hazardous operations."

The CSBF's own Health and Safety Plan (section J of the Contract NAS5-03003) states that the "safety of personnel and facilities will be ensured through the use of existing procedures" and that "written procedures for hazardous procedures will be developed and annually reviewed." The plan also states that "flight line operations procedures are to be maintained by the Operations Manager" and "will be made available to appropriate NASA authorities."

Despite the agency requirements and the CSBF plan, evidence obtained through witness interviews and document review indicates that the CSBF in fact did not develop or use written hazardous procedures.

Witness interviews uncovered that the contractor launch operators rely solely on checklists, the generic ground safety plan, job knowledge, and experience to execute the complicated and hazardous launch operation steps. Therefore, detailed operating procedures were not used for the Alice Springs NCT launch, nor are they typically used for any launch operations.

The failure of the Balloon Program Office and CSBF to conduct launch operations by the instruction of approved written hazardous operating procedures left the participating crew, personnel, and public vulnerable to increased risks.

D1.5 Ground Safety Plan

The Balloon Program Ground Safety Plan is a generic plan that was produced by the WFF Safety Office in 2004. It is supplemented by experimenter payload data provided in the format of questionnaires prior to each mission, which together with the generic plan, made up a Ground Safety Data Package. Even with the supplements included, the plan failed to contain the necessary information.

The primary deficiencies in the Ground Safety Plan are discussed in D1.3 and D1.4.

Interview evidence indicates that the Balloon Program Office and CSBF contractors believed the Balloon Ground Safety Plan to contain comparable comprehensive information as discussed above for a 'typical' ground plan. The Ground Safety Plan was repeatedly referenced in interviews whenever questions relating to system design, operational analysis, keep out zones, hazard controls and hazardous operating procedures were raised. Subsequent review of the generic balloon ground safety plan revealed that the plan failed to provide most of the referenced information.

The Balloon Program Office and the WFF Safety Office failed to sufficiently review the ground safety plan for compliance with the Range Safety requirements and/ or neglected to make the necessary improvements to bring the Balloon Ground Safety Plan into compliance.

D1.6 Safety Oversight

There is evidence of an insufficient safety oversight for the WFF Balloon Program.

NPR 8715.5, Range Safety Program assigns safety oversight requirements to different levels of Agency management, organizations and personnel for the WFF Range Safety and Balloon Programs. There is evidence to suggest that compliance was lacking with regard to oversight responsibilities on all levels.

The NPR 8715.5, Range Safety Program (section 1.3.2) requires that at the Headquarters level, NASA's Range Safety Manager not only evaluates range safety programs but also "ensure consistent implementation of range safety requirements throughout the Agency" Section 1.3.4.2 requires that Center Directors functioning as the authority for fixed or mobile launch sites "establish the processes and associated Center-level requirements needed to ensure the requirements of NPR 8715.5 are met."

Documentation and interview evidence suggest that the Balloon Program was not afforded the same level of safety insight or oversight as other Agency or even WFF Range programs and that range safety requirements were not consistently implemented for the Balloon Program.

NPR 8715.5 (section 1.3.5) gives range safety organization requirements for all range operations that use a Center's range facilities. The requirements state that "the Center range safety organization lead or NASA designee shall: (a) Implement or oversee the implementation of this NPR and associated Center-level processes and requirements including the risk management process of paragraph 3.2.4 of this NPR, (b) identify program data requirements, perform or evaluate and approve required range safety analysis, (c) evaluate and approve all range safety systems, (d) designate a qualified Range Safety Officer (RSO) to support each NASA mission that involves range operations (see paragraph 1.3.8 of this NPR for RSO responsibilities), (e) establish a qualification and training program that satisfies paragraph 3.5 of this NPR for range safety personnel (including RSOs and personnel responsible for range safety systems and range safety analysis) appropriate to the types of vehicles and operations at the range, (f) set operational performance requirements and standards for all range safety systems and (g) ensure the readiness of the range safety systems to support each operation."

The WFF Balloon Program launch activities take place at the contractor CSBF launch facilities or remote locations. However this does not make the BPO exempt from the safety implementation requirements of 1.3.5, based on the intent of NPR 8715.5 Sections 1.3.2 and

1.3.4.2 which are designed to ensure that implementation of safety standards remains consistent for all NASA programs and operations.

The Balloon Program Manager also has a number of required duties designed to provide insight to the balloon launch programs included in NPR 8715.5 (Section 1.3.7, Vehicle Program Manager), the first being to "(a) establish the processes and associated program-level requirements needed to ensure the requirements of this (the Range Safety Program) NPR are satisfied." Additional oversight requirements include: (c) the coordination of range safety organizations including RSO" to develop and implement operational range safety requirements, plans, procedures, and checklists, including mission rules and flight commit criteria"; " (d) designate a Range Safety Representative for the vehicle program"; " (e) involve range safety personnel and begin the tailoring process by the System Requirements Review (SRR), continuing throughout all pertinent vehicle and payload reviews and during Operations."; " (f) ensure adequate resources and data are available to support all range safety requirements and activities, including the design, test, and implementation of vehicle range safety systems required to support range safety requirements, the range safety organization/authority supporting the review, and approval process and operational support"; " (g) incorporate the requirements of this document in all launch service provider contracts and flight or other range operation contracts or agreements.", (j) in coordination with the range safety organization(s), generate a contingency action plan that describes roles and responsibilities in the event of a mishap and provides procedures to secure all data relevant to an investigation."; "(l) in coordination with any Center that supports the range operation, ensure all employees and visitors are informed of potential hazards associated with a range operation and the actions to take in the event of an emergency."; " (o) engage the Center range safety organization regarding, and establish a plan for, monitoring of vehicle and range processes during launches, entries, and other range operations and to ensure timely identification and resolution of any violation that might affect launch, entry, or other operational approval. Engage with the NASA Range Safety Manager to perform this function for range operations not supported by a Center range safety organization; and (v) ensure that any vehicle program personnel who perform a range safety function are qualified and trained in accordance with paragraph 3.5 of this NPR.

Evidence suggests the many of these safety responsibilities were not sufficiently performed on the behalf of the Balloon Program leading to inadequate oversight and insight into the Balloon Program launch operations.

The Range Safety Manual also assigned oversight responsibility to the Balloon Program Office. RSM 2002 Section 2.0 requires that "For the Balloon Program, the Chief, Balloon Program office shall ensure that 1) the requirements and the procedure defined in appropriate safety plans and balloon risks analysis are implemented and (2) the operational responsibilities normally assigned to the Mission Range Safety Officer (MRSO), Operations Safety Supervisor (OSS), or Project Manager in this document are implemented for balloon operations" and defines each of these positions.

Evidence suggests that the Balloon Program was noncompliant with these oversight responsibilities. Evidence collected for the Alice Springs NCT launch shows the BPO in fact, did not ensure the implementation of appropriate protection for hazardous launch operations as required nor did they provide the assignment and subsequent performance of the required safety responsibilities of OSS and MRSO.

There is no flow down of direction from the RSM 2002 in the CSBF documentation that requires personnel to assume the safety responsibilities of the MRSO, OSS (and Project Manager). The CSBF Balloon Ground Safety Plan, Chapter 2–Safety Responsibilities, states simply that "the CSBF Operations Department Head (campaign manager at remote sites) is responsible to ensure compliance with the provisions of the BGSP for CSBF operations and for science user operations." There is no reference to what these "provisions" are and no reference to the duties described in the RSM 2002. (Note: the only other reference to a specific duty is later in the paragraph– "The crew chief is responsible to direct the movement and operation of all heavy equipment used in balloon launch operations in such a way to ensure safety and minimize the number of personnel exposed to hazards associated with this equipment.") There is no discussion of certification, training, no reference to NASA requirements, and no mention of specific duties as outlined in RSM 2002. (Note the only reference to the RSM 2002 is in Section 1 Scope: "The BGSP is derived from the NASA GSFC/WFF Range Safety Manual, identified as RSM 2002". The word 'derived' is ambiguous. There is no required RSO or OSS or MRSO training provided to the CSBF safety designees.

The lack of a dedicated, trained safety officer engaged in reviewing launch procedures, verifying test results, conducting pre-task briefings, monitoring the hazardous launch operations and making abort decisions left both personnel and the general public vulnerable to potential injury or death. The Campaign Manager and Launch Director were over-burdened with the responsibility of assuming safety monitoring duties in addition to their operational duties; they were also not properly trained to do so.

Insufficient oversight by the WFF Safety Leadership, along with the absence of dedicated safety professionals at the launch site significantly added to the risks of the balloon program launch activities.

D1.7 Closure of Audit Findings and Recommendations

Insufficient management oversight regarding the implementation of the 2002 Balloon Program Independent Safety Assessment (reference QA-D-02-04-001) findings and recommendations allowed required corrective actions to remain incomplete.

NPR 8715.5, Range Safety Program, requires that a NASA Headquarters-level, independent assessment of range programs be conducted periodically. The NPR also states that it is the responsibility of the GSFC Center Director to "support range safety independent assessments and (to) respond to all findings and recommendations for which the Center is accountable." The 2002 assessment conducted for the WFF Safety Office (reference QA-D-02-04-001), brought forth twenty-three (23) findings and twenty-five (25) recommendations. Eight years later, many of these findings and recommendations remain inadequately or incompletely addressed. Five such findings have particular relevance to the Alice Springs incident and can be directly linked to either contributing or root causes for the mishap. Discussion of these findings are presented below:

QA-D-02-04-001 Finding 5—*Total Reimbursable Budget Authority (RBA) funding impacts the safety office's ability to perform its mission.* '*There is no Direct Budget Authority (DBA) funding for the WFF range safety function. Since the WFF is a full cost accounting organization, there is only RBA funding available to the range safety organization. Recommendation: GSFC/WFF management should provide DBA funding based on range safety's assessment of need. GSFC/WFF range safety organization could also attempt to gain DBA funds through submittal of a request to HQ Code Q POP process.'*

Interview evidence gives indication the WFF Range safety funding is not independent of the vehicle programs and that the funding structure of the WFF/GSFC safety office may still be an issue.

QA-D-02-04-001 Finding 6—*Safety practices not consistent across projects in 810, 820, 830 and 840*. *'WFF team would benefit from consistent and consolidated application of safety practices across the various program offices. Recommendation: WFF management standardize current safety practices in all WFF programs.'*

Evidence suggests however that Range Safety requirements are not equally or consistently applied to the Balloon Program. This is particularly true regarding the safety oversight and insight provided to the WFF Balloon Programs, including CSBF launch campaigns. Interview and document evidence shows that the Balloon program is not managed in the same manner as other Code 800 range programs and that the WFF Safety Organization, Code 803, has very limited interaction with and oversight of the Balloon Program. Interview evidence and document review show that several standard Code 800 and Code 803 range safety requirements and range safety documents (including processes, procedures, guidelines and work instructions) are not applied to the BPO nor have comparable processes and procedures been developed. For example, the Balloon program missions are not assigned RSOs. Also, contractor personnel have not been assigned the duties of MRSO or OSS nor has the required balloon-specific OSS training been provided as required by RSM 2002.

QA-D-02-04-001 Finding 9—*Range safety involvement with Balloon Program inadequate.* *The balloon programs operated at GSFC/WFF do not have independent range safety oversight or insight. These payloads are potentially hazardous to the public and should be managed consistent with other hazardous, uninhabited programs. Recommendation: GSFC/WFF Management should require range safety involvement in balloon programs. Suggest WFF range* *safety office and balloon program office coordinate a tailored range safety program for balloons.*

Documentation and interview evidence suggest that the Balloon Program was not afforded the same level of safety insight or oversight as other Agency or even WFF Range programs and that range safety requirements were not consistently implemented for the Balloon Program.

WFF Range safety provided little or no insight or oversight for the CSBF launches, nor did they assign dedicated range safety personnel in the form of RSO, MRSO or OSS.

The 2002 assessment aptly pointed out the balloon program activity's potential danger to the public and recommended greater Code 803 involvement. Interview and document evidence supports the fact that the Balloon Program still suffers from a lack of oversight. The Safety office to-date does not perform periodic program audits or requirement, document, or analysis reviews, is not present at launch activities and depends on contractor and BPO to impose and maintain safety requirements.

QA-D-02-04-001 Finding 11—*WFF pre-mishap planning is inadequate.* Recommendation: *WFF should expand and update written pre-mishap plans for operations at WFF. In addition to the initial response actions, plans should also include all mishap hazards, investigation actions and responses in accordance with NPD 8621.1. Failure to adequately pre-plan may place personnel and resources at unnecessary risk and result in loss of investigation critical information.*

The contractor did have a mishap plan, but it was not fully compliant with the requirement of NPR 8621.1. OF-695-21-P, 'Columbia Scientific Balloon Facility Procedures Following Flight Mishap or Incident' requires that after a mishap, hardware not be disturbed prior to inspection by "appropriate personnel" (undefined) and gives the CSBF Operations Department Head or remote Campaign Manager authority to instruct movement or manipulation of hardware. There is no discussion of drug testing in the mishap plan. There is no information regarding potential hazards associated with or the safing of the equipment. The Balloon Program mishap plan does not include IRT information nor adequately address the safing of the mishap area or protection of evidence. The lack of a compliant MPCP left the Balloon Program Office and the CSBF contractors unprepared for the Alice Springs mishap. Evidence shows that post-mishap, the public and personnel were allowed in close proximity to unsafed hazardous systems (including pyrotechnics, and chemical batteries) and that there was significant disturbance of the mishap scene and removal of key evidence.

QA-D-02-04-001 Finding 15—*Training documentation lacking.* *There is little or no evidence that all training is documented and tracked within the safety office.* Recommendation: *An ISO process should be established and followed within the safety office (or at the 800 level) to provide requirements for training and to accurately document that training. Expedite the issuance of the ISO ground safety training process.*

There is no evidence of WFF-provided ground safety training for the Balloon Program contractors (CSBF) who were delegated safety responsibility for launch operations (nor of contractors certified based on WFF review of OSS equivalency). Appropriate NASA training was not mandated nor provided to the contractor by WFF Safety or the BPO. The contractor records only indicate on-the-job training records with no attached curriculum. NASA personnel with appropriate range safety training were not assigned as an alternate solution.

QA-D-02-04-001 Finding 21—*Operations Safety Supervisor qualifications unclear.* *It is not clear how WFF range safety verifies the qualifications of "other personnel" that may be delegated this responsibility. Recommendation: WFF should establish a clear policy for delegation of OSS responsibilities. Consider using EWR 127-1 Para 1.4.3 et al as a guide.*

WFF response to the 2002 audit was that training was being developed to qualify OSS personnel designated by the WFF RSO and that after the summer of 2002; all personnel assigned to OSS duties would be required to have the training. Evidence suggests that this corrective action was never completed. Currently CSBF contractors are not provided OSS training nor are WFF OSS-trained WFF personnel assigned to the balloon launches.

D1.8 Crane Operations

Balloon Program Crane Operations and Hardware was not in compliance with the NASA standards for Lifting Devices and Equipment.

RSM 2002, section 5.3.5.5 requires that "all lifting devices, fixtures, and equipment shall comply with the standards and regulations of NASA-STD-8719.9, Standards for Lifting and Equipment and GPR 8719.1 Certification and Recertification of Lifting Devices and Equipment". It should be noted that the Balloon Launch Program utilized the crane in an unorthodox manner as a launch vehicle for the payloads. The balloon program's expanded use of the mobile crane puts even more responsibility on the program to ensure that the intent of the Lifting Devices and Equipment requirements are fulfilled and that the potential hazards associated with each requirement are adequately controlled.

Based on a review of interview, written, photographic and video evidence supported by the GSFC Lifting Device and Equipment Manager (LDEM), the Alice Springs Balloon Launch operation was not in compliance with, nor did it meet the intent of the following NASA-STD-8719.9 requirements.

- Design Section 5.2.4 "Load capability and the desired controlled characteristics with which the crane/derrick handles the load shall be addressed for all designs. Operation requirements shall be considered in the design phase to ensure load and function are adequately defined and crane/derrick design features are incorporated on the delivered units."

The restraint system yielded under the imposed load and the payload broke free. There is evidence to suggest that the Balloon Program was unaware of the design and operational limitations of the launch system. Analysis was not performed to identify all possible failure modes of the launch hardware.

- Training Section 5.6.2(1)(a) “Classroom training in safety, lifting equipment emergency procedures, general performance standards, requirements, pre-operational and safety related defects, and symptoms (for initial certification and as needed).”

Interview evidence supports the fact that crane operators were not fully knowledgeable regarding the limitations of the system. Crew training did not include emergency or anomaly training, including failed launch attempts. There were also no operating procedures produced or used.

- Operations Section 5.7(i) Cranes/derricks “shall not be side loaded, used to drag loads sideways, or used to pull loads unless specifically designed to do so by the OEM as indicated in the load chart.”

Video and photographic evidence as well as analysis shows that the launch vehicle was indeed at times side loaded and was used both to drag sideways and to pull the balloon induced loads.

- (m) “the operator and ground lead mean shall establish appropriate safety zones before initiating operations. Safety zones should have appropriate barriers (rope, cones or other) established prior to lift.”

Video, photographic and interview evidence support that an effective safety zone designed to protect the public was not implemented. The Category A zone was ill-defined, ineffective, and was breached during the launch sequence. There was also no attempt to mark a safety zone appropriately prior to operations with cones, ropes or other barriers. Lack of marking made it inconceivable that the crane operator or other observers would detect when the zone was violated by the either the balloon train or the moving crane.

- (t) “during hoisting, care shall be taken that there is not sudden acceleration or decelerations of the moving load and that the load does not contact any obstructions.”

Video and interview evidence support that the launch operation consisted of a number of sudden movements including accelerations and decelerations as well as turns that caused the payload to swing widely. At one point the excessive movement of the payload caused the operator to lose control of the payload tag lines. The rough and unimproved terrain contributed to the movement of the suspended payload. The payload also had potential to contact an obstruction when the launch vehicle was driven to the fence.

- (z) “An operator shall be at the crane /derrick controls at times while a load is suspended” (OSHA requirement). Due to the length of some NASA operations, an operator change may be required while a load is suspended. This shall be accomplished via a procedure designed for the specific crane/derrick and operation, assuring the crane controls are manned at all times.

Video, photographic and interview evidence support that the control cabin was not occupied during the launch attempt. The controls were therefore unmanned while the payload was suspended.

- (ai) "when traveling a mobile crane with a load, a person shall be designated responsible for determining and controlling safety and making decisions as to position of the load, boom location, ground support, travel route and speed of the motion."

Interview and documented evidence support the fact that there was considerable confusion among both the crew and the Balloon Program regarding specific personnel safety and decision-making responsibilities and authority. It was clear that the launch director was in charge of travel route and speed of the motion; however, the safety control and decision making was not as well defined. There was confusion over who had the abort authority and who was responsible for assuming the role of the Mission Range Safety Officer.

- (ak) "When rotating cranes/derricks, sudden starts and stops shall be avoided. Speed shall be such that the load does not swing out beyond radii at which it can be controlled. A tag line should be used when rotation of load is hazardous"

Video and interview evidence support the fact that the payload swung beyond the radius of control. Excessive swinging of the load caused the technician to lose control of both payload tag lines. He was only able to regain control of one line prior to the unintentional release of the payload.

- Sling Section 10.7(g) "The following materials and techniques shall not be used in slings or rigging hardware to hoist personnel or loads: natural rope, wire rope clips, the fold back metal pressed sleeve or clip technique."

Photographic evidence shows that the fold back technique was used. The photo also revealed that the cords were improperly taped, making required inspection of the cords impossible.

In addition, video evidence suggested the potential for non-compliance with the Critical and Noncritical Lifting Operations, requirement 1.5.1 that states "Personnel shall not be located under suspended or moving loads unless the operation adheres to the OSHA-Approved NASA Alternate Standard for Suspended Load Operations."

The movement of the payload was sufficient to cause concern regarding personnel safety. It is suggested that Appendix A of the NASA-STD-8719.9 be examined for possible solutions that may include supporting the payload from underneath, in order to eliminate this potential hazard.

D1.9 Independence of Safety

NPR 8715.5 Chapter 1.3.2 (c) states that the HQ Range Safety Manager will "ensure consistent implementation of range safety requirements throughout the Agency." Evidence suggests however that Range Safety requirements are not equally or consistently applied to the Balloon

Program. This is particularly true regarding the independence of the safety oversight or insight provided to the WFF Balloon Programs, including launch campaigns. NPR 8715.5 section 1.3.4.3 requires 'that the Center Director or NASA designee when functioning as the authority for a range shall establish a Center range safety organization (direct or delegated) that is independent of all vehicle programs'.

NPR 8715.3 Section 1.4.3 requires that the Center Director (b) place their safety organization at a level that ensures the safety review function can be conducted independently and (d) "ensure that (1) adequate resources (personnel and budget) are provided to support mishap prevention efforts, (2) resource control is independent from any influence that would affect the independence of the advice, counsel, and services provided and (e) ensure that policies, plans, procedures, and standards that define the characteristics of their safety program are established, documented, maintained, communicated, and implemented."

Evidence suggests that the independent safety oversight provided to the balloon program was inadequate. The majority of the range safety functions for the Alice Springs NCT launch were carried out by the balloon launch service contractor, CSBF, not an independent source.   The WFF Range Safety Office Code 803 had little or no insight or oversight into the technical aspects of the balloon program and provided little in the way of document review, launch site visits, program audits or hazard control verification.

This same lack of independence was observed in the NASA Headquarters' 2002 WFF Independent Assessment Report from which the following statements are taken: "Unlike other uninhabited flight programs, the policy and practice in effect in the balloon programs operated at GSFC/WFF do not require independent safety oversight or insight." "With NASA it is common practice to utilize an organization that has no direct stake in the project to establish and implement safety plans, risk analyses and procedures. This independence ensures that the range safety requirements will not be compromised. These payloads are potentially hazardous to the public and should be managed consistent with other hazardous, uninhabited programs." "Management is accepting an unknown level of risk associated with balloon operations." The Headquarters assessment team recommended that "GSFC/WFF management should require range safety involvement in the balloon programs. The assessment team suggested that the WFF range safety office and balloon program office coordinate a tailored range safety program for balloons."

D1.10 Training

The Balloon Program Office and CSBF in lieu of written procedures and explicit hazard controls relied heavily on the on-the-job training provided to the crew.

Interview data determined that despite many hours of on-the job training; crew training did not include specific training for anomalous situations. There was no instruction on specific abort criteria, response to breach of safety zones or IRT training. Personnel were given limited guidelines regarding hazardous operations and decisions, such as abort criteria. Evidence also indicates uncertainty among both BPO and CSBF personnel regarding who has abort authority, the application of the Category A hazard zone for the launch phase and assigned safety roles and responsibilities.

There is also no evidence of WFF-provided ground safety training for the Balloon Program contractors (CSBF) who were delegated safety responsibility for launch operations (nor of contractors certified based on WFF review of OSS equivalency). The duties of MRSO and OSS were required to be assumed and verified by the BPO in accordance with RSM 2002. However appropriate NASA training was neither mandated nor provided to the contractor by WFF Safety or the BPO. The contractor records only indicate on-the-job training records with no attached curriculum. NASA personnel with appropriate range safety training were not assigned as an alternate solution.

Despite the provision in RSM 2002 (section 2) that the operational responsibilities of the Operational Safety Supervisor (OSS) could be implemented for the balloon program by the contractor; the CSBF personnel were not trained in accordance with the RSM to assume the responsibilities of OSS.

The RSM requires that all personnel designated as OSS are certified by the Safety Office Ground Safety Group (GSG) either by attending a specialized OSS course and successfully completing the testing or by providing satisfactory evidence of the contractor's possession of the required skills and knowledge. The procedure is documented in 800-PG-8715.04A, 'Certification Procedures for Operations Safety Supervisors at WFF'. Balloon-specific (Category II -Balloons) training and certification would have been required for the CSBF crew. Both interview and documentation evidence show that such certification was neither offered by the WFF Safety Office nor otherwise obtained by any of the CSBF crew members.

The Balloon Ground Safety Plan did not provide a full discussion of personnel training and certification requirements for the hazardous operations to be performed. There was no clear system for the verification of the status of operator certification prior to the beginning of the launch operations. Evidence suggests that one of the launch crew member's required crane operator certification was not current.

D1.11 Mishap Response Plan

The CSBF Mishap Plan was not sufficient to meet the requirements of NPR 8621.1 and NPR 8715.5. The plan failed to provide adequate direction to preserve evidence and to keep personnel and public safe in the event of a mishap.

NPR 8715.5, section 1.3.4.2(i) requires that Center Directors functioning as the authority for fixed or mobile launch sites "Develop emergency plans to prevent or mitigate the exposure of the public or employees to any hazard associated with range operation." NPR 8715.5, section 1.3.7(j) stipulates that the Vehicle Program Manager "In coordination with the range safety organization(s), generate a contingency action plan that describes the roles and responsibilities in the event of a mishap and provides procedures to secure all data relevant to an investigation" and stipulates the use of NPR 8621.1, NASA Procedural Requirements for Mishap Reporting, Investigation and Recordkeeping.

NPR 8621.1, Section 2.2 Program and Project Mishap Preparedness and Contingency Plans, 2.2.1.(a) requires that Program Managers concur with a Program and Project Mishap Preparedness and Contingency Plan (MPCP) that "is a comprehensive plan for all mishaps and close calls that occur offsite, at offsite program/project contractor sites, or in flight."

The Balloon Program's contingency plan, 'Procedures Following Launch/Flight Failures, Mishaps, or Incidents CSBF OF-695-21-P', did not meet the content requirements of 2.2.1. The following data requirements were not adequately addressed within BPO's document:

1. Special procedures for emergency response personnel, the IRT, and the incident commander for identifying, safing, and handling hazardous commodities specific to the hardware
2. Training requirements for IRT membership for mishaps and close calls occurring off-site and contractor locations
3. Procedures to impound data, records, equipment, facilities, and property
4. Existing memoranda(s) of agreement with national, state, and local organizations and agencies that may be utilized during a mishap investigation
5. Descriptions of how offsite debris shall be collected, transported, and stored
6. Descriptions of investigation and debris collection process required for any mishap or close call occurring in a foreign country
7. Specification that for NASA-investigated mishaps, NASA personnel shall perform and control the impounding process

The contractor did have a generic mishap plan, but it was not fully compliant with the requirement of NPR 8621.1. OF-695-21-P, 'Columbia Scientific Balloon Facility Procedures Following Flight Mishap or Incident' requires that after a mishap hardware not be disturbed prior to inspection by "appropriate personnel" (undefined) and give the CSBF Operations Department Head or remote Campaign Manager authority to instruct movement or manipulation of hardware. There is no discussion of drug testing in the mishap plan. There is no information regarding potential hazards (including radioactive sources) associated with the equipment. The Balloon Program mishap plan neither includes IRT information nor adequately addresses the safing of the mishap area or protection of evidence.

The lack of a compliant MPCP left the Balloon Program Office and the CSBF contractors unprepared for the Alice Springs mishap. Evidence shows that post mishap, the public and personnel were allowed in close proximity to the ‘unsafed’ hazardous systems (including pyrotechnics, and chemical batteries) and that there was significant disturbance of the mishap scene and removal of key evidence.

D2 – Safety Assessment Results

The safety requirements assessment results are formatted into individual safety topics. Each report references the corresponding Root Cause(s), Intermediate Cause(s), Contributing Factor(s), and/or Observation(s) of this mishap report section 4 (if applicable); followed by a discussion regarding the insufficient application of safety requirements associated with the topic of discussion. The requirements are itemized and then excerpts from the applicable requirements are highlighted for the convenience of the reader.

INADEQUATE PROTECTION OF PUBLIC

Safety Assessment Observation: Public safety is not addressed in the CSBF Ground Safety Plan
Mapping to Report Findings:
R1: WFF safety leadership did not ensure complete flow down of agency requirements to protect the public **R2: WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements (WFF Safety Office and BPO implementing organizations)** **R4: GSFC safety leadership did not verify or provide corrective action for flow down of NASA requirements to protect the public** **I2: A barrier to keep the general public out of all dangerous areas throughout the launch process did not exist** **I3: No trained individual was in place to ensure public safety** **I7: Category A hazard area was not well defined** **I 11: The ground plan did not explicitly address the general public as a target** **I14: GSFC safety management did not verify or provide corrective action for flow down of NASA requirements to protect the public**
Discussion:
"It is NASA policy to protect the public… from potential harm as a result of NASA activities and operations by factoring safety as an integral feature of programs, projects, technologies, operations, and facilities." - NPR 8700.1 **The NASA Policy for Safety and Mission Success, NPD 8700.1 establishes public safety as the Agency's number one policy. [Reference 1] The NASA General Safety Program Requirements, NPR 8715.3C and the NASA Range Safety Program Procedural Requirements NPR 8715.5 both function to provide requirements for implementation of this policy. [Reference 2 & 3] The WFF Range Safety Manual, RSM- 2002, however, fails to flow the policy down into WFF Range Ground Safety requirements. The RSM imposes no requirements for public safety in relation to Ground Safety. [Reference 4] Public safety is only addressed in the context of Flight Safety requirements**

(section 6). [Reference 5]

6.1 As a consequence of this omission in the RSM, the CSBF Ground Safety Plan, in parroting the safety goals of the RSM-2002 Ground Safety requirements, does not address the need for public safety in its scope or practice. [Reference 6] The CSBF Contract NAS5-03003, Attachment D, Safety and Health Plan policy statement also does not include safety of the public, only the safety of personnel and equipment are considered. [Reference 7] The only reference to "public safety" that can be found in the CSBF contract is if one traces the referenced NASA FAR supplemental (NFS) clause 1852.223-70, Safety and Health to its source. [Reference 8]

It is worth noting that neither the CSBF contract NAS5-03003 Statement of Work (SOW) nor the Safety and Health Plan mandate implementation of specific, applicable NASA safety requirements, including, but not limited to NPD 1700.1, NPR 8715.3, NPR 8715.5 or RSM-2002 all of which address public safety policy and requirements. [References 9 & 10]

The Balloon Program also failed to implement standard protective controls that would have benefited public safety. Hazardous operating procedures were not instituted for launch activities as required by NPR 8715.3, NPR 8715.5, NASA FAR supplemental 1852.223-70 and the Contract NAS5-03003 Health and Safety Plan [References 11 -14]; WFF Procedures and Guidelines for control of public, such as those found in 800-PG-8715.1.1 and 800-PG-8715.0.3, including roadblocks and dedicated viewing areas, were not implemented for the Balloon Program [Reference 15&16] nor were dedicated safety professionals (e.g., RSO, MRSO and OSS) assigned to oversee the launch process as required by NPR 8715.5 and RSM-2002, and recommended by the HQ independent audit of 2002. [Reference 17-19] If properly implemented one or all might have served to ensure that hazardous operations would not have begun or continued without properly controlling the presence and proximity of bystanders to the hazardous activities.

These requirement omissions were not captured by WFF safety document review or oversight practices. WFF safety leadership therefore did not ensure complete flow down of agency requirements to protect the public nor did GSFC safety leadership verify or provide corrective actions for the flow down of NASA requirements to protect the public.

Applicable Requirements:

NPD 8700.1E, Section 1.0 Policy

NPR 8715.3, NASA General Safety Program Requirements, Section 1.1 Overview, 1.3.1, 3.8.2, 3.8.3

NPR 8715.5, Range Safety Program, P.1 Programs, Section P.1 Purpose, 1.3.7

RSM-2002-Rev B, Range Safety Manual, Section 5.1 Ground Safety, General

RSM-2002-Rev B, Range Safety Manual, Section 6.1.1 Flight Safety, Policies

OF-610-00-P, CSBF Balloon Ground Safety Plan, Section 1.0 Scope NAS5-03003, Contract for the Implementation of the NASA's Balloon Flight Program, Operation and Maintenance of the National Scientific Balloon Facilities (NSBF) in Palestine, Texas and Fort Sumner, New Mexico, and Engineering Support for NASA's Balloon Program.

NASA FAR supplemental 1852.223-70, Safety and Health (a), (g.3)

Detailed Requirements:

[R1]

<u>NPD 8700.1E 1./Policy</u> "It is NASA policy to – a. Protect the <u>public</u>, NASA workforce, high-value equipment and property, and the environment from potential harm as a result of NASA activities and operations by factoring safety as an integral feature of programs, projects, technologies, operations and facilities." c. "Hold NASA leaders, managers, supervisors, and employees accountable for safety and mission success within their assigned areas of responsibility."

[R2]

<u>NPR 8715.3/P1.1/Overview of the NASA Safety Program/1.1.2</u>. "As stated in NPD 8700.1, NASA Policy for Safety and Mission Success, the objectives of the NASA Safety Program are to protect the <u>public</u> from harm, ensure the safety of employees, and affect positively the overall success rate of missions and operations through preventing damage to high-value equipment and property."

<u>NPR 8715.3/1.3 Public Safety/1.3.1</u> "Center Directors, project managers, supervisors, and NASA employees shall: a. Eliminate risk or the adverse effect of NASA operations on the <u>public</u>, or provide public protection by exclusion or other protective measures where the risk or the adverse effect of NASA operations on the <u>public</u> cannot be eliminated. *Note: The responsibility for public safety includes major events such as air shows, open houses, or other events that may be attended by large crowds.*"

[R3]

<u>NPR 8715.5 / P.1/ Purpose</u> "This NASA Procedural Requirements (NPR) document describes NASA's range safety policy, roles and responsibilities, requirements, and procedures for protecting the safety of the <u>public</u>, the workforce, and property during range operations associated with flight."

<u>NPR 8715.5 /1.3.4.2</u> "When functioning as the authority of a range, launch site, (fixed or mobile), or landing site including any airfield used for range operations); or when onsite personnel are affected by range operations, the Center Director or NASA designee shall:...b Ensure all employees and <u>visitors</u> are informed of potential hazards associated with a range operation and the actions to take in the event of an emergency."

[R4]

<u>RSM-2002 / 5. Ground Safety /5.1 General</u>: "The ground safety goal of the GSFC's WFF is to minimize risks to <u>personnel and property</u> involved in conducting operations at GSFC's WFF and to prevent mishaps that might result in embarrassment to NASA and the United States Government." "It is required that all systems be designed such that it will take a minimum of two independent unlikely failures occurring in order for personnel be exposed to a hazard."

[R5]

<u>RSM-2002 / 6. Flight Safety /6.1 Policies:</u> "The flight safety goal is to protect the <u>public</u>, range participants, and property from the risk created by conducting potentially hazardous operations at WFF and to prevent mishaps that would result in embarrassment to NASA or the United States Government. Although these risks can never by completely eliminated, the flight should be carefully planned to minimize the risks involved while enhancing the probability for attaining the mission objective."

[R6]

<u>OF-610-00-P Balloon Ground Safety Plan / 1 Scope</u>: "The ground safety goal of the CSBF is to minimize risks to <u>personnel and property</u> in conducting operations and to prevent mishaps that might result in embarrassment to CSBF, NASA and the United States Government." "It is the policy of the GSFC/WFF and CSBF that all systems be designed such that a minimum of two independent unlikely failures must occur to expose personnel to a hazard."

[R7]

<u>CSBF Contract NAS5-03003, Attachment D, Safety and Health Plan 1.1/Policy</u>: "The policy of PSL is to provide a safe and healthful workplace for contract, NASA and user personnel 'to conserve and protect Government-owned resources,' and to support the overall NASA safety program. PSL considers the safety of <u>personnel and equipment</u> to be of the utmost importance in all NSBF operations. Every employee knows that safety is a prime consideration for all tasks performed." (Note: in 1.0, employees include public – there is no such definition for personnel)

[R8]

NASA FAR supplemental 1852.223-70, Safety and Health (a.1): "Safety is the freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to or loss of equipment or property, or damage to the environment. NASA's safety priority is to protect: (1) The public, (2) astronauts and pilots (3) the NASA workforce (including contractor employees working on NASA contracts), and (4) high-value equipment and property."

NASA FAR supplemental 1852.223-70, Safety and Health (g.3): "The Contractor (or subcontractor or supplier) shall insert the substance of this clause…when the following conditions exist (3) The work, regardless of place and performance, involves hazards that could endanger the public, astronauts and pilots, the NASA workforce (including contractor employees working on NASA contracts), or (4) high-value equipment or property."

[R9]

CSBF Contract NAS5-03003, Attachment A, Statement of Work 3.0/Summary of Requirements:

To accomplish the objectives of this SOW, the contractor shall: B. Conform with all applicable government and industry standards, procedures and policies. (Note: no specific requirements listed in statement of work.)

[R10]

CSBF Contract NAS5-03003, Attachment D, Safety and Health Plan: (Applicable Requirements) : No Applicable NASA (or other) Safety requirements listed

[R11]

NPR 8715.3/3.8 Hazardous Operations/3.8.1 -3.8.3

3.8.1 "NASA hazardous operations involve materials or equipment that, if misused or mishandled, have a high potential to result in loss of life, serious injury or illness to personnel, or damage to systems, equipment, or facilities. Adequate preparation and strict adherence to operating procedures can prevent most of these mishaps. "

3.8.2 "Center Directors and project managers shall: a. Identify, access, analyze, and develop adequate safety controls for all hazardous operations. b. Ensure that all hazardous operations have a Hazardous Operating Procedure or a Hazardous Operating Permit (HOP)."

3.8.3 "Center SMA Directors or their designee shall review and approve HOPs."

[R12]

NPR 8715.5/1.3 Public Safety/1.3.7 "The Vehicle Program Manager. For each range operation, the vehicle program manager or NASA designee shall: c. Coordinate with the range safety

organization(s), including the RSO or equivalent, to develop and implement operational range safety requirements, plans, procedures, and checklists, including mission rules and flight commit criteria (see paragraph 3.4 of this NPR for operational requirements)

[R13]

NASA FAR supplemental 1852.223-70, Safety and Health (j) "The contractor shall continually update the safety and health plan when necessary. In particular, the Contractor shall furnish a list of all hazardous operations to be performed, and a list of other major or key operations required or planned in the performance of the contract, even though not deemed hazardous by the Contractor. NASA and the Contractor shall jointly decide which operations are to be considered hazardous, with NASA as the final authority. Before hazardous operations commence, the Contractor shall submit for NASA concurrence -

(1) Written hazardous operating procedures for all hazardous operations; and/or

(2) Qualification standards for personnel involved in hazardous operations."

[R14]

CSBF Contract NAS5-03003, Attachment D, Safety and Health Plan/Section 4.0, Hazardous Prevention and Control/4.1.2 Written Procedures: "Written procedures for hazardous operations will be developed. Those procedures currently in use will be reviewed to ensure they address all pertinent safety issues. All procedures will be reviewed to ensure they address all pertinent safety issues. All procedures will be reviewed by the SR&QA manager and the Site Manger and approved by the Program Manger. Copies of all procedures will be reviewed annually or whenever an accident of mishap occurs or when any alteration of the procedure is proposed. Copies of procedures will be maintained by the SR&QA office and in the facility where the procedures occurs. Flight-line operations procedures will be maintained by the Operations Manager. Any information in PSL's possession regarding hazardous operations will be made available to appropriate NASA authorities."

[R15]

800-PG-8715.1.1, Unmanned Roadblocks for Hazardous Operations

P.1 Purpose: "This procedure establishes a process for enforcing road access control for all hazardous operations, especially rocket launch operations on Wallops Island. This directive describes where operational roadblock locations are defined (i.e., in the Ground Safety Plan) how unmanned roadblocks will be enforced, and the possible consequences for violating unmanned roadblocks."

P.2 Applicability: "Due to the nature of activities pursued by Code 800, guidelines are necessary to ensure personnel safety and to maintain the quality of on-the-job performance. This guideline is applicable to all operations managed by or under the auspices of Code 800 at Wallops Flight Facility (WFF). It is applicable to support contractors and other directorates when their work duties support or are impacted by Code 800 missions."

P.6 Safety: "Unmanned roadblocks are established at the WFF to prevent personnel from entering a hazardous operations area. Personnel who violate roadblocks may be exposed to great potential danger."

[R16]

<u>800-PG-8715.0.3, Viewing Location for Personnel Not Essential to Launch Operations</u>

P.1 Purpose: "This procedure establishes a process of safe viewing of launch operations on Wallops Island."

P.2 Applicability: "Due to the nature of activities pursued by Code 800, guidelines are necessary to ensure personnel safety. This guideline is applicable to all launch related operations managed or under the auspices of Code 800 at WFF. It is applicable to all visitors and facility personnel, including tenants."

P.6 Safety: "Viewing areas are established to protect personnel not essential to launch operations from the risks associated with launch operations on Wallops Island."

[R17]

<u>NPR 8715.5 / 1.3.5/ Center Range Safety Organization:</u> "For all range operations that use a Center's range facilities, the Center range safety organization lead or NASA designee shall:… d. Designate a qualified Range Safety Officer (RSO) to support each NASA mission that involves range operations (see paragraph 1.3.8 of this NPR for RSO responsibilities).

[R18]

<u>RSM-2002/ Section 2.0:</u> "For the Balloon Program, the Chief, Balloon Program Office shall assure that (2) the operational responsibilities normally assigned to the MRSO, OSS, or Project Manager in this document are implemented for balloon operations."

[R19]

<u>QA-D-02-04-001 / Finding #21</u>: "Operations Safety Supervisor qualifications unclear. It is not clear how WFF range safety verifies the qualifications of "other personnel" that may be delegated this responsibility. Recommendation: WFF should establish a clear policy for delegation of OSS responsibilities. Consider using EWR 127-1 Para 1.4.3 et al as a guide."

INSUFFICIENT PROTECTION OF PERSONNEL

Safety Assessment Observation: Insufficient protection of personnel from balloon launch hazards
Mapping to Report Findings:
R2: WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements (WFF Safety Office and BPO implementing organizations) **R3: WFF Safety Office was not sufficiently knowledgeable about the details of the balloon launch process** **I1: WFF safety office did not perform rigorous hazard analysis** **I4: The ground safety plan was inadequate to cover all relevant hazards and phases** **I5: No complete and thorough standard procedure exists at CSBF to cover the launch process** **I6: Launch crew training did not address failed launch attempts** **I8: CSBF did not analyze the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt** **I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch vehicle maneuver** **I12: The BPO did not have sufficient insight or oversight into the technical aspects of the CSBF's balloon launch process** **I13: Wind created a challenging environment** **I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program** **I15: WFF safety leadership did not thoroughly review balloon safety documentation**
Discussion:
CSBF contractor as well as the Balloon Program Office and the WFF Range Safety Office provided insufficient protection to personnel from hazards associated with the balloon launch process.

RSM-2002 Ground Safety, section 5.1.1 states that "the ground safety goal of GSFC's WFF is to minimize the risks to personnel and property involved in conducting operations at GSFC's WFF and to prevent mishaps that would result in embarrassment to NASA or the United States Government". Section 5.1.2 also requires "that all systems be designed such that it will take a minimum of two independent, unlikely failures occurring in order for personnel to be exposed to a hazard" and that (section 5.2.4) the Ground Safety Plan identify "the potential hazards and describe the system design and methods employed to control the hazards".

The Balloon Ground Safety Plan (OF-610-00-P) echoes these goals; it too states that CSBF's ground safety goal is to minimize risks to personnel. The Balloon Ground Safety Plan however does not comply with the requirements of the Range Safety Manual. The Balloon Ground Safety Plan does not adequately address the requirements to identify potential hazards, to describe the design of hazardous systems and to provide methods of hazard control for each identified hazard in order ensure personnel safety.

There is also no evidence to support that all hazardous systems were either designed or validated (through test or analysis) to withstand two failures, nor can it be shown that sufficient hazard analysis was performed to identify all hazards for the launch phase (including those caused by mechanical limitations or hardware operational constraints) or that all known controls were effectively implemented.

Examples of inadequate protection of personnel can be described in terms of deficiencies regarding system description, hazard identification and corresponding hazard controls, Personnel Protective Equipment (PPE), hazardous operating procedures, training and safety oversight.

<u>System Description</u>

The Ground Safety Plan is not compliant with the RSM-2002 requirement to describe the hazardous system design. System descriptions of the ground support equipment and flight hardware should include, but not be limited to, such pertinent design data as pressures systems component parameters, pyro specifications and locations, launch vehicle tolerances and inhibit schemes. Lack of proper descriptions left personnel without insight into the design of hazardous systems and the ability to assess their compliance with design requirements. RSM-2002 (section 5.3.3.5) requires "that no personnel shall be allowed with the danger area of a Category A system if the system has been reduced to only one inhibit." Such and evaluation is impossible without clear description of the systems and their required inhibits.

Identified Hazards and Corresponding Controls

The Balloon Ground Safety Plan does not adequately identify potential hazards or identify specific mitigations for identified hazard cause. The potential "independent, unlikely failures" that drive the systems design in accordance to the requirements of RSM-2002 are not identified. A number of hazards are either not identified or not discussed in any detail. Examples included the hazards associated the balloon inflation pressure system, and the mobile crane launch vehicle and its operation (e.g., potential mechanical failures, operational constraints and hazards associated with the swinging load in close proximity to the crew).

In many cases, personnel training is the only identified control for serious hazards, essentially putting the burden of control solely on the individual skill and memory of the operator. It was noted that for RF hazards, in lieu of documented controls within the Ground Safety Plan, personnel are provided a reference document for more guidance ("more guidance (if required) for RF hazards to personnel may be found in IEEE C95.1-1999, listed in the reference in Section 5.0"). For hazards associated with chemicals, personnel are required to reference posted Material Safety Data Sheets. Neither of these discussions constitutes adequate identification and control of hazards.

Protective Personnel Equipment (PPE)

PPE requirements were not enforced for the Alice Spring launch.

The Balloon Ground Safety Plan requires that hardhats be worn by crew members during launch operations, however photographic evidence shows at least two crew members participated in launch activities without hard hats.

The Balloon Program also failed to carry forward lessons learned from a previous balloon launch close call, reported in the IRIS system in 2000. The formal corrective action included installation of a safety cage over and around the personnel platform and requiring safety hats, glasses and shoes to be worn by all flight line personnel. The Balloon Program did not carry any of these protective measures forward. The Balloon Ground Safety Plan did not require safety glasses or safety shoes, or that a protective structure be provided.

Hazardous Operating Procedures

The CSBF launch operations took place without the benefit of hazardous operating procedures. Evidence obtained through witness interviews and document review indicates that the CSBF did not develop or use written hazardous procedures. Lack of written hazardous procedures constitutes non-compliance with both Agency safety requirements and the WFF/CSBF contract.

Witness interviews uncovered that the contractor launch operators rely solely on checklists, the generic ground safety plan, job knowledge and experience to execute the complicated and hazardous launch operation steps. Procedures were not used for the Alice Springs NCT launch, nor are they typically used. The operators and WFF management furthermore, had little or no knowledge regarding the existence of hazardous operation procedures, or of the requirements for their use.

Training

The Balloon Program Office and CSBF in lieu of written procedures and explicit hazard controls relied heavily the on-the-job training provided to the crew. In fact, for many of the hazards listed in the Balloon Ground Safety Plan (including handling of ionizing radiation, handling and installing pyrotechnics, operating of heavy equipment and other tasks performed within the hazard area) lists prior personnel training was the only hazard control.

Interview data determined that despite many hours of on-the job training; crew training did not include specific training for anomalous situations. There was no instruction on specific abort criteria, response to breach of safety zones or IRT training. Personnel were given limited guidelines regarding hazardous operations and decisions, such as abort criteria or procedures relating to failed launch attempts. Evidence also indicates uncertainty among both BPO and CSBF personnel regarding who has abort authority, the application of the Category A hazard zone for the launch phase and assigned safety roles and responsibilities.

The Balloon Ground Safety Plan also did not provide a full discussion of personnel training and certification requirements for the hazardous operations to be performed. There was no clear system for the verification of the status of operator certification prior to the beginning of the launch operations. Evidence suggests s that one of the launch crew crane operator certification was not current.

<u>Safety Oversight</u> **Range Safety oversight was conspicuously absent and not in compliance with Range and Agency requirements.** **The Balloon program and WFF Range Safety did not assign a Mission Range Safety Officer (MRSO) or Operational Safety Manger (OSS) to the Alice Spring NCT launch as required by NPR 8715.5 and RSM-2002. The lack of a dedicated trained safety officer engaged in reviewing launch procedures, verifying test results, conducting pre-task briefings, monitoring the hazardous launch operations and making abort decisions left both personnel and the general public vulnerable to potential injury or death. Contractor personnel were not given the benefit of undergoing simulation scenarios with a RSO in order to gain hands on experience including safety decision-making tools, and processes in conjunction with vehicle systems or mission rules and range safety flight commit criteria.** **The Campaign Manager and Launch Director were over-burdened with the responsibility of assuming safety monitoring duties in addition to their operational duties; they were also not properly trained to do so.**
Referenced Document:
IRIS Report 2000-231-00012
Applicable Requirements:
NPR 8715.5, Range Safety Program, 1.3.2, 1.3.4.3 **RSM-2002, Range Safety Manual, 2.0, 5.0** **NASA FAR supplemental 1852.223-70, Safety and Health (j)** **CSBF Health and Safety Plan (Section J of the Contract NAS5-03003)**
Detailed Requirements:

INSUFFICIENT HAZARD ANALYSIS

Safety Assessment Observation: The hazard analysis for the Pre-flight launch phases of the balloon launch process was insufficient.
Mapping to Report Findings:
R2: WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements (WFF Safety Office and BPO implementing organizations) **R3: WFF Safety Office was not sufficiently knowledgeable about the details of the balloon launch process** **R6: Reliance on past success has become a substitute for good engineering and safety practices in the balloon program** **I1: WFF safety office did not perform rigorous hazard analysis** **I4: The ground safety plan was inadequate to cover all relevant hazards and phases** **I7: Cat A hazard area during launch phase was not well defined** **I8: CSBF did not analyze the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt** **I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt** **I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch vehicle maneuver** **I12: The BPO did not have sufficient insight or oversight into the technical aspects of the CSBF's balloon launch process** **I13: Wind created a challenging environment** **I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program** **I15: WFF safety leadership did not thoroughly review balloon safety documentation**

Discussion:

The Balloon Program's lack of stringent hazard analysis left them vulnerable to non-compliances with Agency and WFF Range Safety Requirements.

NPR 8715.5, Range Safety Program under Range Safety Analysis (section, 3.2.1), requires that "each range operation shall undergo a range safety analysis to establish any design or operational constraints needed to control risk to persons and property". [Reference 1] (Note: Range Operation is defined as the flight of a launch vehicle including payload at, to or from a range, launch sites or landing site.) The Balloon Program Office and the WFF Safety Office failed to perform, or to ensure that adequate analyses were performed, for the preflight phase of the balloon launch process. Due to this omission the balloon program operated without properly identified hazards and without adequate hazard controls.

The Range Safety Manual, RSM-2002 Section 5.2.4 stipulates that a Ground Safety Plan shall "identify the potential hazards and describe the system design and methods employed to control the hazards as well as establish controls to protect high value property." The ground plan must also include description and technical evaluation of the hazardous systems' compliance with the design requirements of section 5.1.2 [Reference 2] and section 5.3 (Specific Policies and Criteria) of the Ranges Safety Manual. Section 5.1 stipulates "that all systems are designed such that it will take a minimum of two independent, unlike design requirements for systems including safety critical Ground Support Equipment (GSE) (5.3.5.1), electrically operated GSE used on Category A systems (5.3.5.6), ground support pressure systems (5.3.5.12), RF systems (5.3.5.8), and lifting devices and equipment (5.3.5.5).

The Balloon Ground Safety Plan, OF-610-00-P does not include the required design descriptions and assessments nor does it identify all know hazards and controls associated with the launch pre-inflation, inflation and launch phases. Examples of hazards not adequately addressed within the current Ground Safety Plan include:

- **Structural failure of launch equipment**
- **Collision of moving/swinging payload with personnel or property (suspended loads)**
- **Collision or tipping of mobile crane with personnel or property**
- **Over pressurization or rupture of the balloon inflation system**
- **Inadvertent/premature release of the payload**
- **Inadvertent/premature ignition of pyrotechnics**
- **Inadvertent/premature abort**
- **Collision with aborted/released parachute train equipment**

There is no evidence to suggest that a comprehensive safety analysis was performed for the balloon program for either the hardware or the operations associated with the launch process. Adequate documentation was not found in the Ground Safety Plan nor any other documentation reviewed. Operational constraints, hardware failure mechanisms, and limits were not identified.

RSM-2002, prescribes the methodology for analysis and control implementation in the Ground Safety Hazard Control (Section 5.2). The RSM requires that the following hazard control methods be used to "protect personnel and property and minimize risk when conducting potentially hazardous operations":

- **Identify all known hazards associated with the program**
- **Implement safety design criteria**
- **Minimize exposure of personnel to hazardous systems**
- **Establish safe operating procedures**
- **Plan for contingencies"**

Proper implementation of this process would have reduced the Balloon Programs risks of mishaps.

A traditional Operating and Support Hazard Analysis (O&SHA) is most often used to identify and evaluate hazards associated with the associated environment, personnel, procedures, and equipment involved throughout the operation (Reference System Safety Society Handbook). A closed-loop process is then employed to identify the hazards in terms of a) hazard description, b) potential consequences, c) cause, and d) established method(s) to control as well as to track and ensure the status of each hazard control prior to the start of the applicable operation.

Individual hazard reports included within the Ground Safety Plan would have helped to ensure that the hazards, their causes, consequences and controls were accounted for appropriately, through the review and update of the reports prior to each mission.

This type of rigor would help the Balloon Program to remain compliant with the RSM requirement to "identify the potential hazards and describe the system design and methods employed to control the hazards".

Applicable Requirements:

NPR 8715.5, Range Safety Program, 3.2.1,

RSM-2002-Rev B, Range Safety Manual, 5.1.2, 5.2, 5.2.4, 5.3.5

Detailed Requirements:
[Ref 1] **6.2 <u>NPR 8715.5,3.2 / Range Safety Analysis/3.2.1</u>: Each range operation shall undergo a range safety analysis to establish any design or operational constraints needed to control risk to persons and property.** **<u>NPR 8715.5,3.2 / Range Safety Analysis/3.2.2</u>: A range safety organization that is independent of the vehicle program shall review and approve the range safety analysis.** **<u>RSM-2002-Rev B, Range Safety Manual/5.0 Ground Safety/5.1 General/ 5.1.1</u>: The ground safety goal of GSFC's WFF is to minimize the risks to personnel and property involved in conducting operations at GSFC's WFF and to prevent mishaps that would result in embarrassment to NASA or the United States Government.** **[Ref 2]** **<u>RSM-2002-Rev B, Range Safety Manual/5.0 Ground Safety/5.1 General/ 5.1.2</u>: It is required that all systems be designed such that it will take a minimum of two independent, unlikely failures occurring in order for personnel to be exposed to a hazard.**

INADEQUATE GROUND SAFETY PLAN

Safety Assessment Observation: The CSBF Ground Safety Plan is not adequate. It does not provide a comprehensive hazard analysis of the launch ground operations and their controls.

Mapping to Report Findings:

R2: WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements (WFF Safety Office and BPO implementing organizations)

R6: Reliance on past success has become a substitute for good engineering and safety practices in the balloon program

I1: WFF safety office did not perform rigorous hazard analysis

I4: The ground safety plan was inadequate to cover all relevant hazards and phases

I7: Cat A hazard area during launch phase was not well defined

I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt

I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch vehicle maneuver

I12: The BPO did not have sufficient insight or oversight into the technical aspects of the CSBF's balloon launch process

I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program

I15: WFF safety leadership did not thoroughly review balloon safety documentation

Discussion:

RSM-2002 Section 5.2.4 states that a Ground Safety Plan shall "identify the potential hazards and describe the system design and methods employed to control the hazards" as well as "to establish controls to protect high value property." [Reference 1]

The Range Safety Manual (RSM) states that ground safety plan must also include description and technical evaluation of the hazardous systems' compliance with the design requirements of section 5.1.2 [Reference 2] which stipulates "that all systems are designed such that it will take a minimum of two independent, unlikely failures occurring in order for personnel to be exposed to a hazard." and section 5.3 (Specific Policies and Criteria) which provides specific requirements for potentially hazardous systems including safety critical Ground Support Equipment (GSE) (5.3.5.1), electrically operated GSE used on Category A systems (5.3.5.6), ground support pressure systems (5.3.5.12), RF systems (5.3.5.8), and lifting devices and equipment (5.3.5.5).

RSM-2002 section 5.2.4.3 allows that, "where applicable, a general Ground Safety Plan may be prepared for repetitive operations/programs which shall identify safety planning for all potential hazards. This plan may be augmented for mission operations by a mission specific Ground Safety Plan." The Balloon Program chose to exercise this option. The Balloon Program Ground Safety Plan is a generic plan that was produced by the WFF Safety Office in 2004. It is supplemented by experimenter payload data provided in the format of questionnaires prior to each mission, which together with the generic plan, made up a Ground Safety Data Package. Even with the supplements included, the plan failed to contain the necessary information.

The CSBF Balloon Ground Safety Plan, OF-610-00-P, is not adequate and is not in compliance with the requirements of RSM-2002. It does not deliver a comprehensive hazard analysis of the launch ground operations, including constraints, a thorough description of the system design and constraints or fully identify the required hazard controls.

The hazard analysis provided by the Balloon Ground Safety Plan is not fully developed. The precautions and controls that are provided are not tied to specifically identified hazards and hazard causes and corresponding, verifiable controls. Many hazards are not identified at all. Examples of hazards not adequately addressed within the current Ground Safety Plan include:

- **Structural failure of launch equipment**
- **Collision of moving/swinging payload with personnel or property (suspended loads)**
- **Collision or tipping of mobile crane with personnel or property**
- **Over pressurization or rupture of the balloon inflation system**
- **Inadvertent/premature release of the payload**
- **Inadvertent/premature ignition of pyrotechnics**
- **Inadvertent/premature abort**
- **Collision with aborted/released parachute train equipment**

Typically, the Ground Operations Plans (GOP) or Ground Safety Plans (GSP) that NASA programs submit for Range Safety approval (e.g., Expendable Launch Vehicle (ELV) and Manned Space missions) provide detailed descriptions of the hazardous and safety critical operations

associated with a flight system and its associated ground support equipment. These GOP contain a description of planned operations including backout steps and the associated hazard analysis of those operations. The typical ground plan will contain a list of all procedures (non- hazardous, hazardous and safety critical), procedure descriptions, task summary details including hazards and precautions, and list of required PPE), identification of emergency and abort/back-out actions and a list of personnel training, certification and experience requirements for each type of hazardous operation such as ordnance, radiation and crane operations, and description of test performed on hazardous and safety critical systems. In addition a hazard analysis is included for each hazardous system and an Operating and Support Hazard Analysis (O&SHA) is provided for each hazardous operation. The O&SHA worksheets typically provide the following information: general hazard group, specific hazard condition, effect of hazard if not controlled, hazard control hardware, hazard control procedure, hazard control personnel. The plan also provides a mechanism for verifying that all hazard controls are in place prior to the beginning of the launch operation.

Interview evidence indicates that the Balloon Program Office and CSFC contractors believed the Balloon Ground Safety Plan to contain comparable comprehensive information as discussed above for a 'typical' ground plan. The Ground Safety Plan was repeatedly referenced in interviews whenever questions relating to system design, operational analysis, keep out zones, hazard controls and hazardous operating procedures were raised. Subsequent review of the generic balloon ground safety plan revealed that the plan failed to provide most of the referenced information.

The Balloon Program Office and the WFF Safety Office failed to sufficiently review the ground safety plan for compliance with the Range Safety requirements and/ or neglected to make the necessary improvements to bring the Balloon Ground Safety Plan into compliance.

Applicable Requirements:

RSM-2002-Rev. B, Range Safety Manual, 5.1.2, 5.2, 5.2.4, 5.3.5,

AFSPMAN 91-710 Vol. 6, Attachment, Ground Operations Plan

Detailed Requirements:

[Ref 1]

RSM-2002-Rev B, Range Safety Manual/5.0 Ground Safety/5.2.4/Ground Safety Plan

5.2.4.1 A Ground Safety Plan will be prepared by the Ground Safety Group (GSG) prior to any potentially hazardous operation or launch conducted at or managed by WFF. This plan will identify the potential hazards and describe the system designs and methods employed to control the hazards. This plan shall also establish controls to protect high value property, as required.

5.2.4.2 For launch or other potentially hazardous ground operations conducted at other ranges, this information shall be provided in a Ground Safety Plan or Ground Safety Data Package.

5.2.4.3 Where applicable, a general Ground Safety Plan may be prepared for repetitive operations/ programs which shall identify safety planning for all potential hazards. This plan may be augmented for mission operations by a mission specific Ground Safety Plan.

[Ref 2]

RSM-2002-Rev B, Range Safety Manual/5.0 Ground Safety /5.1 General/ 5.1.2: It is required that all systems be designed such that it will take a minimum of two independent, unlikely failures occurring in order for personnel to be exposed to a hazard.

INSUFFICIENT HAZARDOUS OPERATING PROCEDURES

Safety Assessment Observation: Hazardous operations are conducted without written operating procedures for NASA balloon launch operations. Failure to provide written procedures constitutes non-compliance with NASA requirements NPR 8715.3, NPR 8715.5 and NASA-STD-8719.9, as well as CSBF policy put forth in the CSBF Health and Safety Plan.

Mapping to Report Findings:

R2: WFF safety leadership did not provide appropriate oversight to WFF implementation of safety requirements (WFF Safety Office and BPO implementing organizations)

R6: Reliance on past success has become a substitute for good engineering and safety practices in the balloon program

I5: No complete and thorough standard procedures exist at CSBF to cover the launch process

I14: GSFC safety management did not verify or provide corrective action for flow down of NASA requirements to protect the public

I15: WFF safety leadership did not thoroughly review balloon safety documentation

Discussion:

The CSBF launch operations took place without the benefit of hazardous operating procedures. Lack of written hazardous procedures constitutes non-compliance with both Agency safety requirements and the WFF/CSBF contract.

NPR 8715.3, NASA General Safety Program Requirements, (section 1.4.3.j) states that the Center Director shall "ensure that for hazardous NASA operations, procedures are developed for the following circumstances: 1) to provide an organized and systematic approach to identify and control risks, 2) when equipment operations, planned or unplanned, are hazardous or constitute a potential launch, test, vehicle, or payload processing constraint, or 3) when an operation is detailed or complicated and there is reasonable doubt that it can be performed correctly without written procedures." NPR 8715.3, section 3.8. Hazardous Operations, also stipulates that Center Directors and project managers "shall ensure that all hazardous operations have a Hazardous Operating Procedure or a Hazardous Operating Permit (HOP), and that all procedures include sufficient detail to identify residual hazards and cautions to NASA personnel." "The Center SMA Director

or designee shall review and approve the HOP." [Reference 1]

NPR 8715.5, Range Safety Program (section 1.3.7.c) requires that "for each range operation, the vehicle program manager or NASA designee shall coordinate with the range safety organization to develop and implement procedures." [Reference 2] and the NASA FAR supplemental 1852.223-70, Safety and Health (j) as attached to the CSBF contract requires that "before hazardous operations commence, the Contractor shall submit for NASA concurrence (1) Written hazardous operating procedures for all hazardous operations; and/or (2) Qualification standards for personnel involved in hazardous operations." [Reference 3]

The CSBF's own Health and Safety Plan (section J of the Contract NAS5-03003) states that the "safety of personnel and facilities will be ensured through the use of existing procedures" and that "written procedures for hazardous procedures will be developed and annually reviewed." The plan also states that "flight line operations procedures are to be maintained by the Operations Manager" and "will be made available to appropriate NASA authorities."

Despite all of these the agency requirements and the CSBF plan, evidence obtained through witness interviews and document review indicates that the CSBF in fact did not develop or use written hazardous procedures.

Witness interviews uncovered that the contractor launch operators rely solely on checklists, the generic ground safety plan, job knowledge and experience to execute the complicated and hazardous launch operation steps. Procedures were not used for the Alice Springs NCT launch, nor are they typically used. The operators and WFF management furthermore, had little or no knowledge regarding the existence of hazardous operation procedures, or of the requirements for their use.

Section 3.8.1 of NPR 8715.3 reads that " NASA hazardous operations involve materials or equipment that, if misused or mishandled, have a high potential to result in loss of life, serious injury or illness to personnel, or damage to systems, equipment, or facilities. Adequate preparation and strict adherence to operating procedures can prevent most of these mistakes. By definition, the balloon launch undeniably constitutes a hazardous operation. The failure of the Balloon Program Office and CSBF conduct launch operations by the instruction of approved written hazardous operating procedures left the participating crew, personnel and public vulnerable increased risks of serious mishaps.

Applicable Requirements:
NPR 8715.3, NASA General Safety Program Requirements, Section 3.8 Hazardous Operations 3.8.1, 3.8.2.b, 3.8.2.g, 3.8.2.h, 3.8.3 **NPR 8715.5, Range Safety Program, 1.3.7.c, 1.3.8.2.b** **NASA FAR supplemental 1852.223-70, Safety and Health, (j)** **NASA-STD 8719.9, NASA Lifting Standard, 5.7.b** **NAS5-03003, Balloon Program and National Scientific Balloon Facilities Contract, Attachment J, Health and Safety Plan, RFP NAS5-03003, 1.2, 4.1.1.2** **820-PG-7120.1.4, Management of the Balloon Program's Safety Implementation, 2.0, 3.0** **803-PG-8715.1.14D, Safety Review Process, P.1, P.2**
Detailed Requirements:
<u>NPR 8715.3, NASA General Safety Program Requirements, Section 3.8 Hazardous Operations:</u> **"3.8.1 NASA hazardous operations involve materials or equipment that, if misused or mishandled, have a high potential to result in loss of life, serious injury or illness to personnel, or damage to systems, equipment, or facilities. Adequate preparation and strict adherence to operating procedures can prevent most of these mistakes. This paragraph applies to operations that occur on a routine or continuous basis."** **3.8.2 Center Directors and project managers shall b) Ensure that all hazardous operations have a Hazardous Operating Procedure or a Hazardous Operating Permit (HOP) (Req 32324)** **Note: HOPs consist of a detained plan listing step-by-step functions or tasks to be performed on a system or equipment to ensure safe and efficient operations. HOPs list special precautions, start and stop time of the operation, and the approving supervisor(s).** **g. Ensure that all procedures include sufficient detail to identify residual hazards and**

cautions to NASA personnel (req 32505)

h. Ensure that hazardous procedures are marked conspicuously on the title page to alert operators that strict adherence to the procedural steps and safety and health precautions contained therein are followed (req 32325).

3.8.3 Center SMA Directors or their designee shall review and approve HOPs (req)

<u>NPR 8715.5, Range Safety Program/ 1.3.7:</u> Vehicle Program Manager. For each range operation, the vehicle program manager or NASA designee shall:

c. Coordinate with the range safety organization(s), including the RSO or equivalent, to develop and implement operational range safety requirements, plans, <u>procedures,</u> and checklists, including mission rules and flight commit criteria.

<u>NPR 8715.5, Range Safety Program/ 1.3.8.2:</u> For each range operation, the RSO or equivalent shall:

b. Coordinate with the program to develop and implement operational range safety requirements, plans, procedures, and checklists, including mission rules and flight commit criteria.

<u>NASA-STD 8719.9/ 5.7 Operations/ b:</u> General operating procedures describing operation, emergency steps, communication requirements, and special requirements shall be prepared, approved, and followed for each crane/derrick. There must be a formal system for review, approval, and update to maintain valid operating procedures. Emergency procedures shall be developed for contingency actions such as power loss, brake failures, or other emergencies (also see para 1.5.1.c)

<u>NAS5-03003, Balloon Program and National Scientific Balloon Facilities Contract, Attachment J, Health and Safety Plan, RFP NAS5-03003, Section 4.0, Hazardous Prevention and Control / 4.1.2 / Written Procedures</u> :Written procedures for hazardous operations will be developed. Those procedures currently in use will be reviewed to ensure they address all pertinent safety issues. All procedures will be reviewed to ensure they address all pertinent safety issues. All procedures will be reviewed by the SR&QA manager and the Site Manger and approved by the Program Manger. Copies of all procedures will be reviewed annually or whenever an accident of mishap occurs or when any alteration of the procedure is proposed. Copies of procedures will be maintained by the SR&QA office and in the facility where the procedures occur. Flight-line operations procedures

will be maintained by the Operations Manager. Any information in PSL's possession regarding hazardous operations will be made available to appropriate NASA authorities.

<u>NAS5-03003, Balloon Program and National Scientific Balloon Facilities Contract, Attachment J, Health and Safety Plan, RFP NAS5-03003, Section 4.0, Hazardous Prevention and Control 4.1.1.2 Methodology to Identify and Submit Procedures:</u> PSL will utilize our existing and newly formalized policies and procedures for the implementation of hazardous operations procedure in lieu of submitting procedures to NASA for review and approval. See Section 4.1.1.1 for further discussion on the planned implementation description.

<u>820-PG-7120.1.4, Management of the Balloon Program's Safety Implementation/ 2.0 Operational Ground Safety:</u> "For operational ground safety, the safety related references (P4 items d through q) should normally have precedence. The cases not covered by these safety references shall require a specific Ground Safety Plan to be generated by the Contractor [CSBF] and approved by the Chief of Balloon Program Office or designee to ensure safe operating procedures are planned and implemented."

<u>820-PG-7120.1.4, Management of the Balloon Program's Safety Implementation</u> /3.0 Operational Payload Safety

"For operational ground safety, the safety related references (P4 items d through q) should normally have precedence. The cases not covered by these safety references shall require a specific Payload Safety Plan to be generated by the Contractor [CSBF] and approved by the Chief of Balloon Program Office or designee to ensure safe operating procedures are planned and implemented."

<u>803-PG-8715.1.14D, Safety Review Process/ P.1 Purpose:</u> This document establishes the procedures for Safety Review of projects and operations conducted and managed by GSFC/WFF.

<u>803-PG-8715.1.14D, Safety Review Process/ P.2 Applicability</u>: The methods in this procedure are used to review all Safety Analyses, Safety Plans, and Operations Plans generated by the Safety Office. This procedure is also applicable to hazardous procedures conducted in support of flight operations, safety graphic display configurations and wind weighting packages.

<u>NASA FAR supplemental 1852.223-70, Safety and Health/ (j):</u> that is a part of the contract which requires that "The Contractor shall continually update the safety and health plan when necessary". In particular, the Contractor shall furnish a list of all hazardous operations to be performed, and a

list of other major or key operations required or planned in the performance of the contract, even though not deemed hazardous by the Contractor. NASA and the Contractor shall jointly decide which operations are to be considered hazardous, with NASA as the final authority. Before hazardous operations commence, the Contractor shall submit for NASA concurrence -

(1) Written hazardous operating procedures for all hazardous operations; and/or

(2) Qualification standards for personnel involved in hazardous operations.

<u>NPR 8715.5, Range Safety Program/ 1.3.7</u>: Vehicle Program Manager. For each range operation, the vehicle program manager or NASA designee shall:

> **c. Coordinate with the range safety organization(s), including the RSO or equivalent, to develop and implement operational range safety requirements, plans, <u>procedures,</u> and checklists, including mission rules and flight commit criteria.**

<u>NPR 8715.5, Range Safety Program/ 1.3.8.2</u>: For each range operation, the RSO or equivalent shall:

> **b. Coordinate with the program to develop and implement operational range safety requirements, plans, procedures, and checklists, including mission rules and flight commit criteria.**

<u>NPR 8715.3, NASA General Safety Program Requirements, Section 3.8 Hazardous Operations:</u>

"3.8.1 NASA hazardous operations involve materials or equipment that, if misused or mishandled, have a high potential to result in loss of life, serious injury or illness to personnel, or damage to systems, equipment, or facilities. Adequate preparation and strict adherence to operating procedures can prevent most of these mistakes. This paragraph applies to operations that occur on a routine or continuous basis."

"3.8.2 Center Directors and project managers shall b) Ensure that all hazardous operations have a Hazardous Operating Procedure or a Hazardous Operating Permit (HOP)"

> **Note: HOPs consist of a detained plan listing step-by-step functions or tasks to be performed on a system or equipment to ensure safe and efficient operations. HOPs list special precautions, start and stop time of the operation, and the approving supervisor(s).**
>
> **g. Ensure that all procedures include sufficient detail to identify residual hazards and cautions to NASA personnel**

h. Ensure that hazardous procedures are marked conspicuously on the title page…..to alert operators that strict adherence to the procedural steps and safety and health precautions contained therein are followed.

3.8.3 Center SMA Directors or their designee shall review and approve HOPs

INSUFFICIENT SAFETY OVERSIGHT

Safety Assessment Observation: GSFC/WFF leadership provided insufficient safety oversight

Mapping to Report Findings:

R2: WFF safety leadership did not provide appropriate oversight to WFF BPO's implementation of safety requirements (WFF Safety Office and BPO as implementing organizations)

R3: WFF Safety office was not sufficiently knowledgeable about the details of the balloon launch process

R4: GSFC Safety leadership did not verify or provide corrective action for flow down of NASA requirements to protect the public

R5: NASA HQ Range Safety Program Office failed to ensure corrective actions were accomplished from previous agency audits

R6: Reliance on past success has become a substitute for good engineering and safety practices in the balloon program

I1: WFF Safety office did not perform rigorous hazard analysis

I3: No trained individual was in place to ensure public safety

I4: The ground safety plan did not cover all relevant hazards and phases

I5: No complete and thorough procedures exists at CSBF to cover launch process

I7: Cat A hazard area during launch phase was not well defined

I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt

I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch vehicle maneuver

I11: The ground safety plan did not explicitly address the protection of the general public

I12: The BPO did not have sufficient insight or oversight into the technical aspects of the CSBF's balloon launch process

I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program **I15: WFF safety leadership did not thoroughly review balloon safety documentation**
Discussion:
There is evidence of an insufficient safety oversight for the WFF Balloon Program. **NPR 8715.5, Range Safety Program assigns safety oversight requirements to different levels of Agency management, organizations and personnel for the WFF Range Safety and Balloon Programs. There is evidence to suggest that compliance was lacking with regard to oversight responsibilities on all levels.** **The NPR 8715.5, Range Safety Program (section 1.3.2) requires that at the Headquarter level, NASA Range Safety Manager not only evaluate range safety programs but also "ensure consistent implementation of range safety requirements throughout the Agency" Section 1.3.4.2 requires that Center Directors functioning as the authority for fixed or mobile launch sites "establish the processes and associated Center-level requirements needed to ensure the requirements of NPR 8715.5 are met."** **Documentation and interview evidence suggest that the Balloon Program was not afforded the same level of safety insight or oversight as other Agency or even WFF Range programs and that range safety requirements were not consistently implemented for the Balloon Program.** **The NPR (section 1.3.5) gives range safety organization requirements for all range operations that use a Center's range facilities. The requirements state that the Center range safety organization lead or NASA designee shall: (a) Implement or oversee the implementation of this NPR and associated Center-level processes and requirements including the risk management process of paragraph 3.2.4 of this NPR (b) identify program data requirements, perform or evaluate and approve required range safety analysis. (c) evaluate and approve all range safety systems, (d) designate a qualified Range Safety Officer (RSO) to support each NASA mission that involves range operations (see paragraph 1.3.8 of this NPR for RSO responsibilities), (e) establish a qualification and training program that satisfies paragraph 3.5 of this NPR for range safety personnel (including RSOs and personnel responsible for range safety systems and range safety analysis) appropriate to the types of vehicles and operations at the range, (f) set operational**

performance requirements and standards for all range safety systems and (g) ensure the readiness of the range safety systems to support each operation.

The WFF Balloon Program launch activities take place at the contractor CSBF launch facilities or remote locations. However this does not make the BPO exempt from the safety implementation requirements of 1.3.5, based on the intent of NPR 8715 Sections 1.3.2 and 1.3.4.2 which a designed to ensure implementation of safety standards remain consistent for all NASA programs and operations.

The Balloon Program Manager also has a number of required duties designed to provide insight to the balloon launch programs included in NPR 8715.5 (Section 1.3.7, Vehicle Program Manager), the first being too (a) establish the processes and associated program-level requirements needed to ensure the requirements of this (the Range Safety Program) NPR are satisfied. Additional oversight requirements include: (c) the coordination of range safety organizations including RSO to develop and implement operational range safety requirements, plans, procedures, and checklists, including mission rules and flight commit criteria; (d) designate a Range Safety Representative for the vehicle program; (e) involve range safety personnel and begin the tailoring process by the Systems Requirement Review (SRR), continuing throughout all pertinent vehicle and payload reviews and during Operations.; (f) ensure adequate resources and data are available to support all range safety requirements and activities, including the design, test, and implementation of vehicle range safety systems required to support range safety requirements, the range safety organization/authority supporting the review, and approval process and operational support; (g) incorporate the requirements of this document in all launch service provider contracts and flight or other range operation contracts or agreements, (j) in coordination with the range safety organization(s), generate a contingency action plan that describes roles and responsibilities in the event of a mishap and provides procedures to secure all data relevant to an investigation; (l) in coordination with any Center that supports the range operation, ensure all employees and visitors are informed of potential hazards associated with a range operation and the actions to take in the event of an emergency; (o) engage the Center range safety organization regarding, and establish a plan for, monitoring of vehicle and range processes during launches, entries, and other range operations and to ensure timely identification and resolution of any violation that might affect launch, entry, or other operational approval. Engage with the NASA Range Safety Manager to perform this function for range operations not supported by a Center range safety organization; and (v) ensure that any vehicle program personnel who perform a range safety function are qualified and trained in accordance with paragraph 3.5 of this NPR.

Evidence suggests the many of these safety responsibilities were not sufficiently performed on the behalf of the Balloon Program leading to inadequate oversight and insight into the Balloon Program launch operations.

The Range Safety Manual also assigned oversight responsibility to the Balloon Program Office. RSM-2002 Section 2.0 requires that the Balloon Program, the Chief, Balloon Program office shall ensure that 1) the requirements and the procedure defined in appropriate safety plans and balloon risks analysis are implemented and (2) the operational responsibilities normally assigned to the Mission Range Safety Officer (MRSO), Operations Safety Supervisor (OSS), or Project Manager in this document are implemented for balloon operations and defines each of these positions.

Evidence suggest that the Balloon Program was non compliant with these oversight responsibilities. Evidence collected for the Alice Spring NCT launch shows the BPO in fact, did not ensure the implementation of hazardous launch operations as required and nor the assignment and subsequent performance of the required safety responsibilities of OSS and MRSO.

There is no flow down of direction from the RSM 2002 in the CSBF documentation that requires personnel to assume the safety responsibilities of the MRSO, OSS (and Project Manager). The CSBF Balloon Ground Safety Plan, Chapter 2 – Safety Responsibilities, states simply that the CSBF Operations Department Head (campaign manager at remote sites) is responsible to ensure compliance with the provisions of the BGSP for CSBF operations and for science user operations. There is no reference to what these "provisions" are and definitely no reference to the duties described in the RSM 2002. (Note: the only other reference to a specific duty is later in the paragraph – "The crew chief is responsible to direct the movement and operation of all heavy equipment used in balloon launch operations in such a way to ensure safety and minimize the number of personnel exposed to hazards associated with this equipment.") No discussion of certification, training, no reference to NASA requirements, and no mention of specific duties as outlined in RSM-2002. (Note the only reference to the RSM-2002 is in section 1 Scope: "The BGSP is derived from the NASA GSFC/WFF Range Safety Manual, identified as RSM-2002". The wording 'derived' is ambiguous. There is no required RSO or OSS or MRSO training provided to the CSBF safety designees.

The lack of a dedicated trained safety officer engaged in reviewing launch procedures, verifying test results, conducting pre-task briefings, monitoring the hazardous launch operations and making abort decisions left both personnel and the general public vulnerable to potentially injury or death. The Campaign Manager and Launch Director were over-burdened with the responsibility of assuming safety monitoring duties in addition to their operational duties; they were also not properly trained to do so.

Insufficient oversight of the WFF Safety Leadership, along with the absence of dedicated safety professionals at the launch site significantly added to the risks of the balloon program launch activities.

Applicable Requirements:

NPR 8715.5, Range Safety Program, 1.3.2, 1.3.4.3, 1.3.5, 1.3.7

NASA FAR supplemental 1852.223-70, Safety and Health (j)

RSM-2002-Rev. B, Range Safety Manual , 2.0

800-PG-8715.1.13E, Ground Safety Process

803-PG-8715.1.1E, Range Safety Operations Process

803-WI-8715.1.2D, Range Safety Operations Plan

803-WI-8715.1.14D, Safety Review Process

820-PG-7120.1.4.B, Management of the Balloon Program's Safety Implementation

CSBF Health and Safety Plan (Section J of the Contract NAS5-03003)

Detailed Requirements:

<u>NPR 8715.5, Range Safety Program/ 1.3.2/ NASA Range Safety Manager</u>: The NASA Range Safety Manager shall perform the following Headquarters-level functions: b. Serves as the Agency range safety policy including this NPR. c. Lead a team of Range Safety Representatives (see paragraph 1.3.6) to evaluate and resolve range safety program concerns and ensure consistent implementation of range safety requirements throughout the Agency. d. Review Center and program implementation of this NPR and provide findings and recommendations to the responsible Center, program manager, and the Office of Safety and Mission Assurance. e. Conduct independent assessments of applicable NASA Centers, component and range facilities, and programs at least once every 2 years to verify conformance with range safety policies, procedures, and requirements.

- **Insufficient Independence of Range Safety from Balloon Program**

<u>NPR 8715.5, Range Safety Program/ 1.3.4/ Center Directors:</u> The Center Director or NASA designee shall: (a) Ensure the implementation of this NPR for each Center program that involves range operations. (b) Ensure all employees and visitors are informed of potential hazards associated with a range operation and the actions to take in the event of an emergency. (d) Support range safety independent assessments and respond to all findings and recommendations for which the Center is accountable.

> **1.3.4.3. <u>When functioning as the authority for a range, the Center Director of NASA designee shall establish a Center range safety organization (direct or delegated) that is independent of all vehicle programs</u> and has safety responsibilities for all range operations that use the Center's range facilities (this should include CSBF offsite launches since WFF is the NASA agency procuring their services.)**

<u>NPR 8715.5, Range Safety Program/ 1.3.5 / Center Range Safety Organization</u>: For all range operations that use a Center's range facilities, the Center range safety organization lead or NASA Designee shall (c) evaluate and approve all range safety systems. (d) designate a qualified Range Safety Officer (RSO) to support each NAA mission that involves range operations.

<u>NPR 8715.5, Range Safety Program/ 1.3.6 / Range Safety Representative for a Center or a vehicle program shall</u>: 1.3.6.1 Monitor the implementation of this NPR

<u>NPR 8715.5, Range Safety Program/ 1.3.8/ Range Safety Officer (RSO) (or equivalent)/1.3.8.1</u>: The RSO or equivalent for each NASA range operation shall be a qualified NASA or DoD employee or a person operating under an FAA license.

<u>820-PG-7120.1.4, Management of the Balloon Program's Safety Implementation/ 2.0/ Operational Ground Safety:</u> For operational ground safety, the safety related references (P4 items d through q) should normally have precedence. The cases not covered by these safety references shall require a specific Ground Safety Plan to be generated by the Contractor [CSBF] and approved by the Chief of Balloon Program Office or designee to ensure safe operating procedures are planned and implemented.

<u>820-PG-7120.1.4, Management of the Balloon Program's Safety Implementation /3.0 Operational Payload Safety:</u> For operational ground safety, the safety related references (P4 items d through q)

should normally have precedence. The cases not covered by these safety references shall require a specific Payload Safety Plan to be generated by the Contractor [CSBF] and approved by the Chief of Balloon Program Office or designee to ensure safe operating procedures are planned and implemented.

INADEQUATE CLOSURE OF AUDIT FINDINGS AND RECOMMENDATIONS

Safety Assessment Observation: Insufficient management oversight regarding the implementation of the 2002 Balloon Program Independent Safety Assessment findings and recommendations allowed required corrective actions to remain incomplete.

Mapping to Report Findings:

R7: NASA Agency Range Safety Program failed to ensure corrective actions were accomplished from previous agency audits

I12: The BPO did not have sufficient insight or oversight into the technical aspects of the CSBF's balloon launch process

I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program

Discussion:

NPR 8715.5, Range Safety Program, requires that a NASA Headquarters-level, independent assessment of range programs be conducted periodically. [Reference 1] The NPR also states that it is the responsibility of the WFF/GSFC Center Director to "support range safety independent assessments and (to) respond to all findings and recommendations for which the Center is accountable." [Reference 2] The 2002 assessment conducted for the WFF Safety Office (reference QA-D-02-04-001), brought forth twenty-three (23) findings and twenty-five (25) recommendations. Eight years later, many of these finding and recommendations remain inadequately or incompletely addressed. Five such findings have particular relevance to the Alice Spring incident and can be directly linked to either contributing or root causes for the mishap. Discussion of these finding are presented below:

QA-D-02-04-001Finding #5 – ***Total Reimbursable Budget Authority (RBA) funding impacts the safety office's ability to perform its mission. 'There is no Direct Budget Authority (DBA) funding for the WFF range safety function. Since the WFF is a full cost accounting organization, there is only RBA funding available to the range safety organization. Recommendation: GSFC/WFF management***

should provide DBA funding based on range safety's assessment of need. GSFC/WFF range safety organization could also attempt to gain DBA funds through submittal of a request to HQ Code Q POP process.'

NPR 8715.5 section 1.3.4.3 requires 'that the Center Director or NASA designee when functioning as the authority for a range, shall establish a Center range safety organization (direct or delegated) that is independent of all vehicle programs'. NPR 8715.3 Section 1.4.3 requires that the Center Director (b) place their safety organization at a level that ensures the safety review function can be conducted independently and (d) ensure that (d) (1) Adequate resources (personnel and budget) are provided to support mishap prevention efforts (2) resource control is independent from any influence that would affect the independence of the advice, counsel, and services provided and (3) ensure that policies, plans, procedures, and standards that define the characteristics of their safety program are established, documented, maintained, communicated, and implemented.'

Interview evidence gives indication the WFF Range safety funding is not independent of the vehicle programs and that the funding structure of the WFF/GSFC safety office may still be an issue.

QA-D-02-04-001Finding #6 - ***Safety practices not consistent across projects in 810, 820, 830 and 840. 'WFF team would benefit from consistent and consolidated application of safety practices across the various program offices. Recommendation: WFF management standardize current safety practices in all WFF programs.'***

NPR 8715.5 Chapter 1.3.2 (c) states that the HQ Range Safety Manager will "ensure consistent implementation of range safety requirements throughout the Agency." Evidence suggests however that Range Safety requirements are not equally or consistently applied to the Balloon Program. This is particularly true regarding the safety oversight and insight provided to the WFF Balloon Programs, including CSBF launch campaigns. Interview and document evidence has repeatedly shown that the Balloon program is not managed in the same manner as other Code 800 range programs and that the WFF Safety Organization, Code 803, has very limited interaction with and oversight of the Balloon Program. Interview evidence and document review show that several standard Code 800 and Code 803 range safety requirements and range safety documents (including processes, procedures, guidelines and work instructions) are not applied to the BPO nor have comparable processes and procedures been developed. The Balloon program missions are not assigned RSO's. Contractor personnel have not been assigned the duties of MRSO or OSS nor has the required balloon-specific OSS training been provided as required by RSM-2002. It is these inconsistencies that led among other things to the absence of a trained safety professional acting to protect the public from harm (through the use of barrier, roadblock and monitoring activities).

QA-D-02-04-001 Finding #9 – ***Range safety involvement with Balloon Program inadequate. The balloon programs operated at GSFC/WFF do not have independent range safety oversight or insight. These payloads are potentially hazardous to the public and should be managed consistent with other***

hazardous, uninhabited programs. <u>Recommendation</u>: GSFC/WFF Management should require range safety involvement in balloon programs. Suggest WFF range safety office and balloon program office coordinate a tailored range safety program for balloons.

Documentation and interview evidence suggest that the Balloon Program was not afforded the same level of safety insight or oversight as other Agency or even WFF Range programs and that range safety requirements were not consistently implemented for the Balloon Program.

NPR 8715.5 (section 1.3.5) stipulates that for *all range operations that use a Center's range facilities*, the Center range safety organization lead or NASA designee shall: (a) Implement or oversee the implementation of this NPR and associated Center-level processes and requirements including the risk management process of paragraph 3.2.4 of this NPR.

(b) Identify program data requirements, perform or evaluate and approve required range safety analysis. (c) Evaluate and approve all range safety systems. (d) Designate a qualified Range Safety Officer (RSO) to support each NASA mission that involves range operations (see paragraph 1.3.8 of this NPR for RSO responsibilities). (e) Establish a qualification and training program that satisfies paragraph 3.5 of this NPR for range safety personnel (including RSOs and personnel responsible for range safety systems and range safety analysis) appropriate to the types of vehicles and operations at the range. (f) Set operational performance requirements and standards for all range safety systems and (g) Ensure the readiness of the range safety systems to support each operation. The BPO launches occur at off-center locations, however Safety Management was required to ensure that comparable Range safety functions be performed to ensure safe operation for all Agency launch operations.

The NPR 8715.5, Range Safety Program (section 1.3.2) requires that at the Headquarter level, NASA Range Safety Manger not only evaluate range safety programs but also "*ensure consistent implementation of range safety requirements throughout the Agency*" Section 1.3.4.2 requires that Center Directors functioning as the authority for fixed or mobile launch sites "*establish the processes and associated Center-level requirements needed to ensure the requirements of NPR 8715.5 are met.*"

Despite these requirements, WFF Range safety provided little or no insight/oversight for the CSBF launches, nor were dedicated range safety personnel in the form of RSO, MRSO or OSS assigned.

The 2002 assessment aptly pointed out the balloon program activity's potential danger to the public and recommended greater Code 803 involvement. Interview and document evidence supports that the Balloon Program still suffers from a lack of oversight. The Safety office to-date does not perform periodic program audits or requirement, document, or analysis reviews, is not present at launch activities and depends on contractor and BPO to impose and maintain safety requirements.

QA-D-02-04-001 Finding #11 – ***WFF pre-mishap planning is inadequate. Recommendation:***

WFF should expand and update written pre-mishap plans for operations at WFF. In additional to the initial response actions, plans should also include all mishap hazards, investigation actions and responses in accordance with NPD 8621.1. Failure to adequately pre-plan may place personnel and resources at unnecessary risk and result in loss of investigation critical information.

The CSBF Mishap Plan was not sufficient to meet the requirements of NPR 8621.1 and NPR 8715.5. The plan failed to provide adequate direction to preserve evidence and to keep personnel and public safe in the event of a mishap.

NPR 8715.5, section 1.3.4.2(i) requires that Center Directors functioning as the authority for fixed or mobile launch sites "Develop emergency plans to prevent or mitigate the exposure of the public or employees to any hazard associated with range operation." NPR 8715.5, section 1.3.7(j) stipulates that the Vehicle Program Manager "In coordination with the range safety organization(s), generate a contingency action plan that describes the roles and responsibilities in the event of a mishap and provides procedures to secure all data relevant to an investigation" and stipulates the use of NPR 8621.1, NASA Procedural Requirements for Mishap Reporting, Investigation and Recordkeeping.

NPR 8621.1, section 2.2 Program and Project Mishap Preparedness and Contingency Plans, 2.2.1.(a) requires that Program Mangers concur with a Program and Project Mishap Preparedness and Contingency Plan (MPCP) that "is a comprehensive plan for all mishaps and close calls that occur offsite, at offsite program/project contractor sites, or in flight."

The contractor did have a mishap plan, but it was not fully compliant with the requirement of NPR 8621.1. OF-695-21-P, 'Columbia Scientific Balloon Facility Procedures Following Flight Mishap or Incident' requires that after a mishap hardware not be disturbed prior to inspection by "appropriate personnel" (undefined) and give the CSBF Operations Department Head or remote Campaign Manger authority to instruct movement or manipulation hardware. There is no discussion of drug testing even though on contract to do so. CSBF Site Manager coordinates appointment of investigation team. There is no information regarding potential hazards associated with or the safing of the equipment. The Balloon Program mishap plan does not include IRT

information nor adequately address the safing of the mishap area or protection of evidence. The lack of a compliant MPCP left the Balloon Program Office and the CSBF contractors unprepared for the Alice Spring mishap. Evidence shows that post-mishap, the public and personnel were allowed in close proximity to unsafed hazardous systems (including pyrotechnics, and chemical batteries) and that there was significant disturbance of the mishap scene and removal of key evidence.

QA-D-02-04-001 Finding #15 – ***Training documentation lacking. There is little or no evidence that all training is documented and tracked within the safety office. Recommendation: An ISO process should be established and followed within the safety (or at the 800 level) to provide requirements for training and accurately document that training. Expedite the issuance of the ISO ground safety training process.***

RSM-2002 requires that the operational responsibilities of the OSS be implemented for the balloon program. The CSBF personnel were however not trained in accordance with the requirements of RSM-2002 to assume the responsibilities OSS.

RSM 2002 states that the Balloon Office "shall ensure that the responsibilities normally assigned to the OSS are implemented for the balloon operations." [Reference 3]

RSM-2002, Section 2.0 the Operational Safety Supervisor (OSS) requires that all personnel designated as OSS are certified by the Safety Office through attending an OSS course and participating in OSS testing performed by the Ground Safety Group (GSG). The procedure for this process is documented in 800-PG-8715.04A, Certification Procedures for Operations Safety Supervisors at WFF. This PG stipulates that there be balloon-specific (Category II -Balloons) training and certification provided for balloon launch OSS or provide satisfactory evidence of the required skill and knowledge.

There is no evidence of WFF provided ground safety training for the Balloon Program contractors (CSBF) who were delegated safety responsibility for launch operations (nor of contractors certified based on WFF review of OSS equivalency). The duties of MRSO and OSS were required to be assumed and verified by the BPO in accordance with RSM-2002. However appropriate NASA training was not mandated for, nor provided to the contractor by WFF Safety or the BPO. The contractor records only indicate on-the-job training records with no attached curriculum. NASA personnel with appropriate range safety training were not assigned as an alternate solution.

QA-D-02-04-001 Finding #21- ***Operations Safety Supervisor qualifications unclear. It is not clear how WFF range safety verifies the qualifications of "other personnel" that may be delegated this responsibility. <u>Recommendation</u>: WFF should establish a clear policy for delegation of OSS responsibilities. Consider using EWR 127-1 Para 1.4.3 et al as a guide.***

RSM-2002 states that the Balloon Office "shall ensure that the responsibilities normally assigned to the OSS are implemented for the balloon operations." [Reference 3]

WFF response to the 2002 audit was that training was being developed to qualify OSS personnel designated by the WFF RSO and that after the summer of 2002; all personnel assigned to OSS duties would be required to have the training. Evidence suggests that this corrective action was never completed. Currently CSBF contractors are not provided OSS training nor are WFF OSS-trained WFF personnel assigned to the balloon launches.

Reference Document:

QA-D-02-04-01, WFF Independent Assessment, Final Report WFF Range Safety Office

Applicable Requirements:

NPR 8715.5, Range Safety, 1.3.2.e, 1.3.4.2.d, 1.3.8.2.d

800-PG-8715.04A

803-WI-8072.1.1 (RSM-93), 2.4, 2.6

Detailed Requirements:

[R1]

<u>NPR 8715.5, Range Safety/section 1.3.2:</u> The NASA Range Safety Manger shall perform the following Headquarters-level functions. (e) Conduct independent assessments of applicable NASA Centers, component and range facilities, and programs at least once every 2 years to verify conformance with range safety policies, procedures, and requirements.

[R2]

<u>NPR 8715.5, Range Safety/section 1.3.4.2:</u> The Center Director or NASA designee shall: (c) Support range safety independent assessments and respond to all findings and recommendations

for which the Center is accountable.

[R3]

RSM-2002/ Section 2.0: **"For the Balloon Program, the Chief, Balloon Program Office shall assure that (2) the operational responsibilities normally assigned to the MRSO, OSS, or Project Manager in this document are implemented for balloon operations."**

UNSAFE CRANE OPERATIONS

Safety Assessment Observation: Balloon Program Crane Operations and Hardware was not in accordance with the NASA standards for Lifting Devices and Equipment.
Mapping to Report Findings:
R2: WFF safety leadership did not provide appropriate oversight to WFF BPO's implementation of safety requirements (WFF Safety Office and BPO as implementing organizations) **R3: WFF Safety office was not sufficiently knowledgeable about the details of the balloon launch process** **R6: Reliance on past success has become a substitute for good engineering and safety practices in the balloon program** **I1: WFF Safety office did not perform rigorous hazard analysis** **I4: The ground safety plan did not cover all relevant hazards and phases** **I5: No complete and thorough procedures exists at CSBF to cover launch process** **I6: Launch crew training did not address failed launch attempts** **I7: Cat A hazard area during launch phase was not well defined** **I8: CSBF did not analyze the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt** **I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt** **I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch vehicle** **I12: The BPO did not have sufficient insight or oversight into the technical aspects of the CSBF's balloon launch process** **I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program** **I15: WFF safety leadership did not thoroughly review balloon safety documentation**

Discussion:
RSM-2002, section 5.3.5.5 requires that "all lifting devices, fixtures, and equipment shall comply with the standards and regulations of NASA-STD-8719.9, Standards for Lifting and Equipment and GPR 8719.1 Certification and Recertification of Lifting Devices and Equipment". It should be noted that the Balloon Launch Program utilized the crane in an unorthodox manner as a launch vehicle for the payloads. The balloon program's expanded of use of the mobile crane puts even more responsibility on the program to ensure that ensure that the intent of the Lifting Devices and Equipment requirements are honored and that the potential hazard associated with each requirement are adequately controlled. **Based on a review of interview, written, photographic and video evidence supported by the GSFC Lifting Device and Equipment Manager (LDEM), there is sufficient indication that the Alice Spring Balloon Launch operation was not in compliance with, nor met the intent of the following NASA-STD-8719.9 requirements.** **•Design Section 5.2.4 "Load capability and the desired controlled characteristics with which the crane/derrick handles the load shall be addressed of all designs. Operation requirements shall be considered in the design phase to ensure load and function are adequately defined and crane/derrick design features are incorporated on the delivered units."** **The restraint system yielded under the imposed load and the spacecraft broke free. There is evidence to suggest that the Balloon Program was unaware of the design and operational limitations of the launch vehicle. Analysis was not performed to identify all possible failure modes of the launch hardware.** **•Training Section 5.6.2(1)(a) ("Classroom training in safety, lifting equipment emergency procedures, general performance standards, requirements, pre-operational and safety related defects, and symptoms (for initial certification and as needed").** **Interview evidence supports that crane operators were not fully knowledgeable regarding the limitations of the system. Crew training did not include emergency or anomaly training, including failed launch attempts. There were also no operating procedures produced or used.** **• Operations Section 5.7(i) Cranes/derricks "shall not be side loaded, used to drag loads sideways, or used to pull loads unless specifically designed to do so the OEM as indicated in the load chart. "** **Video and photographic evidence as well as analysis shows that the launch vehicle was indeed at times side loaded and was used both to drag sideways and to pull the balloon induced loads.**

o (m) "The operator and ground lead mean shall establish appropriate safety zones before initiating operations. Safety zones should have appropriate barriers (rope, cones or other) established prior to lift".

Video, photographic and interview evidence support that an effective safety zone designed to protect the public was not implemented. The Category A zone was ill-defined and ineffective. There was also no attempt to mark a safety zone appropriately prior to operations with cones, ropes or other barriers. Lack of marking made it inconceivable that the crane operator or other observers would detect when the zone was violated by the either the balloon train or the moving crane.

o (t) "During hoisting, care shall be taken that there is not sudden acceleration or decelerations of the moving load and that the load does not contact any obstructions."

Video and interview evidence support that the launch operation consisted of a number of sudden movements including accelerations and decelerations as well as turns that caused the payload to swing widely. At one point the excessive movement of the payload caused the operator to lose control of the payload tag lines. The rough and unimproved terrain contributed to the movement of the suspended payload. The payload also had potential to contact an obstruction when the launch vehicle was driven to the fence.

o (z) "An operator shall be at the crane /derrick controls at times while a load is suspended" (OSHA requirement). Due to the length of some NASA operations, an operator change may be required while a load is suspended. This shall be accomplished via a procedure designed for the specific crane/derrick and operation, assuring the crane controls are manned at all times.

Video, photographic and interview evidence support that the control cabin was not occupied during the launch attempt. The controls were therefore unmanned while the payload was suspended.

o (ai) "When traveling a mobile crane with a load, a person shall be designated responsible for determining and controlling safety and making decisions as to position of the load, boom location, ground support, travel route and speed of the motion."

Interview and documented evidence support that there was considerable confusion among both the crew and the Balloon Program regarding specific personnel safety and decision making responsibilities and authority. It was clear that the launch director was in charge of travel route and speed of the motion; however, the safety control and decision making was not as well defined. Confusion included who had the abort authority and who was responsible for assuming the role of the Mission Range Safety Officer.

o (ak) "When rotating cranes/derricks, sudden starts and stops shall be avoided. Speed shall be

such that the load does not swing out beyond radii at which it can be controlled. A tag line should be used when rotation of load is hazardous" **Video and interview evidence support that the payload swung beyond radii of control. Excessive swinging of the load caused the technician to lose control of both payload tag lines. He was only able to regain control of one prior to the unintentional release of the payload.** **•Sling Section10.7(g) "The following materials and techniques shall not be used in slings or rigging hardware to hoist personnel or loads: natural rope, wire rope clips, the fold back metal pressed sleeve or clip technique".** **Photographic evidence shows that fold back technique was used. The photo also revealed that the cords were improperly taped, making required inspection of the cords impossible.** **In addition, video evidence suggested the potential for non-compliance with the Critical and Noncritical Lifting Operations, requirement 1.5.1 that states "Personnel shall not be located under suspended or moving loads unless the operation adheres to the OSHA-Approved NASA Alternate Standard for Suspended Load Operations."** **The movement of the payload was sufficient to cause concern regarding personnel safety. It is suggested Appendix A of the NASA-STD-8719.9, be examined for possible solutions that may include supporting the payload from underneath, in order to eliminate this potential hazard.**
Applicable Requirements:
RSM-2002-Rev. B, Range Safety Manual, 5.3.5.5 **NASA-STD-8719.9, Standards for Lifting and Equipment, 1.5.1, 5.2.4, 5.6.2, 5.7, 10.7**
Detailed Requirements:
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INSUFFICIENT INDEPENDENCE OF SAFETY

Safety Assessment Observation: Insufficient Independence of Range Safety from Balloon Program

Mapping to Report Findings:

R2: WFF safety leadership did not provide appropriate oversight to WFF BPO's implementation of safety requirements (WFF Safety Office and BPO as implementing organizations)

R5: NASA HQ Range Safety Program Office failed to ensure corrective actions were accomplished from previous agency audits

I12: The BPO did not have sufficient insight or oversight into the technical aspects of the CSBF's balloon launch process

I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program

I15: WFF safety leadership did not thoroughly review balloon safety documentation

Discussion:

NPR 8715.5 Chapter 1.3.2 (c) states that the HQ Range Safety Manager will "ensure consistent implementation of range safety requirements throughout the Agency." Evidence suggests however that Range Safety requirements are not equally or consistently applied to the Balloon Program. This is particularly true regarding the independence of the safety oversight or insight provided to the WFF Balloon Programs, including launch campaigns. NPR 8715.5 section 1.3.4.3 requires 'that the Center Director or NASA designee when functioning as the authority for a range, shall establish a Center range safety organization (direct or delegated) that is independent of all vehicle programs'.

NPR 8715.3 Section 1.4.3 requires that the Center Director (b) place their safety organization at a level that ensures the safety review function can be conducted independently and (d) "ensure that (d) (1) Adequate resources (personnel and budget) are provided to support mishap prevention efforts, (2) resource control is independent from any influence that would affect the independence of the advice, counsel, and services provided and (e) ensure that policies, plans, procedures, and standards that define the characteristics of their safety program are established, documented,

maintained, communicated, and implemented.

Evidence suggests that the independent safety oversight provided to the balloon program was inadequate. The majority of the range safety functions for the Alice Spring NCT launch were carried out by the balloon launch service contractor, CSBF, not an independent source. The WFF Range Safety Office Code 803 had little or no insight or oversight into the technical aspects of the balloon program and provided little in the way of document review, launch site visits, program audits or hazard control verification.

This same lack of independence was observed in the NASA Headquarters' 2002 WFF Independent Assessment Report from which the following statements are taken: "Unlike other uninhabited flight programs, the policy and practice in effect in the balloon programs operated at GSFC/WFF do not require independent safety oversight or insight. With NASA it is common practice to utilize an organization that has no direct stake in the project to establish and implement safety plans, risk analyses and procedures. This independence ensures that the range safety requirements will not be compromised. These payloads are potentially hazardous to the public and should be managed consistent with other hazardous, uninhabited programs. Management is accepting an unknown level of risk associated with balloon operations. The Headquarters assessment team recommended that GSFC/WFF management should require range safety involvement in the balloon programs. The assessment team suggests the WFF range safety office and balloon programs office coordinate a tailored range safety program for balloons." [Ref 2]

Applicable Requirements:

NPR 8715.3, NASA General Safety Program Requirements, 1.4.3

NPR 8715.5, Range Safety Program , 1.3.2, 1.3.4.3

QA-D-02-04-001 Independent Assessment, Final Report Wallops Flight Facility Range Safety Office

Detailed Requirements:

<u>NPR 8715.5, NASA General Safety Program Requirements / 1.3.2 (c):</u> States that the HQ Range Safety Manager will "ensure consistent implementation of range safety requirements throughout the Agency."

[Ref 1]

NPR 8715.5, NASA General Safety Program Requirements/ 1.3.4 Center Directors / 1.3.4.3: When functioning as the authority for a range, the Center Director of NASA designee shall establish a Center range safety organization (direct or delegated) that is independent of all vehicle programs and has safety responsibilities for all range operations that use the Center's range facilities (this should include CSBF offsite launches since WFF is the NASA agency procuring their services.

[Ref 2]

QA-D-02-04-001, Independent Assessment 2002 / Observation: (ITEM 9): Unlike other uninhabited flight programs, the policy and practice in effect in the balloon programs operated at GSFC/WFF do not require independent safety oversight or insight.

Findings: Within NASA, it is.

Methods of Closure: 803 oversight/insight visit to balloon launch contractor planned annually.

Recommendation: GSFC/WFF management should require range safety involvement in the balloon programs. The assessment team suggests that WFF range safety office and balloon programs office coordinate a tailored range safety program for balloons.

INSUFFICIENT TRAINING

Safety Assessment Observation: Contractor safety training insufficient
Mapping to Report Findings:
R2: WFF safety leadership did not provide appropriate oversight to WFF BPO's implementation of safety requirements (WFF Safety Office and BPO as implementing organizations) **R4: GSFC Safety leadership did not verify or provide corrective action for flow down of NASA requirements to protect the public** **R5: NASA HQ Range Safety Program Office failed to ensure corrective actions were accomplished from previous agency audits** **R6: Reliance on past success has become a substitute for good engineering and safety practices in the balloon program** **I2: A barrier to keep the general public out of dangerous areas throughout the launch process did not exist** **I3: No trained individual was in place to ensure public safety** **I4: The ground safety plan did not cover all relevant hazards and phases** **I5: No complete and thorough procedures exists at CSBF to cover launch process** **I6: Launch crew training did not address failed launch attempts** **I7: Cat A hazard area during launch phase was not well defined** **I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt** **I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch vehicle maneuver** **I11: The ground safety plan did not explicitly address the protection of the general public** **I12: The BPO did not have sufficient insight or oversight into the technical aspects of the CSBF's balloon launch process**

I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program
Discussion:
Insufficient oversight by WFF Safety Leadership and the Balloon Program of the balloon program resulted in insufficient contractor training. **<u>Operations Training</u>** **The Balloon Program Office and CSBF in lieu of written procedures and explicit hazard controls relied heavily the on-the-job training provided to the crew. In fact, for many of the hazards listed in the Balloon Ground Safety Plan (including handling of ionizing radiation, handling and installing pyrotechnics, operating of heavy equipment and other tasks performed within the hazard area) lists 'prior personnel training' as the only hazard control.** **Interview data determined that despite many hours of on-the job training; crew training did not include specific training for anomalous situations. There was no instruction on specific abort criteria, response to breach of safety zones or IRT training. Personnel were given limited guidelines regarding hazardous operations and decisions, such as abort criteria. Evidence also indicates uncertainty among both BPO and CSBF personnel regarding who has abort authority, the application of the Category A hazard zone for the launch phase and assigned safety roles and responsibilities.** **<u>MRSO and OSS Training</u>** **There is also no evidence of WFF provided ground safety training for the Balloon Program contractors (CSBF) who were delegated safety responsibility for launch operations (nor of contractors certified based on WFF review of OSS equivalency). The duties of MRSO and OSS were required to be assumed and verified by the BPO in accordance with RSM-2002. However appropriate NASA training was not mandated for, nor provided to the contractor by WFF Safety or the BPO. The contractor records only indicate on-the-job training records with no attached curriculum. NASA personnel with appropriate range safety training were not assigned as an alternate solution.** **Despite the provision in RSM-2002 (section 2) that the operational responsibilities of the Operational Safety Supervisor (OSS) could be implemented for the balloon program by the contractor; the CSBF personnel were not trained in accordance with the RSM to assume the**

responsibilities OSS. **The RSM requires that all personnel designated as OSS are certified by the Safety Office Ground Safety Group (GSG) either by attending OSS an specialized course and successfully completing the testing or by provide satisfactory evidence of the contractor's possession of the required skills and knowledge. The procedure is documented in 800-PG-8715.04A, 'Certification Procedures for Operations Safety Supervisors at WFF'. Balloon-specific (Category II -Balloons) training and certification would have been required for the CSBF crew. Both interview and documentation evidence show that such certification was neither offered by the WFF Safety Office nor otherwise obtained by any of the CSBF crew members.** **<u>Certification Requirements and Verifications</u>** **The Balloon Ground Safety Plan did not provide a full discussion of personnel training and certification requirements for the hazardous operations to be performed. There was no clear system for the verification of the status of operator certification prior to the beginning of the launch operations. Evidence suggests that one of the launch crew required crane operator certification was not current.**
Applicable Requirements:
RSM-2002-Rev. B, Range Safety Manual, 2.0 **800-PG-8715.04A, Certification Procedures for Operations Safety Supervisors at WFF**
Detailed Requirements:

INSUFFICIENT MISHAP RESPONSE PLAN

Safety Assessment Observation: Balloon Program Pre-Mishap Preparedness and Contingency Plan was not compliant with NPR 8621.1
Mapping to Report Findings:
R2: WFF safety leadership did not provide appropriate oversight to WFF BPO's implementation of safety requirements (WFF Safety Office and BPO as implementing organizations) **R5: NASA HQ Range Safety Program Office failed to ensure corrective actions were accomplished from previous agency audits** **I3: No trained individual was in place to ensure public safety** **I5: No complete and thorough procedures exists at CSBF to cover launch process** **I14: WFF safety leadership did not provide appropriate oversight to WFF safety office's responsibilities with regard to the balloon program** **I15: WFF safety leadership did not thoroughly review balloon safety documentation**
Discussion:
The CSBF Mishap Plan was not sufficient to meet the requirements of NPR 8621.1 and NPR 8715.5. The plan failed to provide adequate direction to preserve evidence and to keep personnel and public safe in the event of a mishap. **NPR 8715.5, section 1.3.4.2(i) requires that Center Directors functioning as the authority for fixed or mobile launch sites "Develop emergency plans to prevent or mitigate the exposure of the public or employees to any hazard associated with range operation." NPR 8715.5, section 1.3.7(j) stipulates that the Vehicle Program Manager in coordination with the range safety organization(s), generate a contingency action plan that describes the roles and responsibilities in the event of a mishap and provides procedures to secure all data relevant to an investigation and stipulates the use of NPR 8621.1, NASA Procedural Requirements for Mishap Reporting, Investigation and Recordkeeping.**

NPR 8621.1, section 2.2 Program and Project Mishap Preparedness and Contingency Plans, 2.2.1.(a) requires that Program Mangers concur with a Program and Project Mishap Preparedness and Contingency Plan (MPCP) that "is a comprehensive plan for all mishaps and close calls that occur offsite, at offsite program/project contractor sites, or in flight."

The Balloon Programs contingency plan, 'Procedures Following Launch/Flight Failures, Mishaps, or Incidents CSBF OF-695-21-P', did not meet the content requirements of 2.2.1. The following data requirements were not adequately addressed within their document:

- **Special procedures for emergency response personnel, the IRT, and the incident commander for identifying, safing and handling hazardous commodities specific to the hardware;**
- **training requirements for IRT membership for mishaps and close calls occurring off-site and contractor locations;**
- **procedures to impound data, records, equipment, facilities, and property;**
- **existing memorandas of agreement with national, state, and local organizations and agencies that may be utilized during a mishap investigation;**
- **descriptions of how offsite debris shall be collected, transported, and stored;**
- **descriptions of investigation and debris collection process required for any mishap or close call occurring in a foreign country;**
- **specification, that for NASA-investigated mishaps, NASA personnel shall perform and control the impounding process.**

The contractor did have a generic mishap plan, but it was not fully compliant with the requirement of NPR 8621.1. OF-695-21-P, 'Columbia Scientific Balloon Facility Procedures Following Flight Mishap or Incident' requires that after a mishap hardware not be disturbed prior to inspection by "appropriate personnel" (undefined) and give the CSBF Operations Department Head or remote Campaign Manger authority to instruct movement or manipulation of hardware. There is no discussion of drug testing even though it is in the contract to do so. CSBF Site Manager coordinates appointment of investigation team. There is no information regarding potential hazards (including radioactive sources) associated with or the safing of the equipment. The Balloon Program mishap plan does not include IRT information nor adequately address the safing of the mishap area or protection of evidence.

The lack of a compliant MPCP left the Balloon Program Office and the CSBF contractors unprepared for the Alice Spring mishap. Evidence shows that post mishap, the public and personnel were allowed in close proximity to the 'unsafed' hazardous systems (including pyrotechnics, and chemical batteries) and that there was significant disturbance of the mishap scene and removal of key evidence.

Applicable Requirement:

NPR 8715.5, Range Safety Program, 1.3.4.2.i and 1.3.7 (j) **NPR 8621.1, NASA Procedural Requirements for Mishap Reporting, Investigation and Recordkeeping, 2.2**
Detailed Requirements:
<u>NPR 8621.1, NASA Procedural Requirements for Mishap Reporting, Investigation and Recordkeeping / 2.2 / Program and Project Mishap Preparedness and Contingency Plans:</u> **2.2.1 The program/project manager shall concur in a Program/Project Mishap Preparedness and Contingency Plan that:** **a. Is a comprehensive plan for all mishaps and close calls that occur offsite, at offsite program/project (as defined by NPR 7120.5) contractor sites, or in flight.** **b. Is consistent with the Centers' Mishap Preparedness and Contingency Plans, for all Centers in which the program operates.** **c. Covers any information and procedures required specifically by the program that are not covered in the Centers' Mishap Preparedness and Contingency Plans (i.e., special procedures for safing, handling, or containing hazardous chemicals present in the program's/project's hardware).** **d. Describes the procedures to comply with NPR 8621.1 notification, reporting, investigating, and recording requirements for all program/project activities not located at a Center or managed by a Center (e.g., program/project activities managed by Headquarters and located at a University, contractor site, or other off-Center location).** **e. Describes the training requirements and the IRT's membership for mishaps and close calls that occur offsite, at offsite program/project (as defined by NPR 7120.5) contractor sites, or in flight.** **f. Describes any special procedures for the emergency response personnel, the IRT, and the incident commander that are not covered in the Center Mishap Preparedness and Contingency Plan or the emergency response plan (e.g., identification and handling of hazardous commodities specific to the program) .** **g. Describes the procedures to impound data, records, equipment, facilities, and property not located at a NASA facility.** **h. Identifies existing memoranda of agreement with national, state, and local organizations and agencies that may be utilized during a mishap investigation.** **i. Describes how offsite debris shall be collected, transported, and stored.**

j. Describes the investigation and debris collection process required for any mishap or close call occurring in a foreign country.

k. Requires that, for NASA-investigated mishaps, NASA personnel shall perform and control the impounding process.

l. Lists the personnel who will assist in performing the procedures to impound data, records, equipment, facilities, and other property.

m. Identifies the national, state, and local (and, where applicable, international) organizations and agencies which are most likely to take part in debris collection; identifies the roles and responsibilities of each organization; and identifies a point of contact.

n. Addresses the responsibilities and procedures for mishap investigation in the bilateral or multilateral agreements when the program involves international partners, program managers, and project managers.

o. Describes the resources that may be needed from other government agencies (e.g., Federal Emergency Management Agency, NTSB, DoD, Department of Justice) during a Type A mishap or Type B mishap investigation; identifies the point of contact and contact information for each of these Agencies; describes the procedures to acquire their assistance; and identifies the potential roles and responsibilities of each Agency.

p. Includes a list of information such as databases, Web sites, documentation (including hardware history), drawings, basic system operation, and procedures that may be scrutinized in a Type A mishap involving loss of a vehicle and/or major facility damage and frequently updates this information so that it is easily deliverable to a mishap investigation board, and includes points of contact for the information.

q. Describes the information technology plan to provide computer data retrieval and data archive support to the investigating authority.

r. Describes the requisite security clearances, if any, for investigating authority members, chair, and ex officio participating in program/project investigations.

s. Describes the "chain of custody process" that will be used to secure and safeguard personal effects and sensitive information related to injured or deceased individuals.

t. Names of key personnel from the Agency Public Affairs Office and Office of External Relations (OER) that should be notified for all Type A and Type B mishaps.

u. States the expiration date.

v. Describes appropriate steps to be taken in advance to ensure that assigned IRT and potential MIB members have authority and resources (including, but not limited to, travel, contractual authority, and salaries) to expeditiously deploy to the mishap scene, effectively preserve mishap evidence, interview witnesses and conduct an orderly investigation without administrative delay.

D3 – Human Error Assessment

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
1	CSBF crew allowed general public to gather in the projected flight path	Error of Omission: Public not prevented from entering unsafe area.	Interpretation Error – failure to recognize data as hazardous: CSBF crew did not initially recognize the public gathering outside of fence to watch the launch as a hazardous situation and took no action to restrict access or to move the people.	Barriers to keep general public out of all dangerous areas thorough launch process did not exist. No trained individual was independently in place to ensure range safety. There were no written procedures on how or where to control crowds nor was there any information in the Ground Safety Data Package. The only safety zone designated (the Cat A. zone) did not work as a mechanism to keep spectators situated. The public was rarely, if ever in a downwind location during launch operations therefore CSBF may not have recognized the hazard associated with the collecting crowd outside of the fence.	Recommend training the crew in hazard identification, using analysis to determine safe viewing areas, using procedures for spectator controls, setting up barriers and providing an independent, trained safety officer on-sight during launch operations. Analysis •Recommendation I1-1: WFF safety office should perform a complete hazard analysis, considering all phases of the balloon launch process. This hazard analysis should be validated by independent review. Barriers •Recommendation I2-1: In each launch location, the BPO should ensure that dedicated safety personnel thoroughly examine(s) the potential for spectators or passer-by entering hazardous areas and implement barriers or controls to prevent entry during the launch process. *(12:A barrier to keep the general public out of all dangerous areas throughout the launch process did not exist)* Safety Personnel •Recommendation I3-1: WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring mission success. *(I3: No trained individual was in place to ensure public safety)*

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					Launch Procedures **•<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedures to cover the launch process in accordance with NPR 8715.3.** **Recommendation I5-2 BPO should establish Launch Commit Criteria and flight rules.** ***(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).*** **Ground Safety Plan Protection of Public** **•<u>Recommendation I11-1</u>: WFF safety office should specifically address how to deal with the general public in the ground safety plan.** ***(I11: The ground safety plan did not explicitly address the protection of the general public)*** **Hazard Awareness Training** **•<u>Recommendation O10-1:</u> WFF safety office should ensure CSBF personnel has appropriate hazard awareness training for all hazards associated with each launch.** ***(O-10 – CSBF personnel seemed unaware of a number of potential operational hazards and constraints)***

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
2 [Timeline Event 16]	Launch personnel does fails to move public to safe location.	Error of Commission: In appropriate movement/placement of spectators	Decision Making Failure – failure to select correct/ appropriate action: Personnel failed to effectively move general public to a safe area.	Launch director notices spectators in the downwind flight path and request their relocation. Launch Director recognized hazard associated with public in the intended launch path and asked that they be moved. South Wales University personnel, CSBF crew and volunteers when alerted attempted to move the spectators out of the way; however did so without the benefit of a procedure, explicit directions or an understanding of which locations were hazardous and which were safe. The move(s) were not effective and ultimately people were moved more into harm's way. There was no independent, trained safety officer in place to ensure public was protected or to stop operations until safe to continue.	Recommend using safety analysis to determine safe areas for launch viewing, putting procedures in place for erecting barriers and restricting public access, and providing an independent, trained safety officer on-sight during launch operations. Analysis •<u>Recommendation I1-1:</u> WFF safety office should perform a complete hazard analysis, considering all phases of the balloon launch process. This hazard analysis should be validated by independent review. *(I1: WFF did not perform rigorous hazard analysis)* Barriers •<u>Recommendation I2-1:</u> In each launch location, the BPO should ensure that dedicated safety personnel thoroughly examine(s) the potential for spectators or passer-by entering hazardous areas and implement barriers or controls to prevent entry during the launch process. *(I2:A barrier to keep the general public out of all dangerous areas throughout the launch process did not exist)* Safety Personnel •<u>Recommendation I3-1</u>: WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring mission success. *(I3: No trained individual was in place to ensure public safety)*

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					Launch Procedures •<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedures to cover the launch process in accordance with NPR 8715.3. •<u>Recommendation I5-2</u>: BPO should establish Launch Commit Criteria and flight rules. *(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).* Ground Safety Plan Protection of Public •<u>Recommendation I11-1</u>: WFF safety office should specifically address how to deal with the general public in the ground safety plan. *(I11: The ground safety plan did not explicitly address the protection of the general public)* Hazard Awareness Training •<u>Recommendation O10-1:</u> WFF safety office should ensure CSBF personnel has appropriate hazard awareness training for all hazards associated with each launch. *(O-10 – CSBF personnel seemed unaware of a number of potential operational hazards and constraints)*
3	Launch Director and Campaign Manager failed to get	Error of Omission: Failed to obtain positive feedback on request to	Decision Making Error/Perception Error: Attention	Both the Launch Director and the Campaign Manager have been tasked to be the pseudo safety officers for	Recommend providing an independent, trained safety officer on-sight during launch

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	confirmation that people were relocated to a safe location.	move spectators	Overload	the launch operations. The additional safety oversight responsibility was 1) in conflict with their primary goal to complete the launch and 2) incompatible with their primary responsibilities to pay attention to the balloon overhead and to concentrate on the relative positioning of the launch vehicle and balloon for a successful collar release/launch. In addition, neither had had the required safety training. A dedicated, independent, and properly trained safety officer should have been assigned to the launch – whose sole responsibility was to ensure the safety of the operations without additional distractions or conflicting interests.	operations. Safety Personnel •<u>Recommendation I3-1:</u> WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring mission success. *(I3: No trained individual was in place to ensure public safety*
4 [Timeline Event 16]	CSBF continued launch operations without verification of corrected positioning of public	Error of Commission: Continued hazardous operations without moving public to safe location.	Interpretation Error – failure to understand severity of the hazard: CSBF Crew continued the launch operations with general public still in launch path.	After direction to move people was given, there was no verification on the part of the CSBF crew (including Campaign Manager and Launch Director) that spectators were out of the flight path. Although the hazard of the public in the launch path was initially acknowledged, the severity of it was not. Therefore, not recognizing the severity of the hazard, the operation was continued. There was no safety professional in place to ensure public was no longer in a hazardous area nor to stop operations until safe to continue. No analysis to determine safe area. There were no procedures in place for public safety and	Recommend training the crew in hazard identification, putting procedures and defining go-no go criteria in writing, and providing an independent, trained safety officer on-sight during launch operations. Analysis •<u>Recommendation I1-1:</u> WFF safety office should perform a complete hazard analysis, considering all phases of the balloon launch process. This hazard analysis should be validated by independent review. *(I1: WFF did not perform rigorous hazard analysis)* Barriers •<u>Recommendation I2-1:</u> In each launch location, the BPO should ensure that dedicated safety

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
				spectator control.	**personnel thoroughly examine(s) the potential for spectators or passer-by entering hazardous areas and implement barriers or controls to prevent entry during the launch process.** ***(12:A barrier to keep the general public out of all dangerous areas throughout the launch process did not exist)*** **Safety Personnel** **• Recommendation I3-1: WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring mission success.** ***(I3: No trained individual was in place to ensure public safety)*** **Launch Procedures** **•Recommendation I5-1: BPO should develop a hazardous operating procedures to cover the launch process in accordance with NPR 8715.3.** **Recommendation I5-2 BPO should establish Launch Commit Criteria and flight rules.** ***(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).*** **•Ground Safety Plan Protection of Public** **Recommendation I11-1: WFF safety office should specifically address how to deal with the general public in the ground safety plan.** ***(I11: The ground safety plan did***

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					not explicitly address the protection of the general public) **Hazard Awareness Training** **•<u>Recommendation O10-1:</u> WFF safety office should ensure CSBF personnel has appropriate hazard awareness training for all hazards associated with each launch.** ***(O-10 – CSBF personnel seemed unaware of a number of potential operational hazards and constraints)***
5 **[Timeline Events 24, 29, 30]**	**Launch vehicle did not follow a suitable path to enable a successful launch**	**Error of Commission: Irregular launch vehicle path.**	**Perception Error- failure to perceive or detect: Launch driver's perception of the anticipated balloon direction and speed may have been inaccurate and negatively influenced the path chosen to align with it.**	**The Launch Director is responsible for guiding the launch vehicle into an acceptable orientation for launch. This involves anticipating the movement of the balloon and giving the driver directions designed to position the vehicle under the balloon in a timely manner.** **The launch director relies on his/her perception of wind direction, balloon movements, launch vehicle speed and relative position, and depends on perceived knowledge of the crane's maneuverability.** **The Launch Director ordered driver to drive forward, making a sweeping right 90 degree turn, and later to turn left to align with balloon's flight path. The vehicle slows down due to loss of traction and then speeds up to catch the balloon.**	**Recommend that the Balloon Program taking initiative to characterize and expand launch opportunities, defining launch operation criteria (including launch conditions and acceptable maneuvers), and writing and using launch procedures.** **Launch Procedures** **•<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3.** **•<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules.** ***(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).*** **System Analysis for Payload Release** **•<u>Recommendation I9-1:</u> BPO should require in the contract that CSBF perform a thorough analysis**

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
				The very fragile nature of the balloon launch process leaves little margin for error. Evidence from analysis shows that the window for opportunity is exceedingly small. Evidence shows that some of the turns taken by the launch vehicle caused the vehicle to lose ground on catching the balloon; wind, rough terrain and limited launch area contributed as well.	of the payload restraint and release system to establish an acceptable angular range of balloon relative to crane for launch attempt. ***(I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt)*** **Wind criteria** •__Recommendation I13-1__: The BPO should establish firm, written criteria for wind limits and factor these into all go/no-go and abort criteria and any specific restrictions on a particular launch. ***(I-13 Wind created a challenging)*** **Improved Launch Conditions** •__Recommendation I8-1__: BPO should perform a cost, utility and feasibility assessment for improving the terrain at Alice Springs, Airport. ***(I8: Terrain was rough and unimproved.)***
6 [Timeline Event 31]	Launch Vehicle Breaches Category A Hazard Zone	Error of Commission: Breach of hazard zone.	Perception Error – Failure to perceive or detect: CSBF crew failed to detect breach of Category A hazard zone.	There were no markings or barriers to indicate the designated safety zone, nor to indicate when the zone was breached. Whether static or moving – at some point the Category A hazard zone (the hazardous area surrounding the launch vehicle) was breached either by the vehicle leaving the fixed hazardous area or by the vehicle moving within a prohibited proximity to personnel and	Recommend clearly defining and marking Category A zone and providing an independent, trained safety officer on-sight during launch operations. **Safety Personnel** • __Recommendation I3-1__: WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring

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				public not authorized within the zone. This breach was not noticed because the zone was not visibly marked. Interview evidence revealed that the launch crew only visually identified of the boundaries of the zone by landmarks in the terrain and relied solely on memory to identify the area during operations. There was no safety officer assigned to ensure the zone was properly maintained.	**mission success.** ***(I3: No trained individual was in place to ensure public safety)*** **Launch Procedures** **•<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3.** **•<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules.** ***(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).*** **Category A Hazard Area** **•<u>Recommendation I7-1:</u> WFF safety office should clearly and unambiguously define the Category A hazard zone and should require that it be implementable in practice with visible markings.** ***(I7: Cat A hazard area during launch phase was not well-defined)*** **Ground Safety Plan** **•<u>Recommendation I4-1</u>: The WFF Safety Office should revise the balloon ground safety plan to cover all phases, from inflation through recovery, identify all hazards from the Hazard Analysis, and resulting restrictions and implementation of operational requirements.** ***(I4: The ground safety plan did not cover all relevant hazards and phases)***

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					Ground Safety Plan Protection of Public •<u>Recommendation I11-1</u>: WFF safety office should specifically address how to deal with the general public in the ground safety plan. *(I11: The ground safety plan did not explicitly address the protection of the general public)* Hazard Awareness Training •<u>Recommendation O10-1:</u> WFF safety office should ensure CSBF personnel has appropriate hazard awareness training for all hazards associated with each launch. *(O-10 – CSBF personnel seemed unaware of a number of potential operational hazards and constraints)*
7 [Timeline Event 32]	Launch director was not in suitable position to begin launch attempt	Error of Commission: Launch director began launch attempt when balloon was not suitably overhead	Error of Perception-failure to perceive or detect: appropriate position of balloon	Launch director did not attempt pin release under the right conditions Launch director thought that the balloon was suitably (sufficiently) overhead to attempt a launch The balloon was not within acceptable range of the launch vehicle during the attempt. No definition of acceptable angular range of balloon relative to launch vehicle	Recommend analysis of launch parameters, launch procedures, clearly defined launch constraints and possible improvements of surface conditions. Launch Procedures •<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3. •<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules. *(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance*

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				exists. CSBF has not analyzed system to establish acceptable ranges. There are no written launch procedures. There are no definitive mechanical indications of correct balloon/launch vehicle positions. Visual cues are the only determination. Operators rely on On-the-job training in place of explicit rules and procedures. The launch process is fragile; based on dependency of visual assessments and good judgment. The launch process is highly sensitive to errors in judgment, perception and visualization.	***with NPR 8715.5).*** **System Analysis for Payload Release** **•<u>Recommendation I9-1:</u> BPO should require in the contract that CSBF perform a thorough analysis of the payload restraint and release system to establish an acceptable angular range of balloon relative to crane for launch attempt.** ***(I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt)*** **Improved Launch Conditions** **•<u>Recommendation I8-1</u>: BPO should perform a cost, utility and feasibility assessment for improving the terrain at Alice Springs, Airport.** ***(I8: Terrain was rough and unimproved.)*** **Wind criteria** **•<u>Recommendation I13-1</u>: The BPO should establish firm, written criteria for wind limits and factor these into all go/no-go and abort criteria and any specific restrictions on a particular launch.** ***(I-13 Wind created a challenging)***
8 [Timeline	Payload controller lost hold of the payload taglines (Team member	Change in State: The tag lines are pulled from hands of operator when the payload jerks in response to sharp	Action Execution Error – Physical inability to make response: Controller loses grip	The path of the vehicle along with the wind creating a challenging environment and rough and unimproved terrain and the	Recommend analysis of launch parameters, launch procedures, clearly defined launch constraints and possible improvements of

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
Event 33]	controlling the taglines to the payload loses hold of the payload restraint straps and the payload starts swinging wildly)	deceleration.	on tag lines.	launch vehicle could not catch the balloon within the confines of the fenced area. No standard procedures exist at CSBF to cover the launch process; training did not provide sufficient guidance to deal with all credible situations during launch (insufficient guidance to deal with anomalous or contingency situations).	surface conditions. Launch Procedures •<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3. •<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules. *(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).* System Analysis for Payload Release •<u>Recommendation I9-1:</u> BPO should require in the contract that CSBF perform a thorough analysis of the payload restraint and release system to establish an acceptable angular range of balloon relative to crane for launch attempt. *(I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt)* Improved Launch Conditions •<u>Recommendation I8-1</u>: BPO should perform a cost, utility and feasibility assessment for improving the terrain at Alice Springs, Airport. *(I8: Terrain was rough and unimproved.)*

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					Wind criteria •<u>Recommendation I13-1</u>: The BPO should establish firm, written criteria for wind limits and factor these into all go/no-go and abort criteria and any specific restrictions on a particular launch. *(I-13 Wind created a challenging environment)*
9 [Timeline Events 34/35]	Failed Launch attempt(s)	Correct Action: The Launch Director correctly pulled on the launch release cable	Action Execution Error – Physical inability to make response: Launch Director lacked physical strength to pull the launch release cable to open restraint pin	The payload did not release when launch cable pulled. The release mechanisms experienced loads requiring superhuman forces to enable release. The restraint pin would not come free when pulled. A secondary release mechanism did not exist.	Recommend performing analysis of launch parameters, clearly defining launch constraints and abort criteria and writing launch procedures, conducting anomaly training including failed launch attempts and possibly adding a secondary release mechanism. Launch Procedures •<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3. •<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules. •<u>Recommendation I5-3:</u> BPO should establish and document firm and unambiguous criteria for aborts during the launch phase. *(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).* Failed launch attempts •<u>Recommendation I6-1</u>: BPO should ensure that training for the launch crew covers the widest possible set of anomalous

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					occurrences in the launch process including, but not limited to, failed launch attempts, breaches and near-breaches of the Hazard Zone, loss of payload control straps, loss of communication, and scenarios that would lead to an abort. ***(I6: Launch crew training did not address failed launch attempts)*** **System Analysis for payload release** **•<u>Recommendation I9-1</u>: BPO should require in the contract that CSBF perform a thorough analysis of the payload restraint and release system to establish an acceptable angular range of balloon relative to crane for launch attempt.** ***(I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt.)*** **Wind criteria** **•<u>Recommendation I13-1</u>: The BPO should establish firm, written criteria for wind limits and factor these into all go/no-go and abort criteria and any specific restrictions on a particular launch.** ***(I-13 Wind created a challenging)*** **Restraint pin lubrication** **•<u>Recommendation CF1-1</u>: BPO should perform analysis and/or test to determine the relationship between pin lubrication and lanyard pull force to establish lubrication guidelines for proper operation.** **(CF1: Restraint pin was not**

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					sufficiently lubricated.) **No secondary release mechanism** **•<u>Recommendation CF2-1</u>: BPO should analyze, evaluate, and test the hardware to understand its capabilities and operating range, as well as to determine failures and associated sensitivities. Based on the results of this analysis and a mapping against detailed understanding of the launch process, BPO should determine whether a hardware re-design is in order and take appropriate steps.** ***(CF2: Secondary release mechanism did not exist.)***

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
10 [Timeline Event 37]	Continuation of launch attempt	Error of Commission: Continued to chase balloon in the direction of public spectators	Decision-Making Error - failure to consider alternate behaviors, failure to select correct or appropriate action: Possible missed opportunity for abort	Launch director felt there was a chance he could still chase the balloon and launch successfully. (Launch driver orders launch vehicle driver to go forward to catch the balloon.) In the past CSBF has launched successfully after failed attempt. Launch operator was most likely applying his training – without taking into account dissimilar situations and surroundings. Documentation does not specify abort criteria, training does not address attempt failed launches or abort criteria, CSBF has previously launched successfully after a failed attempt.	Recommend performing analysis of launch parameters, clearly defining launch constraints and abort criteria and writing launch procedures, conducting anomaly training including failed launch attempts and abort scenarios and providing an independent, trained safety officer on-sight during launch operations. Launch Procedures •<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3. •<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules. •<u>Recommendation I5-3:</u> BPO should establish and document firm and unambiguous criteria for aborts during the launch phase. *(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).* Failed launch attempts •<u>Recommendation I6-1</u>: BPO should ensure that training for the launch crew covers the widest possible set of anomalous occurrences in the launch process including, but not limited to, failed launch attempts, breaches and near-breaches of the Hazard Zone, loss of payload control straps, loss of communication, and scenarios that would lead to an abort. *(I6: Launch crew training did not address failed launch attempts)*

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					System Analysis for payload release •<u>Recommendation I9-1</u>: BPO should require in the contract that CSBF perform a thorough analysis of the payload restraint and release system to establish an acceptable angular range of balloon relative to crane for launch attempt. ***(I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt.)*** Wind criteria •<u>Recommendation I13-1</u>: The BPO should establish firm, written criteria for wind limits and factor these into all go/no-go and abort criteria and any specific restrictions on a particular launch. ***(I-13 Wind created a challenging)*** Improved Launch Conditions •<u>Recommendation I8-1</u>: BPO should perform a cost, utility and feasibility assessment for improving the terrain at Alice Springs, Airport. ***(I8: Terrain was rough and unimproved.)***
11 [Timeline Event 39]	Launch vehicle stops at airport perimeter fence.	Error of Commission: Driving launch vehicle to proximity of public spectators.	Interpretation Error-Failure to recognize data as hazard/ severity of hazards: Crew did not recognize the potential for unintentional release of payload due to	Launch Director and the launch crew only recognized the danger to the public as 1) collision with the launch vehicle and 2) aborting over people.	Recommend performing analysis of launch parameters and mechanisms, clearly defining launch constraints and abort criteria and writing launch procedures, conducting anomaly training including failed launch attempts and abort scenarios and providing an independent, trained

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
			mechanical failure.	Launch Director made attempt to avoid both of these hazards. Additional hazards and their associated severity were not considered. CSBF crew did not consider breach of safety zone as a serious hazard nor did they recognize the hazard of unintentional release of the payload due to structural failure. This hazard had not been properly analyzed and communicated to the crew. There was no hazard awareness, procedures or training. There was no independent safety officer overseeing the launch.	safety officer on-sight during launch operations and crew hazard awareness training. Launch Procedures •<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3. •<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules. •<u>Recommendation I5-3:</u> BPO should establish and document firm and unambiguous criteria for aborts during the launch phase. *(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).* Failed launch attempts •<u>Recommendation I6-1</u>: BPO should ensure that training for the launch crew covers the widest possible set of anomalous occurrences in the launch process including, but not limited to, failed launch attempts, breaches and near-breaches of the Hazard Zone, loss of payload control straps, loss of communication, and scenarios that would lead to an abort. *(I6: Launch crew training did not address failed launch attempts)* System Analysis for payload release •<u>Recommendation I9-1</u>: BPO should require in the contract that CSBF perform a thorough analysis of the payload restraint and release system to establish an

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					acceptable angular range of balloon relative to crane for launch attempt. *(I9: CSBF has not analyzed the payload release system to establish acceptable angular range of balloon relative to launch vehicle for launch attempt.)* Mechanism Evaluation •<u>Recommendation I10-1</u>: BPO should evaluate balloon launch hardware mechanisms through testing and review of documentation and specifications to determine proper operating conditions and ranges. The results of this evaluation should then be used to define operating limits of launch hardware and specify abort criteria. *(I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch attempt)* Wind criteria •<u>Recommendation I13-1</u>: The BPO should establish firm, written criteria for wind limits and factor these into all go/no-go and abort criteria and any specific restrictions on a particular launch. *(I-13 Wind created a challenging)*
12 [Timeline Event 40]	Decision on Safe Method for abort. (Due to spectators being in the downwind path and close proximity launch	Error of Omission: Launch crew failed to consider alternate solutions for abort.	Decision-Making Error: Failed to consider moving spectators prior to any abort attempt.	Launch Director was correct in recognizing that an abort over the people would be dangerous. There was a missed opportunity to hold the	Recommend performing analysis of launch parameters and mechanisms, clearly defining launch constraints and abort criteria and writing launch procedures, conducting anomaly training including failed launch attempts and abort scenarios and providing an independent, trained

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
	director cannot order flight termination.)			launch vehicle position and clear the area of people. Crew was not aware of potential for structural failure. Did not consider this hazard. There were no written procedures or abort criteria. System analysis had not been sufficiently performed to characterize the launch system and launch constraints. Crew training did not include anomaly and contingency training including failed launch attempt and abort scenarios. No safety officer was overseeing the launch operation.	safety officer on-sight during launch operations and crew hazard awareness training. Safety Personnel •<u>Recommendation I3-1</u>: WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring mission success. *(I3: No trained individual was in place to ensure public safety)* Launch Procedures •<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3. •<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules. •<u>Recommendation I5-3:</u> BPO should establish and document firm and unambiguous criteria for aborts during the launch phase. *(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).* Failed launch attempts •<u>Recommendation I6-1</u>: BPO should ensure that training for the launch crew covers the widest possible set of anomalous occurrences in the launch process including, but not limited to, failed launch attempts, breaches and near-breaches of the Hazard Zone, loss of payload control straps, loss of communication, and scenarios

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					that would lead to an abort. ***(I6: Launch crew training did not address failed launch attempts)*** **Mechanism Evaluation** **•<u>Recommendation I10-1</u>: BPO should evaluate balloon launch hardware mechanisms through testing and review of documentation and specifications to determine proper operating conditions and ranges. The results of this evaluation should then be used to define operating limits of launch hardware and specify abort criteria.** ***(I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch attempt)*** **Hazard Awareness Training** **•<u>Recommendation O10-1:</u> WFF safety office should ensure CSBF personnel has appropriate hazard awareness training for all hazards associated with each launch.** ***(O-10 – CSBF personnel seemed unaware of a number of potential operational hazards and constraints)***
13 **[Timeline Event 41]**	**Launch vehicle starts moving in reverse**	**Error of Commission- Backing up of the launch vehicle induced excessive load on system.**	**Interpretation Error – Failure to recognize data as hazard: CSBF failed to recognize the potential for structural failure due to loads excerpted induced by the backing operation.**	**Lack of procedures, anomaly and contingency training, lack of analysis all contributed to the crew not recognizing the hazards associated with backing the launch vehicle and pulling the balloon.**	**Recommend performing analysis of launch parameters and mechanisms, clearly defining launch constraints and abort criteria and writing launch procedures, conducting anomaly training including failed launch attempts and abort scenarios and providing an independent, trained safety officer on-sight during launch operations and crew hazard awareness training.**

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					Launch Procedures **•<u>Recommendation I5-1</u>: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3.** **•<u>Recommendation I5-2:</u> BPO should establish Launch Commit Criteria and flight rules.** **•<u>Recommendation I5-3:</u> BPO should establish and document firm and unambiguous criteria for aborts during the launch phase.** ***(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).*** **Failed launch attempts** **•<u>Recommendation I6-1</u>: BPO should ensure that training for the launch crew covers the widest possible set of anomalous occurrences in the launch process including, but not limited to, failed launch attempts, breaches and near-breaches of the Hazard Zone, loss of payload control straps, loss of communication, and scenarios that would lead to an abort.** ***(I6: Launch crew training did not address failed launch attempts)*** **Mechanism Evaluation** **•<u>Recommendation I10-1</u>: BPO should evaluate balloon launch hardware mechanisms through testing and review of documentation and specifications to determine proper operating conditions and ranges. The results of this evaluation should then be used to define operating limits of**

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					launch hardware and specify abort criteria. ***(I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch attempt)*** **Hazard Awareness Training** **•Recommendation O10-1: WFF safety office should ensure CSBF personnel has appropriate hazard awareness training for all hazards associated with each launch.** ***(O-10 – CSBF personnel seemed unaware of a number of potential operational hazards and constraints)***
14 **[Timeline Event 43]**	**Launch vehicle turns 90 degrees – attempting to turn around.**	**Error of Commission: Turning of the launch vehicle induced excessive load on system.**	**Interpretation Error – Failure to recognize data as hazard. CSBF failed to recognize the potential for structural failure due to loads induced by the turning of the launch vehicle.**	**Lack of procedures, anomaly and contingency training, lack of analysis all contributed to the crew not recognizing the hazards associated with turning the launch vehicle while pulling the balloon.**	**Recommend performing analysis of launch parameters and mechanisms, clearly defining launch constraints and abort criteria and writing launch procedures, conducting anomaly training including failed launch attempts and abort scenarios and providing an independent, trained safety officer on-sight during launch operations and crew hazard awareness training.** **Launch Procedures** **•Recommendation I5-1: BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3.** **•Recommendation I5-2: BPO should establish Launch Commit Criteria and flight rules.** **•Recommendation I5-3: BPO should establish and document firm and unambiguous criteria for aborts during the launch phase.**

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5). **Mechanism Evaluation** **•<u>Recommendation I10-1</u>: BPO should evaluate balloon launch hardware mechanisms through testing and review of documentation and specifications to determine proper operating conditions and ranges. The results of this evaluation should then be used to define operating limits of launch hardware and specify abort criteria.** ***(I10: CSBF was not aware of hardware limitations that might give rise to a failure during a launch attempt)*** **Hazard Awareness Training** **•<u>Recommendation O10-1:</u> WFF safety office should ensure CSBF personnel has appropriate hazard awareness training for all hazards associated with each launch.** ***(O-10 – CSBF personnel seemed unaware of a number of potential operational hazards and constraints)***
15	**Failure to Safe and Secure Mishap Site**	**Error of Omission: CSBF failed to secure the mishap scene.**	**Interpretation Error – Failure to recognize data as hazard: Crew did not recognize the hazards of the payload nor the danger of letting personnel and public in close proximity to unsafed hazardous systems after launch abort.**	**Lack of procedures, anomaly and contingency training, lack of analysis all contributed to the crew not recognizing the hazards associated with backing the launch vehicle and pulling the balloon.**	**Recommend writing launch procedures, Mishap and Contingency Plan in accordance with requirements, IRT training, conducting anomaly training including failed launch attempts and abort scenarios and providing an independent, trained safety officer on-sight during launch operations and crew hazard awareness training**

#	Human Event	Action Type	Error Type	Discussion of Failed Barriers	Recommendations and Finding Mapping
					Safety Personnel • <u>Recommendation I3-1</u>: **WFF Safety Office should assign a range safety officer who is properly trained in range safety and who does not have a role in ensuring mission success.** ***(I3: No trained individual was in place to ensure public safety)*** Launch Procedures •<u>Recommendation I5-1</u>: **BPO should develop a hazardous operating procedure to cover the launch process in accordance with NPR 8715.3.** •<u>Recommendation I5-2:</u> **BPO should establish Launch Commit Criteria and flight rules.** •<u>Recommendation I5-3:</u> **BPO should establish and document firm and unambiguous criteria for aborts during the launch phase.** ***(I5: Intermediate Cause: No complete and thorough standard procedure exists at CSBF to cover the launch process in accordance with NPR 8715.5).*** Hazard Awareness Training •<u>Recommendation O10-1:</u> **WFF safety office should ensure CSBF personnel has appropriate hazard awareness training for all hazards associated with each launch.** ***(O-10 – CSBF personnel seemed unaware of a number of potential operational hazards and constraints)***

APPENDIX E: Definitions

Amelioration	Mitigation. The actions that are taken after a target has been affected (from a problem or accident) to reduce the damage that may occur to the target. Amelioration reduces the severity of the undesired outcome by limiting the effects of the hazard. Amelioration includes a detection and correction component; however, these components of amelioration detect and correct the undesired outcome after some form of a negative effect has occurred. Also called Mitigation.
Appointing Official	The official authorized to appoint the investigating authority for a mishap or close call, to accept the investigation of another authority, to receive endorsements and comments from endorsing officials, and to approve the mishap report.
Barrier	A passive physical device or an administrative intervention that is used to prevent or reduce the likelihood that the undesired outcome will occur. Barriers provide physical intervention (e.g., a guardrail) between hazards and the target or provide procedural separation in time and space (e.g., lock-out/tag-out procedure).
Barrier Analysis	A systematic process used to identify physical and administrative barriers and/or controls that should have prevented the occurrence of an undesired outcome.
Cause	An event or condition that results in an effect. Anything that shapes or influences the outcome.
Close Call	An event in which there is no injury or only minor injury requiring first aid and/or no equipment/property damage or minor equipment/property damage (less than $1000), but which possesses a potential to cause a mishap.
Condition	Any as-found state, whether or not resulting from an event, that facilitates the occurrence of an event and may have safety, health, quality, security, operational, or environmental implications. Conditions exist and are inactive elements in a causal chain.
Contributing Factor	An event or condition that may have contributed to the occurrence of an undesired outcome but, if eliminated or modified, would not by itself have prevented the occurrence. Contributing factors increase the probability that an event or condition will occur.
Corrective Actions	Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a mishap.
Control	An active mechanism that is used to detect the initiating event and/or the hazard and enable an active device (hardware, software, or human) to prevent or reduce the potential (likelihood) that the hazard will affect the target (produce an undesired outcome). Controls minimize the effects of the initiating event by detecting and correcting them before they transition to a negative effect.
Descriptor	A phrase that provides detail about the actor, what an actor did, or what object the actor acted on.
Direct Cost of Damage	(For the purpose of mishap and close call classification) The sum of the costs (the greater value of actual or fair market value) of damaged property, destroyed property, or mission failure, actual cost of repair or replacement, labor (actual value of replacement or repair hours for internal and external/contracted labor), cost of the lost commodity (e.g., the cost of the fluid that was lost from a ruptured pressure vessel), as well as resultant costs such as environmental decontamination, property cleanup, and restoration, or the estimate of these costs.
Effect	A change or changed state that occurs as a direct result of an action by somebody or something else. An effect is an outcome.
Engineered Barriers	Hardware and software features that make it less likely that a user will carry out an

	undesirable action.
Event	A real-time occurrence describing one discrete action, typically an error, failure, or malfunction. Examples: pipe broke, power lost, lightning struck, and person opened valve.
Event and Causal Factor Analysis	Event and Causal Factor Analysis identifies the time sequence of a series of tasks and/or actions and the surrounding conditions leading to the occurrence of an undesired outcome. The results are displayed in a graphic that provides an illustration of the relationships between the events, conditions, and undesired outcome.
Event and Causal Factor Tree	A graphical representation of a mishap or close call that shows the undesired outcome (problem or accident) at the top of the tree, depicts the logical sequence of events, illustrates all causal factor(s) (including condition[s] and events) necessary and sufficient for the undesired outcome (mishap or close call) to occur, and depicts the root cause(s) at the bottom of the tree.
Facilities Maintenance	The recurring day-to-day work required to preserve facilities (buildings, structures, grounds, utility systems, and collateral equipment) in such a condition that they may be used for their designated purpose over an intended service life. Maintenance minimizes or corrects wear and tear and thereby forestalls major repairs. Facilities maintenance includes Preventative Maintenance, Predicative Testing & Inspection, Grounds Care, Programmed Maintenance, repair, Trouble Calls, Replacement of Obsolete Items, and Service Request (Not a maintenance item but work performed by maintenance organizations). Facilities Maintenance includes the cost of labor, materials, and parts but does not include new work.
Failure	The inability of a system, component, process, or crew to perform its required functions within specified performance requirements. For humans, this includes Unsafe Acts (violations). A violation is not an error: it is intentional and deliberate on the part of the actor.
Fault	Any change in a state of an item that is considered anomalous and may warrant some type of corrective action.
Fault Tree	An analytical technique, whereby an undesired system state is specified and the system is analyzed in the context of its environment and operation to find all credible ways in which the undesired event can occur. This can be performed by way of a symbolic or graphical logic diagram showing the cause-effect relationship between an undesired top event or failure and one or more contributing causes.
Fault Tree Analysis	An analysis that begins with the definition or identification of an undesired event (failure). The fault tree is a symbolic logic diagram showing the cause-effect relationship between a top undesired event (failure) and one or more contributing causes. It is a type of logic tree that is developed by deductive logic from a top undesired event to all sub-events that must occur to cause it.
Finding	A conclusion, positive or negative, based on facts established during the investigation by the investigating authority (i.e., cause, contributing factor, and observation).
First Aid	Refer to the Occupational Safety and Health Administration definition in 29 CFR 1904.7, General Recording Criteria.
High Visibility Mishap	Those particular mishaps or close calls, regardless of the amount of property damage or personnel injury, that the Administrator, Chief/OSMA, CD, ED/OHO, or the Center SMA director judges to possess a high degree of programmatic impact or public, media, or political interest including, but not limited to, mishaps and close calls that impact flight hardware, flight software, or completion of critical mission milestones.
Incident	An occurrence of a mishap or close call.
Initiating Event	An active event that results in the release of the hazard, energy (kinetic, potential,

	electromagnetic, thermal, steam, or other types of energy) that has the potential to affect the target and lead to an undesired outcome or end state.
Interim Response Team (IRT)	A team that arrives at the mishap scene immediately after an incident; secures the scene; documents the scene using photography, video, sketches, and debris mapping; identifies witnesses; collects written witness statements and contact information; preserves evidence; impounds evidence (at the scene and other NASA locations as needed); collects debris; implements the chain-of-custody process for the personal effects of the injured and deceased; notifies the NASA Public Affairs Officer about casualties, damages, and any potential hazards to the public and NASA personnel; advises the supervisor if drug testing should be initiated; and provides all information and evidence to the investigating authority. The team is considered "interim" because it operates as a short-term response team and concludes its mishap-response activities when the official NASA-appointed investigating authority arrives to the scene and takes control.
Intermediate Cause	An event or condition that created the proximate cause that, if eliminated or modified, would have prevented the proximate cause from occurring. There may be one too many intermediate causes for a single proximate cause. The intermediate cause is between the proximate cause and the root cause in the causal chain.
Investigating Authority	The individual mishap investigator, mishap investigation team, or mishap investigation board authorized to conduct an investigation for NASA. This includes the mishap investigation board chairperson, voting members, and ex officio but does not include the advisors and consultants.
Lessons Learned	The written description of knowledge or understanding that is gained by experience, whether positive (such as a successful test or mission), or negative (such as a mishap or failure).
Lost Time Injury/Illness	A nonfatal traumatic injury that causes any loss of time from work beyond the day or shift it occurred; or a nonfatal no traumatic illness/disease that causes disability at any time.
Maintenance	The recurring day-to-day, periodic, scheduled or unscheduled work required to preserve or restore a piece of equipment, a system, or utility to such a condition that it can be effectively utilized for its intended purpose, output, redundancy, and availability. The term includes work undertaken to prevent damage to a facility that otherwise would be more costly to restore.
Mishap	An unplanned event that results in at least one of the following: a. Injury to non-NASA personnel, caused by NASA operations. b. Damage to public or private property (including foreign property), caused by NASA operations or NASA-funded development or research projects. c. Occupational injury or occupational illness to NASA personnel. d. Mission failure before the scheduled completion of the planned primary mission. e. Destruction of, or damage to, NASA property except for a malfunction or failure of component parts that are normally subject to fair wear and tear and have a fixed useful life that is less than the fixed useful life of the complete system or unit of equipment, provided that the following are true: 1) there was adequate preventative maintenance; and 2) the malfunction or failure was the only damage and the sole action is to replace or repair that component.
Mishap Investigation Board (MIB)	A sponsored board that: a. Is appointed for a Type A mishap, Type B mishap, high-visibility mishap, or high-visibility close call. Requires concurrence from the Chief, Safety and Mission Assurance, Office of Safety and Mission Assurance (Chief/OSMA), and the Chief Engineer on membership. c. Consists of an odd number of Federal employees (including the chairperson) where the majority of the members are independent from the operation or activity in which the mishap occurred. d. Has a minimum of five voting members for Type A mishaps and three voting members for Type B mishaps. e. Includes a safety officer and a human factors mishap investigator.

	For all Type A mishaps involving injury, illness, or fatality, also includes an occupational health physician (or flight surgeon for aircraft-related mishaps) as a member. f. Is tasked to investigate the mishap or close call and generate the mishap report per the requirements specified in this NPR.A sponsored board that: a. Is appointed for a Type A mishap, Type B mishap, high-visibility mishap, or high-visibility close call. b. Requires concurrence from the Chief, Safety and Mission Assurance, Office of Safety and Mission Assurance (Chief/OSMA), and the Chief Engineer on membership. c. Consists of an odd number of Federal employees (including the chairperson) where the majority of the members are independent from the operation or activity in which the mishap occurred. d. Has a minimum of five voting members for Type A mishaps and three voting members for Type B mishaps. e. Includes a safety officer and a human factors mishap investigator. For all Type A mishaps involving injury, illness, or fatality, also includes an occupational health physician (or flight surgeon for aircraft-related mishaps) as a member. f. Is tasked to investigate the mishap or close call and generate the mishap report per the requirements specified in this NPR.
Mishap Response Contingency Action Plan (MRCAP)	Pre-approved documents outlining timely organizational activities and responsibilities that must be accomplished in response to emergency, catastrophic, or potential (but not likely) events encompassing injuries, loss of life, property damage, or mission failure.
Mission Failure	A mishap of whatever intrinsic severity that prevents the achievement of the mission's minimum success criteria or minimum mission objectives as described in the mission operations report or equivalent document.
Operation	Any activity or process that is under NASA direct control or includes major NASA involvement.
Observation	A factor, event, or circumstance identified during the investigation that did not contribute to the mishap or close call, but, if left uncorrected, has the potential to cause a mishap or increase the severity of a mishap; or a factor, event, or circumstance that is positive and should be noted.
Organizational Factor	Any operational or management structural entity that exerts control over the system at any stage in its life cycle, including, but not limited to, the system's concept development, design, fabrication, test, maintenance, operation, and disposal. Examples: resource management (budget, staff, training); policy (content, implementation, verification); and management decisions.
Pilot Balloon (PiBal)	A meteorological balloon used to observe air currents.
Pivotal Event (or Condition)	An event that is a success or a failure of a barrier or control's response, (or a condition that has occurred or has failed to occur after the initiating event); that can prevent, mitigate, or aggravate the response of the target (change the severity of the consequences).
Preventive Maintenance	Also called time-based maintenance or interval-based maintenance. PM is the planned, scheduled periodic inspection (including safety), adjustment, cleaning, lubrication, parts replacement, and minor (no larger than Trouble Call scope) repair of equipment and systems for which a specific operator is not assigned. PM consists of many check point activities on items that, if disabled would interfere with an essential operation, endanger life or property, or involve high cost or long lead time for replacement. In a shift away from reactive maintenance, PM schedules periodic inspection and maintenance at predefined time or usage intervals in an attempt to reduce equipment failures.
Property Damage	Damage to any type of government or civilian property, including, but not limited to, flight hardware, flight software, facilities, ground support equipment, and test equipment.

Proximate Cause	The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in the occurrence of the undesired outcome and, if eliminated or modified, would have prevented the undesired outcome. Also known as the direct cause(s).
Recommendation	An action developed by the investigating authority to correct the cause or a deficiency identified during the investigation.
Responsible Organization	The organization responsible for the activity, people, or operation/program where a mishap occurs or the lowest level of organization where corrective action shall be implemented.
Root Cause	One of multiple factors (events, conditions, that are organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated or modified, would have prevented the undesired outcome. Typically, multiple root causes contribute to an undesired outcome.
Root Cause Analysis	A structured evaluation method that identifies the root causes for an undesired outcome and the actions adequate to prevent recurrence. RCA should continue until organizational factors have been identified or until data are exhausted.
Serious Workplace Hazard	A condition, practice, method, operation, or process that has a substantial probability that death or serious physical harm could result and the employer did not know of its existence or did not exercise reasonable diligence to control the presence of the hazard.
Situational Awareness	Perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.
Type A Mishap	A mishap resulting in one or more of the following: (1) an occupational injury or illness resulting in a fatality, a permanent total disability, or the hospitalization for inpatient care of 3 or more people within 30 workdays of the mishap; (2) a total direct cost of mission failure and property damage of $1 million or more; (3) a crewed aircraft hull loss; (4) an occurrence of an unexpected aircraft departure from controlled flight (except high performance jet/test aircraft such as F-15, F-16, F/A-18, T-38, OV-10, and T-34, when engaged in flight test activities).
Undesired Outcome	An undesired outcome in this context refers to any event or result that is unwanted and is different than the desired and expected outcome. This can be loss of productivity, poor quality, production of scrap, increased risk, increased cost, delay in schedule, damage to property, harm to the environment, or harm to personnel. Undesired outcomes may also include intangible costs such as loss of public confidence or a decline in motivation. (When describing an undesired outcome for a mishap or close call investigation, the description should focus on the reason it was classified as a mishap or close call; e.g., property damage, mission failure, fatality, permanent disability, lost-time case, first aid case, etc.)
Witness	A person who has information, evidence, or proof about a mishap and provides his/her knowledge of the facts to the investigating authority.
Witness Statement	A verbal or written statement from a witness that describes his/her account including a description of the sequence of events, facts, conditions, and/or causes of the mishap.

APPENDIX F: Abbreviations and Acronyms

ACT	Australian Central Time
ATC	Air Traffic Control
BGSP	Balloon Ground Safety Plan
BPO	Balloon Program Office
CAP	Corrective Action Plan
CASA	Civil Aviation Safety Authority
CCM	CSBF Crew Member
CD	Center Director
CHMO	Chief Health and Medical Officer
CM	Campaign Manager
CSBF	Columbia Scientific Balloon Facility
CSIRO	Commonwealth Scientific and Research Organization
E&CFT	Event and Causal Factor Tree
FT	Fault Tree
FTA	Fault Tree Analysis
GHB	Goddard Handbook
GMT	Greenwich Mean Time
GPD	Goddard Policy Directive
GPR	Goddard Procedures Requirements
GSFC	Goddard Space Flight Center
HQ	NASA Headquarters
IRIS	Incident Reporting Information System
IRT	Interim Response Team

LD	Launch Director
LDEM	Lifting Device and Equipment Manager
LVD	Launch Vehicle Driver
MI	Mishap Investigator
MIB	Mishap Investigation Board
MISO	Mishap Investigation Support Office
MIT	Mishap Investigation Team
MRCAP	Mishap Response Contingency Action Plan
MRSO	Mission Range Safety Officer
NASA	National Aeronautics and Space Administration
NCT	Nuclear Compton Telescope
NOTAM	Notice to Airmen
NPR	NASA Procedural Requirement
NSC	NASA Safety Center
NT	Northern Territory
OCE	Office of Chief Engineer
ODIN	Outsourcing Desktop Initiative for NASA
OJT	On-the-Job Training
Ops	Operations
OSMA	Office of Safety and Mission Assurance
OSS	Operational Safety Supervisor
PET	Phased Elapsed Time
PI	Principal Investigator
PiBals	Pilot Balloons
PPE	Personal Protective Equipment

PPRS	Payload Parachute Recovery System
RCA	Root Cause Analysis
RCAT	Root Cause Analysis Tool
RFQ	Request for Quotation
RSM	Range Safety Manual
RSO	Range Safety Officer or Office
RSQA	Reliability, Safety, and Quality Assurance
SD	Site Director
SMD	Science Mission Directorate
SMA	Safety and Mission Assurance
TIGRE	Tracking and Imaging Gamma Ray Experiment
WFF	Wallops Flight Facility

APPENDIX G: Photo Evidence

Balloon Inflation


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Balloon Inflation


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Balloon Inflation


Long RangePicgture.BOM Station.jpg


NCT Boggs Abort 011.JPG


NCT Boggs Abort 012.JPG


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Balloon Post Abort


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Crane Launch


Launch Crane.JPG


Balloon Launc Crane Head 1.JPG


Balloon Launch Crane Head 2.JPG


Balloon Launch Crane Head 3.JPG


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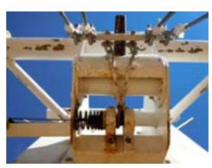
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Crane Launch


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Launch Area


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Launch Area


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Launch Area


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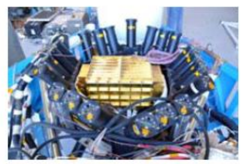
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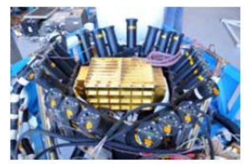
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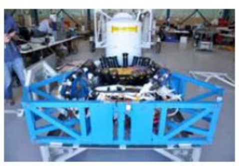
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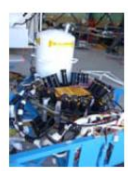
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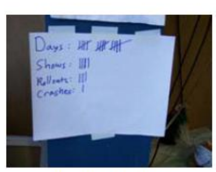
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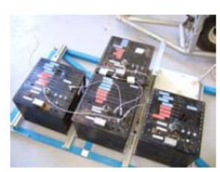
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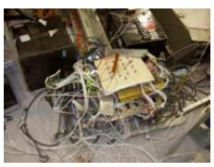
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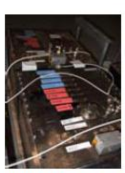
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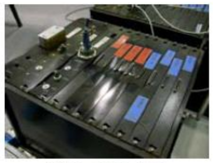
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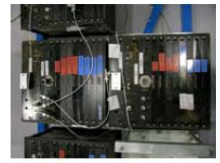
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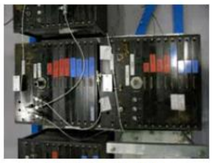
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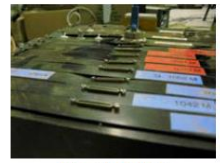
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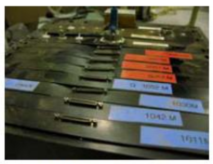
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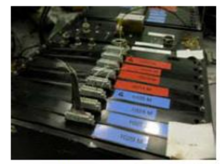
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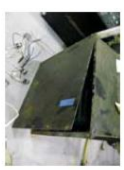
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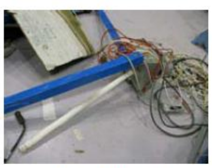
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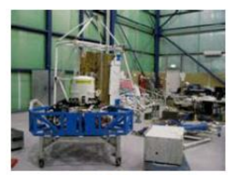
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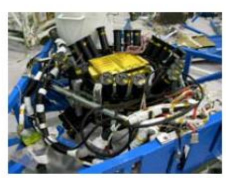
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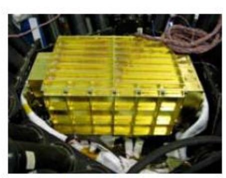
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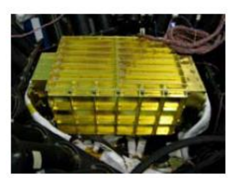
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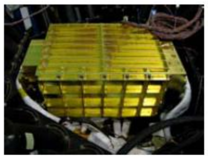
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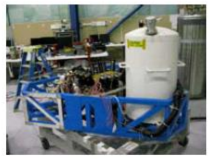
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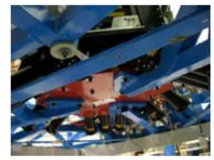
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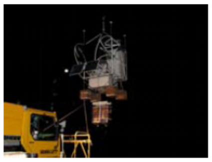
Payload Pickup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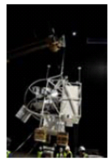
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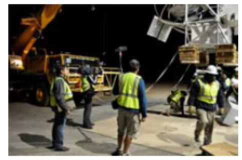
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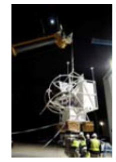
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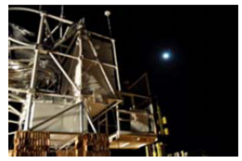
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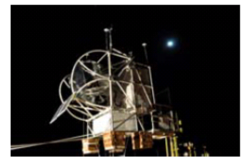
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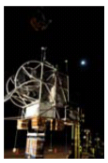
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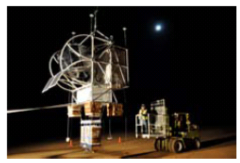
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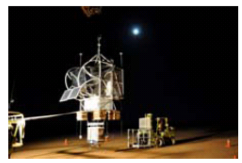
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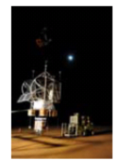
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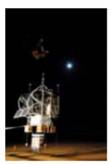
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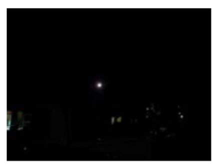
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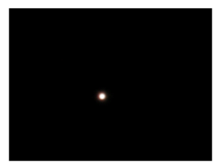
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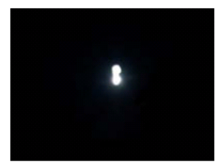
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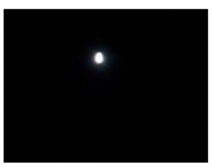
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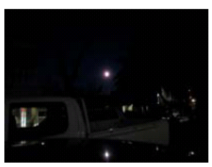
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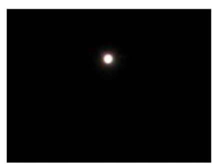
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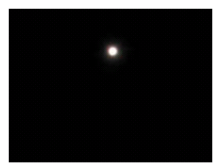
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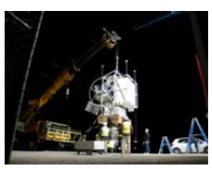
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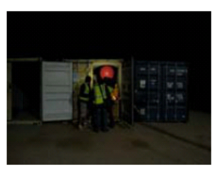
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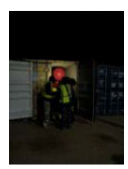
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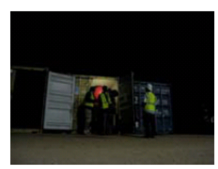
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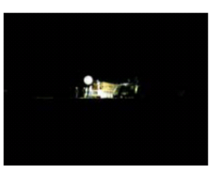
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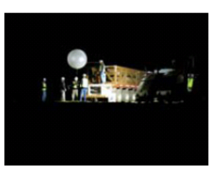
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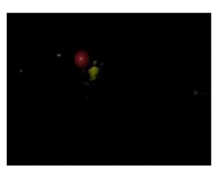
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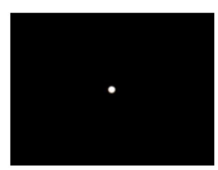
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Payload Pickup


IMG_2409.JPG


IMG_2410.JPG


IMG_2411.JPG


IMG_2412.JPG


IMG_2413.JPG


IMG_2414.JPG


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IMG_4582.JPG


IMG_4807.JPG

Post Spool Release


snapshot2.PNG


DSC_0207.JPG


DSC_0212.JPG


DSC_0213.JPG


DSC_5399.JPG


DSC_5400.JPG


DSC_5401.JPG


DSC_5402.JPG


DSC_5403.JPG


DSC_5405.JPG


IMG_2456.JPG


IMG_2457.JPG


IMG_2458.JPG


IMG_2459.JPG


IMG_2460.JPG


IMG_2461.JPG


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IMG_2474.JPG


IMG_2475.JPG


IMG_2476.JPG


IMG_2477.JPG


IMG_2478.JPG


IMG_2479.JPG


IMG_2480.JPG

Post Spool Release


IMG_2481.JPG


IMG_2482.JPG


IMG_2483.JPG


IMG_2484.JPG


IMG_2485.JPG


IMG_2486.JPG


IMG_2487.JPG


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IMG_2500.JPG


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IMG_2550.JPG

Post Spool Release


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Post Spool Release


IMG_4835.JPG


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Launch Position.JPG


Long RangePicgture.BOM Station.jpg


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P1030959.JPG


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snapshot1.PNG

Pre-Launch Layout


NCT Boggs Abort 010.JPG


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NCT Boggs Abort 003.JPG


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10K Scale.JPG


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15' Cable Ladder Extension.JPG


65' Cable Ladder_Truck Plate.JPG


65' Cable Ladder_Truck Plate_Tri Plate.JPG


120' Chute & Top_Bottom Rings.JPG


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Balloon Soft Collar.JPG


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Balloon Top Plate_He Valves.2.JPG


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Chute Top Ring.JPG


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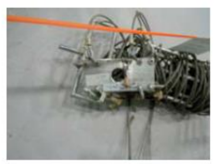
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Ground Cloths & Pads.JPG


Heisse Scale SN0084.JPG


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Various_Antennas DwnRad Xmit Camera ScrapMetal....


Accelerometer_Payload.JPG


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Chute Separate(R)_GAPR (L).JPG


CIP(R)_CIPBOX(M)_ATC Xpond(L).JPG


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TM GSE Congig NCT 2.JPG


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Vehicle Payload Damage


Vehicle damage.JPG


Chute location.JPG


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Damage Site 3.JPG


Damage Site 4.JPG


Damage Site.JPG


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Vehicle Payload Damage


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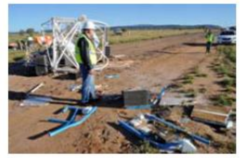
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DSC_0274.JPG


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Vehicle Payload Damage


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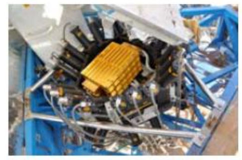
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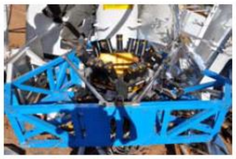
Vehicle Payload Damage


DSC_5586.JPG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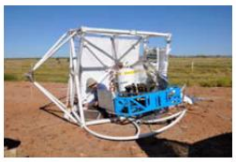
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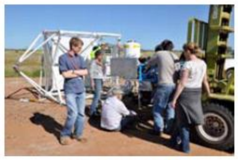
Vehicle Payload Damage


DSC_5673.JPG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Vehicle Payload Damage


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Vehicle Payload Damage


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Vehicle Payload Damage


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IRT Ops.JPG


IRT.JPG


NCT Boggs Abort 022.JPG


NCT Boggs Abort 023.JPG


NCT Boggs Abort 024.JPG


NCT Boggs Abort 025.JPG


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sd_lvfence16.jpg

TIGRE


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Spectators Photos


sd_prespool4.jpg


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sd_lvfence1.jpg


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sd_prespool3.jpg

APPENDIX H: Incident Reporting Information System – IRIS Report

Safety Incident Detail Report

As of : 08/19/2010 06:59:45

Incident Number	: S-2010-119-00007	**Incident Status**	: Open	**ARs Open**	: 0 Of 0

General

Region	: Global Region	**Country**	: United States of America	**Site**	: Wallops Flight Facility
Campus	: WFF-Wallops - Offsite	**General Location**	: Offsite	**Contractor**	: New Mexico State University Physical science Laboratory
Contract	: NAS5-03003	**Mission Directorate**	: All	**Program**	: All
Project	: All	**Record Type**	: Contractor	**Incident Owner**	: PIERCE, DAVID L.
Incident Classification	: Type C	**Location**	: Alice Springs, Austrailia	**Incident Date**	: 04/28/2010 07:50:00
Incident Type	: Aircraft-Ground	**Incident Sub Type**	: Ground Handling	**Incident Category**	: Mishap
Date Reported	: 04/29/2010	**Originator**	: Smith, Florence	**Reported Date and Time**	: 04/29/2010 12:40:00
Incident Stage	: Open Pending Investigation	**Report Source**	: Normal	**Reportable**	: Headquarters Reportable
Privacy	: No	**Site Type**	: Offsite	**Created On**	: 04/29/2010 10:03:09
Last Updated On	: 08/14/2010 06:58:29	**Specific Location**	: Alice Springs, Austrailia	**Location**	: Outdoor

Brief Description : Balloon launch failure of Nuclear Compton Telescope

Detail Description : The NCT payload balloon mission launch took place on 4/28/10. Layout and balloon inflation was nominal. Civilians who were located outside the airport security fence on the public road were instructed to move to another location prior to launch. Launch was nominal, winds (11-13kts) do not at this time appear to have been an issue. Balloon release from the spool was nominal. In the process of releasing the payload from the launch vehicle, the crew chief was unable to release the payload due to friction between the pin and truck plate pressing up against the safety cables. The Crew Chief attempted to catch up with the balloon to relieve the friction, but the launch vehicle became stuck in the dirt. When free, the launch vehicle was unable to catch the balloon for proper release. In an attempt to abort launch, the crew chief noticed personnel outside the fence, and for safety reasons, decided the safest way to abort was by pulling the balloon down to te ground. During this attempt to abort, the safety cables failed and the NCT payload self released, and then was dragged across the airfield and through the safety fence, impacting a SUV. The payload was substantially damaged.

Associations

Module	:	**Number**	:	**Date**	:
Type	:	**Status**	:		

Notes

Investigation Notes : 8/14/10 Extension letter drafted.

Details

RAC/Code	:	**Potential Severity**	:	**Probability**	:

Indicators

https://nasa.ex3host.com/iris/reports/html_asp_excel_report.asp?report_name=EX3_SAFE... 8/19/2010

Indicators	Indicator Status

Vehicle

Class	:	Owner	:	Aircraft Type/Model	:
N-Number/Serial Number	:	Description	:	Affected System (Top 1)	:
Estimated Cost	:	Actual Cost	:	Equipment Damage Details	:
Remarks	:				

Transition

Tab	Field	Old Value	Transition Date	New Value	Reason For Change

Lesson Learned

Lesson Learned Date	:	Lesson Learned Text	:

Action Request

AR Number	:	AR Status	:	AR Assigned To	:
AR Assigned By	:	Parent Case #	:	AR Type	:
AR Action Type	:	Record Type	:	Region	:
Country	:	Site	:	Contractor	:
Contract	:	Directorate	:	Organization	:
Mission Directorate	:	Program	:	Project	:
Sch. Comp. Date	:	Actual Completion Date	:	Secure?	:
Does this AR contain Private Medical Information?	:	AR Title	:	Action To Take	:
Action Taken	:	Created on	:	Last Updated on	:

Attachments

Type	Document Description	Privacy Act	Last Updated	Document Tag
pdf	Balloon MIB Appt Letter.pdf	No	05/14/2010	
PDF	MIB Appoint Ltr.PDF	No	05/24/2010	
pdf	Ballon Mishap 60 day status.pdf	No	08/14/2010	

Investigations

Investigation Code	Investigation Title

Property

Class	Description	ID Number	Estimate Cost	Damage Cost	Details	Remarks

Safety Incident I/I

Employee Name :	**Case No.** :	**Injury/Illness** :
Injury/Illness Type :	**Case Type** :	**Employee Statement** :

Print

Powered By Ex3 Technologies

APPENDIX I: Mishap's Direct Cost Breakdown Estimates

Program's estimated cost of the NCT Mishap

Mission Expendables (Balloon, Helium, Batteries) *	$ 336,978
Pro-Rata Campaign Cost (Travel, Per Diem, OT, etc) – divided by 3 Payloads *	$ 659,321
Damage to NCT payload	$500,000 - $2,000,000
Damage to CSBF hardware	$ 20,000
Marching army cost for HERO team	$ 385,000
Privately Owned Vehicle Damage	$ 13,500
Airport Property Damage	$ 10,000
Total	$928,500 - $2,428,500

*- Baseline Mission Model sunk cost per 7120.8 Project Plan, under definition of accepted risk. Acceptable risks have been defined in section 3.3.4 to include: In accordance with baseline programmatic implementation and in agreement with the undersigned stakeholders, accepted risks that may result in mission failure shall include, but are not limited to: failure of the balloon during the launch, ascent, or float phases; failure of support equipment or instrumentation; failure of science equipment or instrumentation; and personal property damage or loss.

Payload estimate as of mid August: ~$1.050k, which includes replacement of the gondola and refurbishment of the instrument. This does not include any student/scientist support, just engineering & materials.

NOTE:

At the time of the Balloon mishap on April 29, 2010, the costs associated with damaged hardware were under assessment by the Balloon Program Office (BPO). The mishap was originally classified as a High Visibility, Close Call mishap. Recently, the BPO provided the MIB with an updated mishap cost estimate. While the BPO does not consider the cost of consumables in their calculations, the NPR clearly requires that the "cost of the lost commodity" be included. After accounting for the cost of the consumables, the current mishap cost estimate is $1,815,478.00. This falls into the range of a Type B mishap. The Board will note for the record that this mishap is classified as High Visibility Type B mishap. This classification will be noted in the Board's report.

APPENDIX J: CASA Permits

Australian Government

Civil Aviation Safety Authority

File Ref: EF09/24054

INSTRUMENT NUMBER: WOA 7058

I, Donald Andrew Campbell, Team Leader Flying Operations, Western Region – Adelaide, a delegate of CASA, make this instrument under subregulation 101.030(1) and 101.030(6) of the *Civil Aviation Safety Regulations 1998*.

D A Campbell
Team Leader - Flying Operations
CASA Operations
Western Region – Adelaide

8 February 2010

Approval – area for the operation of a heavy balloon

1. **Application**

   This instrument applies to the approval of an area for the operation of a heavy balloon, School of Physics, University of New South Wales (Australian Defence Force Academy) ***(the operator).***

2. **Approval**

   I approve the area of Alice Springs Airport S23° 48.4, E133° 54.1 as an approved area for the operation of a heavy balloon ***(the approved area).***

3. **Conditions**

   The approval is subject to the conditions mentioned in Schedule 1.

4. **Validity**

   This instrument ceases to have effect at the earlier of:

   (a) the letter of agreement between the operator and Airservices Australia ceasing to have an effect; or

   (b) the end of 30 May 2010.

Schedule 1 Conditions

1. The operator must ensure that all operations of the heavy balloon in the approved area are under the control or supervision of Associate Professor Ravi Sood ***(the co-ordinator).***

GPO Box 2005 Canberra ACT 2601 Telephone 131 757

Canberra, Brisbane, Darwin, Cairns, Townsville, Tamworth, Bankstown, Mascot, Moorabbin, Melbourne, Adelaide, Perth

2. The co-ordinator must ensure that he and all operational staff under his control comply with Letter of Agreement Number 3146, Version 1, effective 15 February 2010 to 30 May 2010, between Airservices Australia and School of PEMS, University of NSW.
3. The co-ordinator must ensure the landing area is at least 20 kilometres away from a populous area, as defined in the Civil Aviation Safety Regulations 1998 101.025.

APPENDIX K: NCT Flight Folder Documents

K-1 Flight Plan

K-2 Balloon Flight Requirements

K-3 Operations Pre-Flight Readiness Review

K-4 Pre-Flight Minimum Success Criteria

K-5 Launch Equipment Certification

K-6 Payload & Gondola Certification

K-7 Balloon “AS BUILT” Specifications

K-8 Balloon Load Altitude Curve

K-9 Flight Data Summary

K-10 Inflation Computation

K-11 Launch Director’s Checklist

K-12 Balloon Condition at Launch

K-13 Recovery Information

K-14 Quality Control Information

K-15 Collar Flight Record

K-16 Flight Operations – Rigging Job Assignments

K-17 Rigging Weight Sheet

K-1 Flight Plan

Flight Folder

National Scientific Balloon Facility			Flight Plan
OF-310-00-P	Rev-B	Date: 4 October 2005	Page 1 of 2

Approved by: Bill Stepp Date: 4 October 2005

NOTICE: This Flight Plan data is only valid for a launch within 72 hours of the Approved date and time or Renewed date and time. DOCUMENT FOLLOWS.

FLIGHT PLAN

PRINCIPAL INVESTIGATOR / ORGANIZATION Steven Boggs / SSL-UC Berkeley (NCT)

1 SCIENTIFIC REQUIREMENTS

LAUNCH WINDOW April - May 2010 **DESIRED LAUNCH TIME** Morning

DESIRED FLOAT DURATION (HR) 4 days **ALTITUDE** (KFT) 130

FLIGHT PROFILE High as possible as long as possible. Evaluate multiple day durations in real time.

MINIMUM FLOAT DURATION (HR) 24 **ALTITUDE** (KFT) See below

FLIGHT PROFILE (IF DIFFERENT FROM ABOVE) Altitudes: 120 Kft during first day / 110 Kft overnight first night / 100 Kft subsequent nights

DOWN-RANGE SUPPORT AND/OR SPECIAL REPORTING Downrange TM support at Longreach. Need 110 vac for two computer stations. Power and access to the GSE

2 REQUIREMENTS FOR ALTITUDE AND TIME CONTROL

BALLOON (1066) W39.57-2-76

PAYLOAD WEIGHT With Ballast (lb) 5489 Without Ballast (lb) 4289

BALLAST 1200 (lb) of Sand with Flow Rate of 169 (lb/min)

ALTITUDE With Ballast (Kft) 128 Without Ballast (Kft) 130.5

Ballast for Sunset (1^{st}) 685 lb (2^{nd}) ______ lb Ballast for Drive-up 370 lb

Ballasting Instructions Conserve ballast on ascent and first sunset, as necessary to meet minimum altitude requirements

VALVE(S) 2 Type EV13 Valving Instructions ______

ANEROID(S) Set Altitude to Arm/Fire N/A / , /

3 Support Personnel

Down Range NSBF Don Burt

Science Steve McBride

Aircraft Pilot Captain Sr. Observer E Sevis E. Tech N/A

Passenger(s) Steve McBride

Recovery NSBF Dave Sullivan + 1 contract hire

Science Steve McBride

Recovery Instructions Attached Yes ✓ No

Special Equipment Equipment provided - Need to go with recovery truck/crew

Hazardous or Radioactive Materials None

Other

4 Flight Line

Launch Director Frank Candelaria Electronics Supervisor Scott Hadley

5 Tower

Flight Director Bill Stepp / Frank Candelaria Electronics Supervisor Scott Hadley

****

Prepared by W Stepp / F Candelaria	Date 14 April 10	Time 10:00
Approved by Bill Stepp	Date 14 April 10	Time 10:00
Renewed by Bill Stepp	Date 25 April	Time 15:30

NOTES:

1) All changes on the Balloon Flight Support Application must be approved by the Head of NSBF Operations.
2) **ANY** changes on this Flight Plan **MUST** be approved by the Head of NSBF Operations or the appropriate Campaign Manager.
3) The Flight Plan is only valid for a launch within 72 hours of the Approved date and time or the Renewed date and time.

K-2 Balloon Flight Requirements

Flight Folder

Columbia Scientific Balloon Facility	Balloon Pre-Flight Requirements Data Sheet
OF-300-00-D Rev – B Date- 05-24-06	page 1 of 3

Approved by ________Mark Cobble________ date ______5/24/2006________

NOTICE: This Checklist is used to review the data received from the customer during a Flight Review checkout: **DOCUMENT FOLLOWS:**

Balloon Flight Requirements **Date** 15 / March 2010

Organization: SSL – University of California - Berkeley
Project Scientist Steven Boggs (NCT)

Balloon Assignment:
(1) Model (i.e., W29.47-2-01) W39.57-2-76 CSBF # 1066
Recommended Payload: Max 6000 lbs. Min 100 lbs.
(2) Model (i.e., W29.47-2-01) W39.57-2-75 CSBF # 970
Recommended Payload: Max 6000 lbs. Min 100 lbs.

Flight Requirements:

Number of Flights: 1 Readiness Date: 1 April
Launch Time (Hr): 07:00 Launch Time (Date): 8 April
Desired Altitude (K Ft): 130 Minimum Altitude (K Ft): 100
Desired Float (Hrs): 4 Day Minimum Float (Hrs): 24
Flight Profile: (*If other than as high as possible for as long as possible*)
H
____

(Issue Pre-Flight Minimum Success Criteria Form to P.I.)

Flight Operations Briefing:

Estimated Weight (lbs) of Scientific Payload	3100
Estimated Weight (lbs) of NSBF Equipment	1081
Ballast (lbs): Steel ____ Sand X Other____	1200

TOTAL ESTIMATED PAYLOAD WEIGHT (LBS) 5381

Estimated Float Altitude: w/Ballast 128 (KFt); w/o Ballast 130.5 (KFt)
Chute Diameter: 130 (Ft.); Release: YES ; Suspension Ladder (Ft) 75'
Special flight train length, components, etc... GAPR / SAPR
Launch Vehicle: Tiny Tim________ KATO________ MLV________
BOSS ____ HERCULES____ Recovery Truck ____ LIEBHERR CRANE XX
Flight Line Checkout (Hrs/Mins) 45 MIN Estimated Show Time TBD
20 min before move to flt line

Recovery Requirements:

Special recovery requirements/equipment: Remove harddrives/batteries before loading -

(Issue recovery form to Principal Investigator)

Hazardous Materials and Conditions: *(check appropriately)*

Radioactive Sources	Ground Support ✓	Flight ___	Recovery ___
Laser Hazards	Ground Support ___	Flight ___	Recovery ___
Chemical/Cryo/Gas	Ground Support ___	Flight ___	Recovery ___
Pressure Vessel	Ground Support ___	Flight ___	Recovery ___
High Voltage	Ground Support ___	Flight ___	Recovery ___
Pyrotechnics	Ground Support ___	Flight ___	Recovery ___
Magnets	Ground Support ___	Flight ___	Recovery ___

(If required, Issue Ground Safety Plan and Pressure Vessel Certification)

Science Emergency Information – Contact Name @ Location @ Phone #

(1) Eric Beelm @0416-860-236 @AonTodd#216
(2) Steve McBride @0415934366 @AonTodd#102

Aviation Support Briefing:

Passengers: Downrange Station 1 Recovery 1 (if downrange)
(C90 Tail # 240RE (6S) 441 Tail # N6860C (7S)
CIP Check - Date 1 April Time TBD

SAR Considerations and Limitations:

Restrictions: Standard NASA restriction and 20 nm from cities for CASA requirements

(Palestine – minimum impact 150, 250, 350 miles west, footprint dependent)
(Ft. Sumner – impact < 550 miles west; < 450 miles east & outside corridor.
Corridor East of Ft. Sumner – 069 deg to 112 deg and 265—450 miles.)

Meteorological Briefing:

Average Float Wind : –7 S,D,14 Sunrise 0645 Sunset 1927
Post Flight Met Date (Y/N) ___
Supplemental WX Data/Support: [illegible]

Non-Standard Elect/Mech. Configuration/Squib Applications:

NSBF: SAPR/GAPR – CSBF test solar panel - Video test unit
Science: Test solar panel

National Scientific Balloon Facility		Balloon Pre-Flight Requirements Data Sheet	
OF-300-00-D	Rev – A	Date- 10-27-03	page 3 of 3

Helium Valves: None________ One __________ Two EV-13 Three________

Data Rates:

Rate : 784 kb Code: Ri∅

Rate :__________ Code:__________

Rate :__________ Code:__________

Rate :__________ Code:__________

VCO Requirements:

VCO Channels(s) 1 CMD. Verify, 3 MKS, 5__________, 7 __________

8__________, 9__________ 10 Mini Encoder, 11 GPS # 1, 12 GPS # 2,

B __________, E __________ HH __________,

Power Requirements:

CIP : 9·90 Science Transmitters: __________ Other:__________

Special Electronics Considerations:

video xmit + camera

____

Ground Station Requirements:	Launch Site	Down Range
Bit Syncs		
Decom's	X	X

Project Scientist: Eric C. Bellm

NSBF Representation: Bill Stepp

K-3 Operations Pre-Flight Readiness Review

Flight Folder

National Scientific Balloon Facility		Operations Preflight Readiness Review Checklist
OF-312-00-C Rev-B	Date: 4 October 2005	Page 1 of 1

Approved by: Bill Stepp Date: 4 October 2005

NOTICE: DOCUMENT FOLLOWS.

OPERATIONS PREFLIGHT
READINESS REVIEW CHECKLIST

Principal Investigator / Organization: Dr. S. Boggs/UC-Berkeley
Proposed Flight Date / Campaign: April-May 2010 / Australia

A. SCIENTIFIC REQUIREMENTS

Down Range Support / Special Recording	✓
Minimum Success Criteria	✓
Recovery Instructions	✓
Science Command Sheet	✓
Ground Safety Plan	✓

B. FLIGHT OPERATIONS

SAR / Risk Analysis Review	✓
Launch Equipment Configuration and Certification (LECC)	✓
Pressure Vessel Certification	N/A
Gondola Mechanical Certification	✓
Vehicle Pin and Chute Weight	Within limits
Max/Min Weight on Balloon	Within limits

C. FLIGHT ELECTRONICS

Command Sheets	✓
Science Off Command(s)	✓
Electronic Certification	✓ LDB ✓

D. MISCELLANEOUS

Video Personnel	✓
Down Range Crew	✓
Aircraft Crew	✓
Recovery Crew	✓
Flight Line Crew	✓
Tower Crew	✓
Paperwork Distribution	TBD

NSBF REPRESENTATIVE Bill Stepp DATE 4/14/10

Approved by: *Bill Stepp* Date: 4 October 2005

NOTICE: DOCUMENT FOLLOWS.

OPERATIONS PREFLIGHT READINESS REVIEW CHECKLIST

Principal Investigator / Organization: *Dr. Steven Boggs / UC-Berkeley*

Proposed Flight Date / Campaign: *April-May 2010 / Australia*

A. SCIENTIFIC REQUIREMENTS

Down Range Support / Special Recording	*No Change*
Minimum Success Criteria	✓
Recovery Instructions	✓
Science Command Sheet	✓
Ground Safety Plan	✓

B. FLIGHT OPERATIONS

SAR / Risk Analysis Review	✓
Launch Equipment Configuration and Certification (LECC)	✓
Pressure Vessel Certification	✓
Gondola Mechanical Certification	✓
Vehicle Pin and Chute Weight	✓
Max/Min Weight on Balloon	✓

C. FLIGHT ELECTRONICS

Command Sheets	✓
Science Off Command(s)	✓
Electronic Certification	✓

D. MISCELLANEOUS

Video Personnel	✓
Down Range Crew	✓
Aircraft Crew	✓
Recovery Crew	✓
Flight Line Crew	✓
Tower Crew	✓
Paperwork Distribution	✓

NSBF REPRESENTATIVE *Bill Stepp* DATE *25 April 2010*

Approved by: Bill Stepp Date: 4 October 2005

NOTICE: DOCUMENT FOLLOWS.

OPERATIONS PREFLIGHT READINESS REVIEW CHECKLIST

Principal Investigator / Organization: Dr. Steve Boggs / UC-Berkeley

Proposed Flight Date / Campaign: April - May 2010 / Australia

A. SCIENTIFIC REQUIREMENTS

Down Range Support / Special Recording	No Changes
Minimum Success Criteria	✓
Recovery Instructions	✓
Science Command Sheet	✓
Ground Safety Plan	✓

B. FLIGHT OPERATIONS

SAR / Risk Analysis Review	✓
Launch Equipment Configuration and Certification (LECC)	✓
Pressure Vessel Certification	✓
Gondola Mechanical Certification	✓
Vehicle Pin and Chute Weight	✓
Max/Min Weight on Balloon	✓

C. FLIGHT ELECTRONICS

Command Sheets	✓
Science Off Command(s)	✓
Electronic Certification	✓

D. MISCELLANEOUS

Video Personnel	✓
Down Range Crew	✓
Aircraft Crew	✓
Recovery Crew	✓
Flight Line Crew	✓
Tower Crew	✓
Paperwork Distribution	✓

NSBF REPRESENTATIVE Bill Stepp DATE 28 April 2010

K-4 Pre-Flight Minimum Success Criteria

Flight Folder

National Scientific Balloon Facility		Pre-Flight Minimum Success Criteria	
OF-314-00-F	Rev-A	Date: 10-20-2004	Page 1 of 1

Approved by _______________William Stepp___________ Date _____10/20/04______

NOTICE: DOCUMENT FOLLOWS

PRE-FLIGHT
MINIMUM SUCCES CRITERIA

Organization Berkeley / NCT Principal Investigator Steven Boggs

1.) Give a brief statement of minimum scientific objectives which must be met to achieve a mission success (scientific windows, flight profile, valving requirements, etc.)

Observe at least one transit of the Galactic Center at an altitude of 110,000 ft or higher with LOS telemetry.

2.) Balloon / Flight Performance Requirements:

Altitude - Desired 130,000 ft. Minimum Acceptable { 120,000 ft - day; 110,000 ft - first night; 100,000 ft - subsequent nights }

Duration - Desired 4 days Minimum Acceptable 24 hours

Altitude Stability n/a - see minimums.

3.) Required Experiment Performance - Detectors, Pointing Systems, etc . . .

pointing: maintain source in instrument field of view

detectors: 6 detectors x 24 hours or better.

4.) Telemetry Requirements:

LOS telemetry + commanding.

Principal Investigator [signature] Date 4/14/10

NSBF Ops. Manager [signature: Bill Stepp] Date 4/14/10

K-5 Launch Equipment Certification

March 20, 2010

To: Operations Department

From: Engineering Department, Erich Klein

Subject: *Launch Equipment Configuration Certification (LECC) for 2010 Australia Balloon Campaign*

The following launch equipment has been certified for the 2010 Australia Balloon Campaign.

- **LTM 1100/2 Liebherr Crane (100 metric ton capacity)**: Pull tested to a minimum load of 17,000 lbs. (18,000 lb. peak load) using three 65 ft. cable ladders connected end to end. Concrete blocks weighing 4400 lbs. were suspended from the vehicle to simulate an actual payload. The pull test was maintained for more than 5 minutes with no observed deficiencies with the equipment. See attached e-mails dated March 16 and 19 from Mark Cobble addressed to the Engineering Department for specific details.

  Reason for pull test: 1 year standard certification.

- **Launch Spool Trailer (NASA # 2126)**: Pull tested to a minimum load of 16,000 lbs. (17,400 lb. peak load) for 6 minutes using the LTM 1100/2 Liebherr launch crane. Total weight of the spool was 20,500 lbs. including a fixed steel ingot and 3-2000 lb. drums of steel ballast secured to the trailer. No deficiencies were observed with the equipment. See above referenced emails from Mark Cobble for specific details.

  Reason for pull test: 1 year standard certification.

All readings made with a NASA 30k dynamometer. Digital pictures are available as well as support documentation filed with this memo. The launch equipment will remain certified through the **2010 Australia Balloon Campaign.**

EOM

National Scientific Balloon Facility	Launch Equipment Configuration Checklist (LECC)
OM-100 -10-C Rev – A	Date- 07/15/04 page 1 of 2

Approved by ________Erich Klein________ date ________7/15/04__________

NOTICE: Checklist for LECC information. **DOCUMENT FOLLOWS:**

LAUNCH EQUIPMENT CONFIGURATION CHECKLIST (LECC)

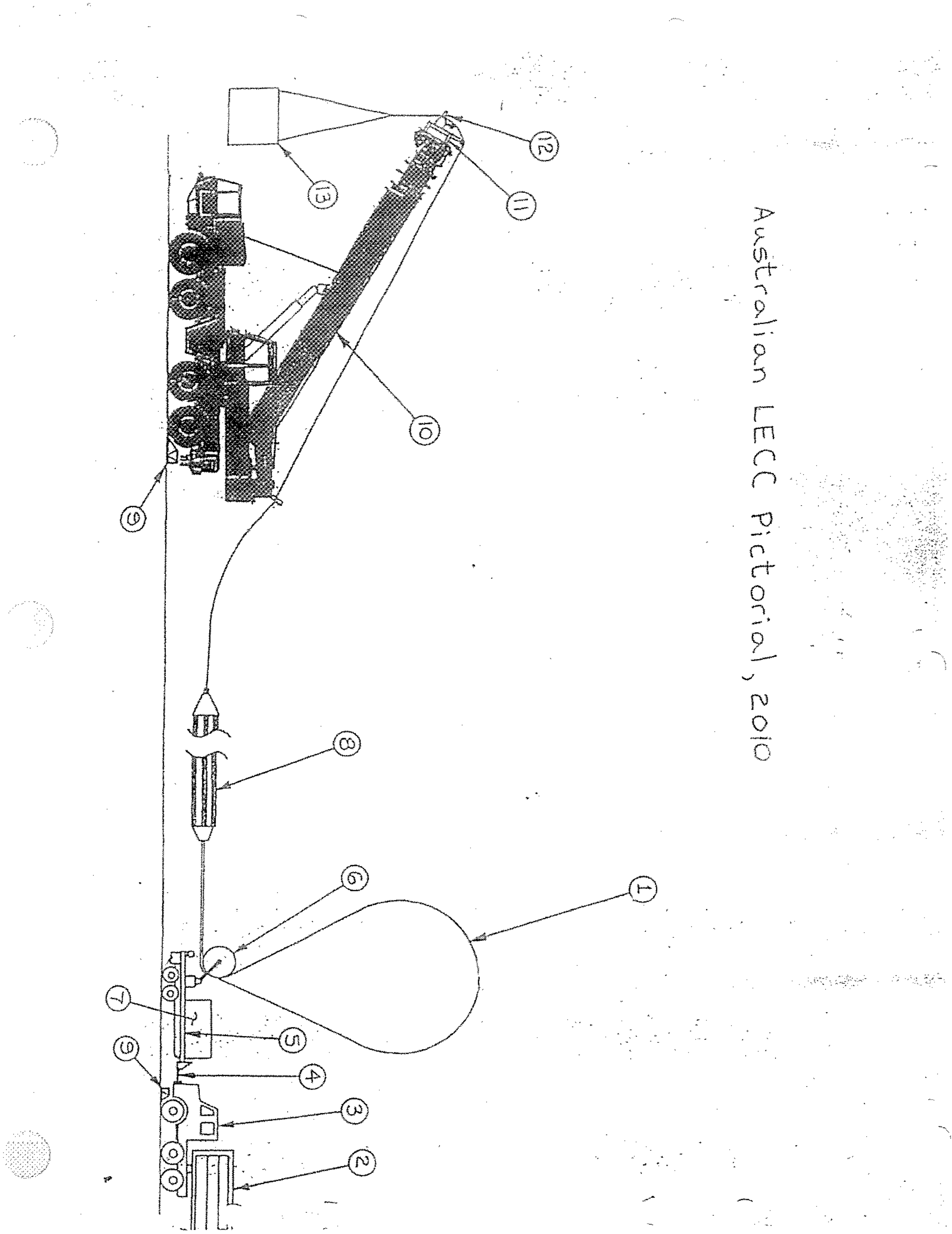
Date ___**March 20, 2010**____

Location: Palestine _____ Ft. Sumner _____ McMurdo Station _____ Lynn Lake _____ Other _Australia___________

ITEM NO	EQUIPMENT DESCRIPTION	MAXIMUM STRENGTH (LBS)	MAXIMUM WEIGHT (in LBS) ALLOWED BELOW BALLOON	NOTES (see below *)
1	Balloon, R 39.57–2	6060 lbs	6060 lbs	
2	Flat bed trailer with 8 tube helium rack	N/A	8000 lbs	1
3	Kenworth tractor leased from Rentco of Darwin, N.T., Australia	N/A	8000 lbs	1
4	Front bumper/chassis hitch for Australian road trains	N/A	8000 lbs	1
5	Australian spool trailer	N/A	8000 lbs	1 & 2
6	Standard short arm spool assembly	28,800 lbs	8000 lbs	1 & 2
7	Three drums of steel ballast, 2000 lbs. each	N/A	N/A	2
8	Flight train – see mechanical certifications for details	N/A	N/A	4
9	Wheel Chocks	N/A	N/A	
10	LTM 1100/2 Liebherr crane, 100 metric ton capacity	N/A	8000 lbs	1 & 3
11	Crane head adapter for item no. 10	N/A	8000 lbs	1
12	Standard crane head	N/A	8000 lbs	1
13	Science gondola – see mechanical certification for details	N/A	N/A	

Notes:
1. Maximum allowed weight is based on maximum payload weight limit of a 34.43-3H balloon
2. Total Spool Weight 20,500 lbs

3. Maximum launch pin height: 39 ft.
4. NO parachute was used for the LECC pull test (as shown in the illustration).


Australian LECC Pictorial, 2010
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Erich Klein

From: Mark Cobble [mark.cobble@csbf.nasa.gov]
Tuesday, March 16, 2010 7:53 PM
Erich Klein
Cc: Frank Candelaria
Subject: Spool Pull Test for Australia Campaign LECC

NASA EQUIPMENT PULL TEST

The existing launch spool trailer (NASA #2126) in Alice Springs was refurbished during the latter weeks of February 2010. Those refurbishments included removal and replacement of all springs, 8 tires and wheels, 2 axles, and 2 outer hangers. The tandem axle system was upgraded to a 12 ton capacity (6 ton per axle). The tire/wheel combinations are Firestone Transforce HT LT235/85R16. The spool padding boot was installed afterwards, and was air sprayed with 4 coats of a Mosite 3 part mixture (clear, slippery coating) on 3-17-10 . The old spool weights were removed from the deck and the spool weight was observed at 14,500 lbs. Three each 2000 lb barrels of ballast were prepared (6000 lbs total) and secured to the top deck of the spool with three heavy duty ratchet straps. This combined total of *trailer, spool and weights* equals 20,500 lbs.

On March 16, 2010, a successful pull test of the Launch Spool Trailer (NASA # 2126) was conducted at the Balloon Launching Station in Alice Springs, Australia. The process consisted of a Rental Tractor connected to a rental trailer loaded with an 8 tube Supagas Helium Reservoir and connected to the hitch of the Launch Spool Trailer. The Liebherr (Type LTM 1100/2) 100 metric ton rental crane was backed into the front of the spool trailer/tractor/trailer combo and the crane boom was rotated 180 degrees over the center of the spool. The spool tester unit was attached to the crane hoist and to a pin located at the rear frame of the crane to simulate the force of the balloon angle during inflation. Ethafoam was placed between the spool pull test harness and the spool padding boot. Tension was applied by raising the crane hoist. Incremental observations were made up to a peak load of 17,400 lbs. The test was held in position for 6 minutes as the system tension decreased to 16,000 lbs. The spool was observed by Cobble, Candelaria, Masters, Roberts, and McCabe. This test was absent of any incidence.

Erich Klein

From: Mark Cobble [mark.cobble@csbf.nasa.gov] **Sent:** Fri 3/19/2010 5:27 PM
To: Erich Klein
Cc:
Subject: Crane Pull Test for Australian Campaign LECC
Attachments:

NASA EQUIPMENT PULL TEST

The crane to support the 2010 Australia Campaign was leased from "Wanna Lift" of Alice Springs. During the early weeks of March 2010 this crane was modified into a balloon launch vehicle. This modifications consisted of a launch director platform, 2 outriggers with 4 tire/wheel combo, crane head adapter and release, bullhorns, sheaves, turnbuckles, wire rope, chains, clevis, ratchet binders and slings.

The pull test was conducted by CSBF personnel on March 18, 2010. These personnel include Cobble, Candelaria, Roberts, Masters, Chambers, and McCabe. To simulate gondola weight, a pair of concrete blocks totalling 4400 lbs (3000 lbs and 1400 lb) were bound together and attached to the crane head suspension. The crane boom was raised 39 feet in height, with the pin approximately 10' from the front edge of the launch director platform. The hoist cable was routed through a sheave and connected to a chain that was secured to the front frame of the crane. A soft sling was doubled and wrapped around the connection area of the boom housing and main hydraulic piston. Chains and clevises were routed from the soft sling to a tab welded on the front end of the outriggers and tightened with ratchet binders. The crane rotation pin was locked into place and a turnbuckle/double wire rope was used from the rotating body of the crane to a tab welded on the rear of the outriggers. All of these attachments are designed to supplement boom strength (whether upward and/or sideways) during the launch process.

After configuration of the Liebherr LTM 1100/2 (100 metric ton) crane, three 65' ladders were joined in length and extended from the crane head to the 30K dynamometer (NASA # 4172). The dynamometer was connected to the rear of the rental truck (Kenworth tractor). The Kenworth tractor driver was instructed to drive forward and apply tension to the 195' ladder system. The first pull test was performed with the crane axles in the "suspended" mode. During the maximum tension, the rear end of the crane lowered significantly and the rear axle pressure increased. This test proved that "suspended" mode was not recommended for our launch operation. The second pull test was performed with the axles in the "blocked" mode. This test proved to be successful in all regards, including a more even load distribution upon the five axles.

The max load applied was 18,000 lbs. The tension during the test was held in excess of 17,000 lbs for more than 5 minutes. This test was performed twice, once by tensioning with the Kenworth tractor and the other test by tensioning with the Launch Crane. No chocks were used under the wheels for each respective pull test.This pull test was also documented with digital photos. No incidence was observed.

K-6 Payload & Gondola Certification

DATE: April 14, 2010
MEMO TO: Operations Department
FROM: Engineering Department
SUBJECT: Gondola Certification
ORGANIZATION: UC Berkeley
SCIENTIST: Dr. Steven Boggs
PROJECT NAME: NCT

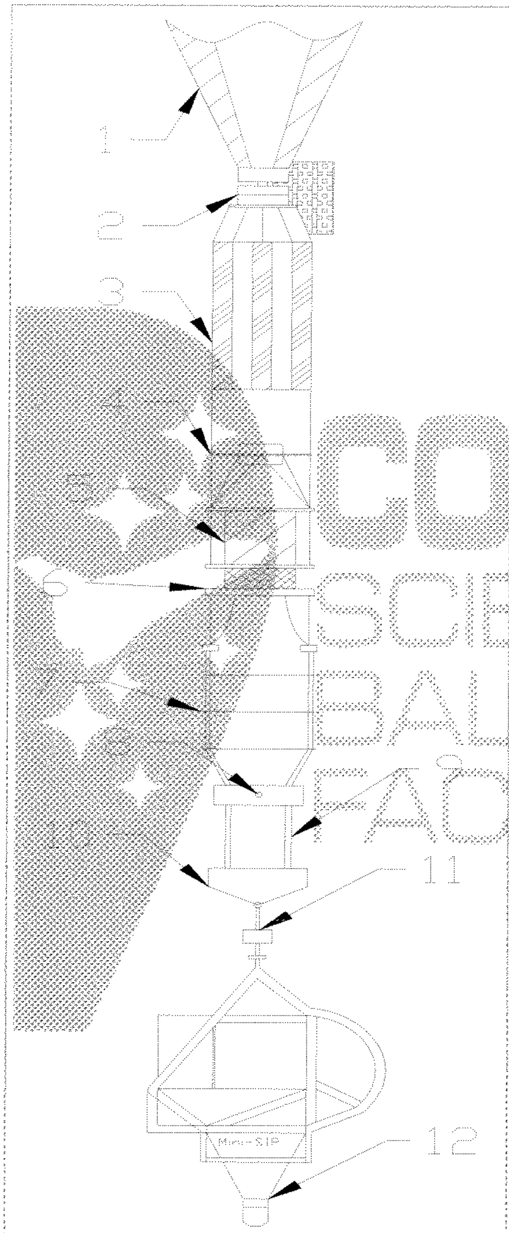
The re-certification documents for this payload and rotator have been reviewed and found to be in compliance with CSBF structural requirements. This payload/rotator has now been certified for 5000lbs below the gondola suspension point including 1200 lbs of ballast.

NOTES:

Safety cable will not be required for this flight and any future flights provided the suspended weight below the rotator does not exceed 5,000 lbs.

Signature:

National Scientific Balloon Facility | Certification Sheet
OF-317-01-D Rev - A | Date: 30 Apr 2004 | Page 1 of 1
Approved by: Hugo Franco | Date:



ITEM NO.	DESCRIPTION	MAXIMUM ALLOWED (LBS)
1	W39.57-2-76, #1066	6060
2	Cable Loop Terminate W/Rip Stitch	8000
3	130 ft. Diameter Parachute	6000
4	Parachute Ring W/UTP	5760
5	External Battery Box	5760
6	GAPR Cutaway System with 4 Strand Cutaway and four 1/2" All Thread Rods	5760
7	4 Strand 3/8" Cable Ladder (~~75~~ ft. long) ~60 ft.	5760
8	Standard Truck Plate with four 7/16" Farmers Shackles on top	5760
9	Four 3/8" dia. X 77" Steel Cables with 7/16" four Farmer Shackles on top and bottom (8)	5760
10	Tri-Plate with four 7/16" Farmer Shackles (Tri-plate provided by science)	5300
11	Science Rotator	5000
12	Double Ballast Hopper	1200
Notes: Ballast hopper suspension: 4 x ¼" x 56" Cables		

Scientist		NCT-Boggs		
Organization		SSL, Univ. Cal-Berkeley		
Operations File No.		C1000-09		
Approximate Weights (Lbs)	Science Wgt.	3141		
	NSBF Above Pin	702		
	NSBF Below Pin	451		
	Ballast	1200		
	Total	5494		
Certified By			Date	
Rigged as Certified By		[signature]	Date	19 APR 10
Flight No.		ABORT 23	Date	29 APR 10

K-7 Balloon "AS BUILT" Specifications

AEROSTAR™ INTERNATIONAL INC.
Sulphur Springs, Texas
Balloon Specifications for
(1066) W39.57-2-76

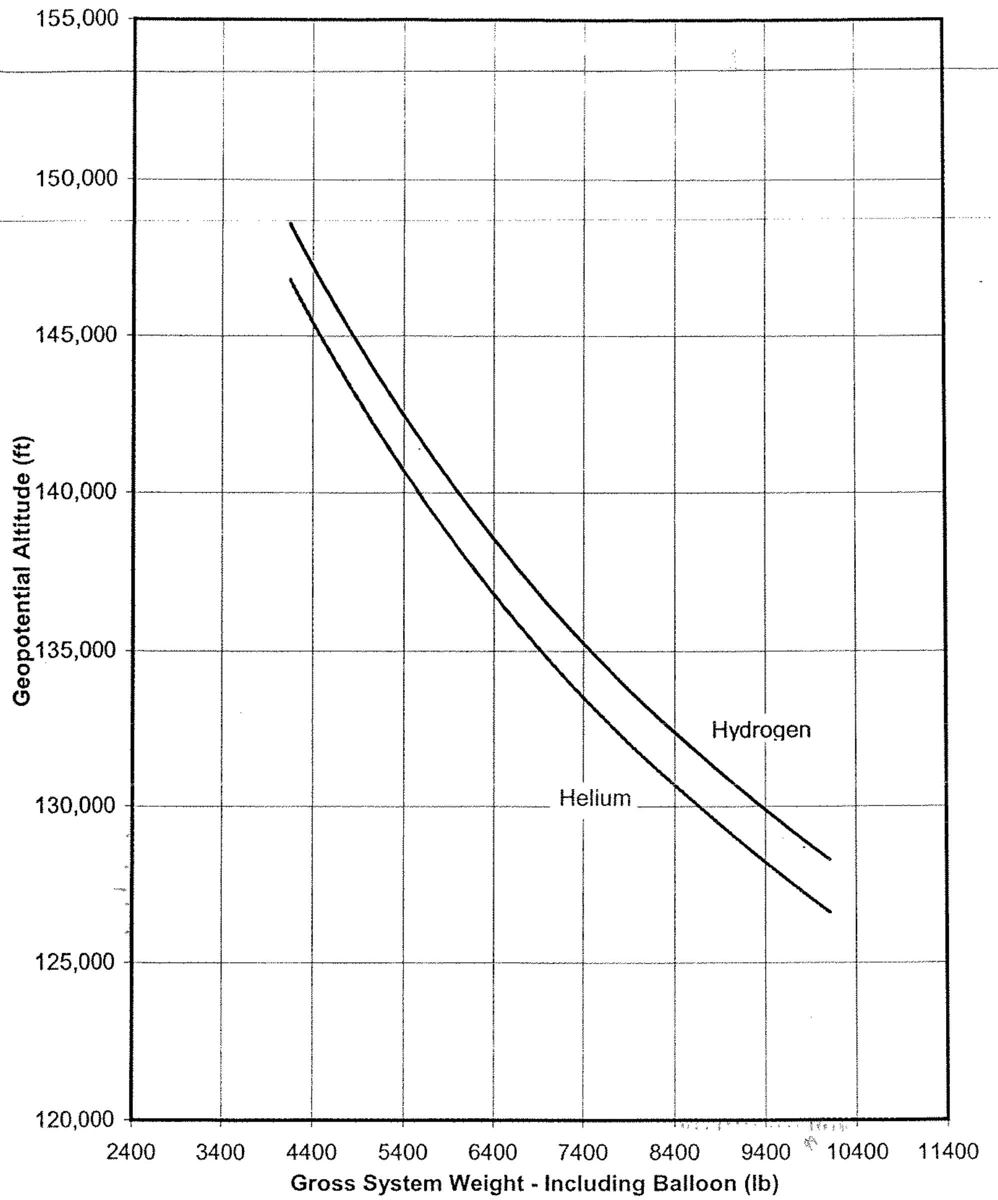
Contract Information	A) RFQ No.: R091809	B) Proposal Number: 16150	C) Specification Date: 10/30/08		
	D) Purchase Order No. P0079802	E) Customer Project No.:	F) Work Order No. 37711	G) Sequence 1 of 1	
2) Balloon Information	A) Manufacturer Aerostar International	B) Model No.: SF4-39.57-.8/.8/.8-NA	C) S/N 76	D) Incl. Dates of Mfr: 10/14/09 - 11/20/09	
3) Film Information	A) Manufacturer: Raven	B) Name: SF-450	C) Film Series 277		
4) Balloon Design:	A) Type: Natural shape, taped, capped		B) Volume: 39.57 mcf	C) No. Gores: 172	D) Theta 57.6°
	E) Gore Widths: Max.: 100.69 in.	Top: 0.77 in. Base: 2.00 in.	F) Inflated Dimensions: Height: 396.00 ft. Diameter 459.37 ft.		
	G) Nominal Load: 4,000 lbs.	H) Nominal Altitude: 131,700 ft.	I) Recommended Payload Weights: Min: 100 lbs. Max: 6,060 lbs.		
		Shell	Cap 1	Cap 2	Cap 3
	J) Film Gauge:	0.80 mils	0.80 mils	0.80 mils	N/A
	K) Surface Area:	574,134 ft²	96,199 ft²	112,800 ft²	
	L) Length:	662.63 ft.	176 ft.	191 ft.	
	M) Cap Location External	N) Balloon Wt. 4,124 lbs. FC	O) Bubble Marks Every Ten Feet: Min.: 120 ft. Max.: 150 ft.		P) Nominal Launch Mark: 132 ft.
5) Load Tapes:	A) Type: Laminated Polyester Fibers	B) Load Rating: 400 lbs	C) Radar Yarn: None		
Reefing Sleeve:	A) Film Gauge: Tear Panel: 0.70 mils Sleeve: 3.0 mils	B) Gore Seam No.: 172	C) Distance from Apex: 160 ft.		
7) Inflation Tubes	A) Qty 2	B) Distance From Apex: 48 ft.	C) Gores Locations: 2 and 88	D) Length 200 ft.	E) Gauge 3.0 mils; F) Diam. 9.55 in.
8) Venting Ducts:	A) Qty 6	B) Distance From Base: 165 ft.	C) Type: Attached	D) Length: 165 ft.	
	E) Gauge: 0.80 mils	F) Area Each: 125 ft²	G) Total Area: 750 ft²	H) Located on Seams 10, 39, 67, 96, 125, and 153	
9) Destruct Device:	A) Rip Line Rating: 1,000 lbs Type: Braided Nylon	B) Break line rating: 25 lbs.	C) Dist. from Apex: 10 ft.	D) Gore No. 169	
10) Valve Cable:	A) Wires: Qty.: 4 Gauge: AWG #16	B) Sheath Gauge: 1.5 mils	C) Located on Seam No.: 172		
11) Top Fitting:	A) Type: Plate, hoop and segmented clamp ring	B) No. of Ports: 1-33" or 2-13"	C) Diameter: 42 in.	D) Weight: 35.4 lbs	
12) Bottom Fitting:	A) Type: Banded Collar and Wedges	B) Load Attachment: 1"-8 UNC Eyenut	C) Diameter 6.10 in.	D) Weight: 10.1 lbs	
13) Shipping Information:	A) Gross Weight: 5,846 lbs.	B) Box Dimensions: 144 in. long x 72 in. wide x 58 in. high		C) Box Volume: 348 ft³	

14) Notes:
A) Raven Industries, Inc. Stable Table: U.S. Patent No. 4,877,205
B) Longest cap is the outermost layer of the balloon wall.
C) All exposed surfaces (inside & out) of apex and base fittings painted with Sherwin-Williams White 1400522.
D) Collar marks on reefing sleeve at 48.8, 51.8, and 54.9 meters (160, 170, and 180 ft.)
E) Use vapor barrier
F) Reinforced lower 1 ft of external box between cleats
G)
H)

As Built 20-Nov-09
HWP 11-20-2009

K-8 Balloon Load Altitude Curve

Aero[illegible]ar International Balloon Performan[illegible]		
LIFT GAS: HELIUM OR HYDROGEN	ATMOSPHERE: 1962 U.S. STANDARD	
Balloon Design Volume	Balloon Model Number	
39.572 mcf	SF4-39.57-.8/.8/.8-NA	
Nominal Balloon Weight	Max Rec. Payload	Min Rec. Payload
4052 lbs	6060 lbs	100 lbs



Graph No. 102968

May 3, 2006

K- 9 Flight Data Summary

National Scientific Ball[illegible]n Facility Flight Data Summary Me[illegible]
OF-332-00-M Rev – A Date- 10-27-03 page 1 of 1
Approved by _______Mark Cobble_______ date ____10-27-03____

MEMO TO: **NSBF Operations Department Head**

FROM: **Flight Operations Supervisor, Mechanical**

SUBJECT: **Flight Data Summary**

DATE: 29 APR 2010

Flight Number: ABORT 23 P PT N NT

Organization/Experimenter: UNIV. CALIFORNIA-BERKELEY - STEVEN BOGGS (NCT)

Date/Time Launched (Zulu): 22:38:28Z

Balloon (i.e. Winzen 29.47-3-005): W39.57-2-76

NSBF Balloon Number: 1066 Mil Thickness:(SHELL/CAPS) 0.8 / 0.8

Balloon Weight (lbs): 4124 Experiment Weight (lbs): 3481

Suspended Weight (lbs): 5489 Gross Inflation (lbs): 10574

Free Lift (%): 10

Float Altitude (kft): —

Terminate Date/Time: 28 April 2010 / 22:38:28Z

Impact Date/Time: 23.798S/133.883E/within boundary of Alice Springs Airport

Location of Impact: Same time as termination – abort

Total Flight Time (hrs, min): N/A

Condition of Payload: ______ Good ______ Fair ______ Poor

Remarks: Aborted launch. Payload sustained significant major damage.

K-10 Inflation Computation

National Scientific Balloon Facility	Inflation Computation WorkSheet (ref Conversion Factor)
OF-324-00-D Rev-C	Date 09-12-05 Page 1 of 1

Approved by Mark Cobble Date 9/12/2005

INFLATION COMPUTATION - Conversion Factor

FLIGHT # ABORT 23

LAUNCH DATE 4 / 29 / 10 L TIME: :08 :08 L COMPUTED BY: FC CHECKED BY: MDC

BLN. MFG. & VOL.: W39.57-2 SN: 76 NSBF: 1066	4124	LAUNCH SITE: Alice Springs, Aus.
PARACHUTE SIZE: 130' S/N: 0718 LADDER SIZE: 4 x 3/8" LENGTH: 65'	473	LAUNCH TIME 22 / 38 / 28 Z
STROBE (4) VALVE(S) (14) RFU (6) UTP (38) BATT. BOX w/cutaway/GAPR (97)	159	LAUNCH DRVR. D. Roberts
MISC ABOVE PIN: Ripstitch (27) 10 ft. Ladder extension (13) Suspension (26)PVC (4)	70	GND REC. , ,
SCIENTIFIC EXPERIMENT w/MiniSip, Solar Shields, CSBF camera, cryogens, CSBF PV's	3481	A/C CREW: Aussies , Embry , ,
BALLAST TYPE: SAND FLOW RATE 1 @ 87, 1 @ 82 = 169 PPM	1200	LAUNCH CREW FC , MDC , RH
HOPPER(S) (30) DBL FRAME (23) w/ 1/4" x 56" CABLES	53	DR , ~~RM~~ , RW , LF ,
CRUSH PAD (52) 2 bottles Deuterium depleted water (1)	53	, , , ,

GONDOLA WEIGHT COMPUTATIONS	GROSS LOAD	9613	SAO N/A WX: Mullenax	
SCIENCE GROUP: U.Cal Berkeley	FREE LIFT 10 %	961	TERMINATE #BT-20A	
Steven Boggs (NCT)	GROSS INFLATION	10574	EXPLOSIVE BOLT # N/A	
DATE/TIME OF WEIGH OFF: 12 Apr 10 1730L	LIFT/TUBE HANDBOOK	91.7	91.0	91.0
SCALE/MFG./TYPE: Challenger 2	MULT. BY CONV. FACTOR	8.28	8.47	8.55
	LIFT/TUBE (JBK/OTHER)	759.2	770.17	778.05
DATE OF CALIBRATION: 4/7/2009	MULT. BY NUM TUBES OPEN	8	8	8
WEIGHT VERIFIED BY: (2 OR MORE)	TOTAL LIFT AVAILABLE	6074	6166	6224
FC / J. Jones	SUBTRACT GROSS INFLATION	3524	3525	3525
GONDOLA WT. 3481 SCI. 3132	TOTAL LIFT RMG IN TRAILER	2550	2641	2699
1. WEIGHT INCLUDE BALLAST? NO	DIVIDE BY CONVERSION FACTOR	8.28	8.47	8.55
2. WEIGHT INCLUDE ELECT? Yes, MiniSip	LIFT/TUBE RMG (JBK/OTHER)	307.97	311.8	315.6
3. WEIGHT INCLUDE CRUSH PAD? NO	DIVIDE BY NUMBER TUBES OPEN	8	8	8
4. CRUSHPAD INSTALLED BY? CSBF	P.S.I. EQUIV. (FM HANDBOOK)	38.49	38.97	39.45
5. WEIGHT INCLUDE CRYOGENS ETC? _____	VALVING FROM P.S.I.	2500	2480	2480
yes, 95 lbs.	TO P.S.I.	995	1005	1025
6. GONDOLA FLOWN BEFORE? Yes	SUBTRACT FOR COOLING	-80	-70	-80
7. IF (6) ABOVE IS YES, IS THERE A DIFFERENCE IN WEIGHT? Yes, minus science PV	**FINAL CUTOFF PRESSURE P.S.I.**	915	935	945
	HELIUM TRAILER #	ISO-3	ISO-1	ISO-2
	CONVERSION FACTOR	8.28	8.47	8.55
	NUMBER OF TUBES OPEN	8	8	8
8. HAVE ALL WEIGHTS BEEN INCLUDED ON	STARTING PRESSURE	2500	2480	2480
INFLATION COMPUTATION SHEET? Yes	TEMERATURE FRONT	8	8	8
COLLAR ID 21	TEMPERATURE REAR	8	8	8
CUT-A-WAY #26	TEMPERATURE USED	8	8	8
BURST DETECTOR #1007 (Round)	COMMENTS: Minisip (266) SIP solar shields (40)			
BALLAST MOTOR # #570 = 87ppm; #550 = 82ppm	CSBF Test camera w/accessories (35)			
CREW CHIEF F. CANDELARIA	2 CSBF PV panels (4)			

F Candelaria

K-11 Launch Director's Checklist

National Scientific Balloon Facility	Launch Director's Checklist (Zero Pressure)
OF-322-10-C Rev–B Date- 10-03-05	page 1 of 2

Approved by ________Victor Davidson____________ date ________10/03/2005___________

LAUNCH DIRECTOR'S CHECK LIST (Zero Pressure)

FLIGHT #ABQRT23 **NOMINAL ALTITUDE** ________ **DATE/TIME** 29 APR 2010

PRE-BALLOON LAYOUT

✓ Chocks in place ✓ Brakes Set

✓ Spool and table clean and free of scratches and latched

B+8 Bubble and ground cloths properly deployed

LF ✓ Bubble and ground cloths swept clean

yes ✓ Ethafoam used?

BALLOON

✓ Properly laid out

✓ End fitting OK

✓ Pull or stretched places marked and noted

MDC ✓ Valves installed and working

1000 lb Rip line – Strength or size

144' Bubble length inflation complete (Feet)

10574 ✓ Gross Inflation (lbs.)

✓ Bubble lengths for cone angle __ 40%______ 50%______ 60%______

FLIGHT TRAIN ITEMS

FS ✓ Balloon properly mated to parachute and rigging

✓ Parachute and rigging properly laid out over launch vehicle (cable slack management for parachute/ladder, etc)

✓ Rigging properly tied into launch vehicle and safeties.

✓ Special rigging properly done (ballast tubes, swivel or stabilizing devices, ETC)

LAUNCH COLLAR

JMA INSTALLATION CHECK BY CAMPAIGN MANAGER

FLIGHT TRAIN CONTINUED

✓ Recovery tags

✓ NSBF instrumentation completed and checked

National Scientific Balloon Facility	Launch Director's Checklist (Zero Pressure)
OF-322-10-C Rev--B Date- 10-03-05	page 2 of 2

HELIUM TRAILER AND INFLATION DATA

MDC ✓ Valves on and off according to inflation sheet

MAC ✓ Heise gauge valve on

FE ✓ Final Pressure check

LF/RW ✓ Inflation tubes tied off

PRE-RELEASE CHECK

✓ Scientist ready and OK to launch

✓ DR 7 second delay safety pin pulled

N/A Terminate fitting safety cable removed

Launch Vehicle:

✓ TINY TIM ____ BIG BILL ____ BOSS ____ CRANE X OTHER

✓ Communications check with Driver and Electronic personnel B. Marzell

DR ✓ Driver ready and engine running

✓ Chocks removed (if necessary)

N/A Safety off (if necessary)

✓ Launcher ready

✓ Release pi-bal

✓ Notify personnel at spool release (radio command or light system)

✓ Brake off

Balloon released at 22:38:28 Z By: [signature]

LAUNCH CONDITIONS

Surface Direction & Speed 290 @ 2 Sky conditions CLEAR

Low level Direction & Speed 118 @ 11 Temperature C 11.7

Layout Direction 108 Crosswind(Y/N) N Surface Pressure(MB) 961.4

FRANK CANDELARIA LAUNCH DIRECTOR

K-12 Balloon Condition at Launch

National Scientific Balloon Facility		Balloon Condition at Launch Checklist
OF-329-00-D	Rev – A Date- 10/28/03	page 1 of 1

Approved by ______Mark Cobble________ date ____10-28-03___

NOTICE: Copies to Flight Folder and Balloon Engineer: **DOCUMENT FOLLOWS:**

FLIGHT LINE REPORT

BALLOON CONDITION AT LAUNCH

Flight# ABORT 23

Balloon I.D. (1066) W 39.57 - 2 - 76
NSBF I.D. MANUFACTURER VOLUME #CAPS S/N

Launch Date: 29 APR 2010 **Time:** 0808 L **Location:** ALICE SPRINGS, AUS.

Fully describe any problems found, including location, etc. If damage was caused on launch pad, describe circumstances.

PACKAGING (Balloon box, airing out, condition of protective wrap, markings, folding, etc):

GOOD

BASE & APEX FITTING: (Paint Finish, Connectors, Valve Plates, Bolts.)

GOOD

ACCESSORIES (Inflation tubes, reefing sleeve, valve cables, vent ducts, high slip, etc):

GOOD

DEPLOYMENT (Rope sections, position of valve cables, orientation of inflation tubes, etc):

OK

Report Completed by: [signature] Date: 29 APR 10

K-13 Recovery Information

National Scientific Balloon Facility Recovery Information Data Sheet
OF-306-00-D Rev – A Date- 10-28-03 page 1 of 1

Approved by _____Mark Cobble_______ date ______10-28-03______

NOTICE: Use to document the recovery information. Copies to **Flight Ops, Pilots, Flight Electronics,** and **Head of Operations**. Pre-printed "NCR" forms are acceptable. **DOCUMENT FOLLOWS:**

RECOVERY INFORMATION

Scientific Group: NCT / Boggs Scientific Rep. on Recovery: Steve McBride

Aircraft: ________ Vehicle: ________

Payload Dimensions: 11 ft H 5 ft W 15 ft L - Weight 4,289 Lbs.

Batteries: No. 36 Types B7901-12, ____, ____, ____

Location: Two white boxes on the floor of the electronics bay

Dimensions: 1) ____H ____W ____L, 2) ____H ____W ____L,
3) ____H ____W ____L, 4) ____H ____W ____L,

Removal Inst.: Remove securement straps by loosening bolts. Disconnect power cables on outside edges.

Radioactive Sources: ______Yes X No Type________

Location: ________

Precautions: ________

Other Hazards: Cryogenic liquid nitrogen (may be evaporated on recovery)

Location: White dewar in instrument cradle.

Precautions: If gondola lands upright, avoid tipping and transport upright.

Special Equipment: Allen + adjustable wrenches

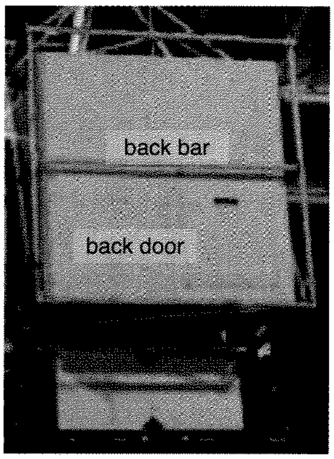
Other Recovery instructions: Remove + safeguard data drives from flight computer. Support gondola on bottom of frame rather than protruding SIP pegs.

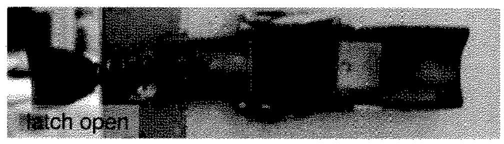
Certification: ✓ Flt. Ops.: ✓ Flt. Elec.: ✓

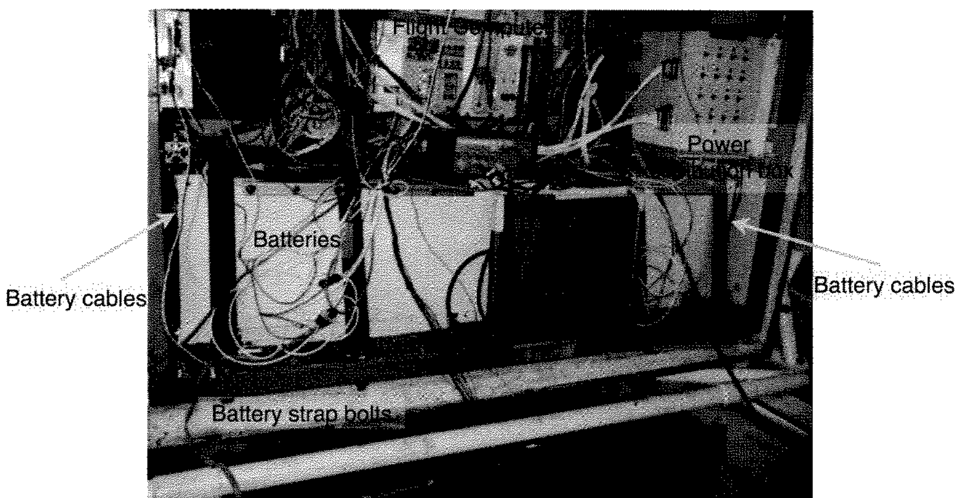
NCT Recovery Instructions
Alice Springs, Australia 2010

I. Battery Removal

1. Remove back bar (5/16" Allen wrench) and back door (latches) to electronics bay.

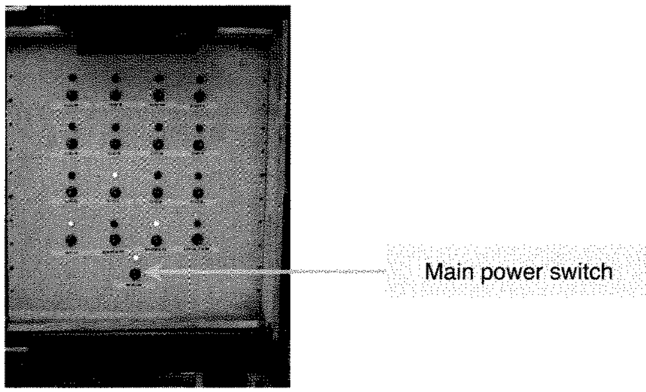




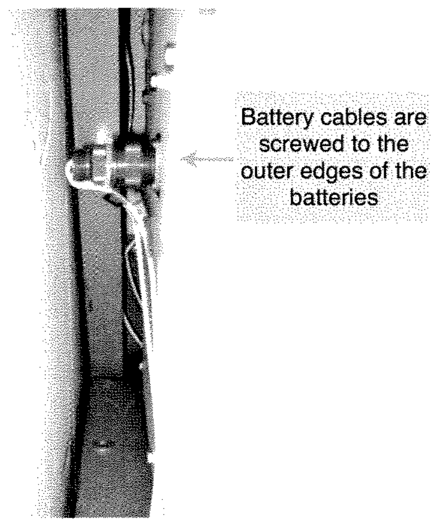


Inside the electronics bay

2. Ensure main power (bottom switch on Power Distribution Box) is off. All LEDs should be off. See supplemental document to shut down solar panel control box.



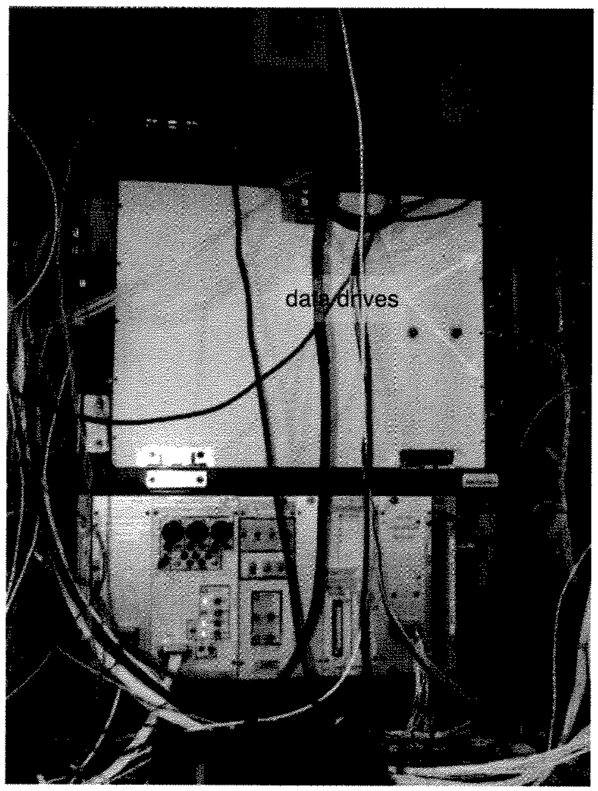
3. Remove battery securement straps with adjustable wrenches.

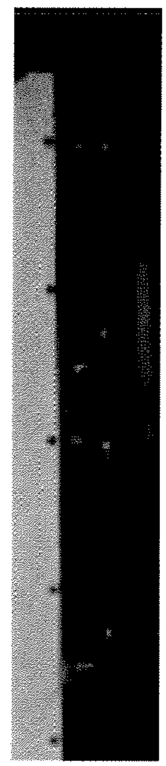


4. Unscrew battery cables. Connectors are on the outside edges of the batteries--it may be necessary to rotate batteries or take off the sides of the electronics bay to access them). For safety, don't cut the cables!
5. Remove batteries from electronics bay.

II. Data drive removal

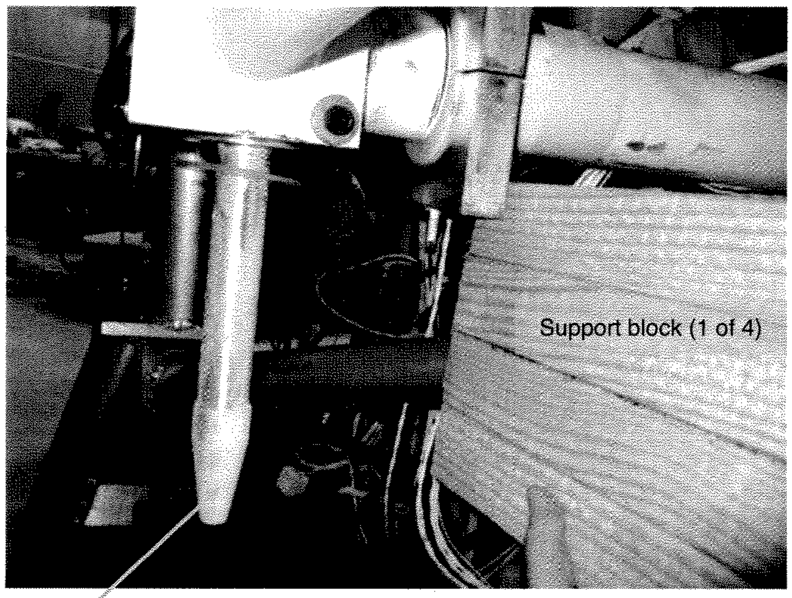
1. Unscrew thumb screws holding in the two data drives into the flight computer and pull them out. Remove the cables attached at the back by pulling gently.





III Transport

The SIP cage is secured to the gondola by metal pegs which protrude from the bottom of the gondola. Whether or not the pegs bend on landing, it will likely be easier to support the gondola on blocks (supplied) during transit than on the pegs.



Remove the tapered peg tip by unscrewing it.

K-14 Quality Control Information

National Scientific Ball... n Facility		Quality Control Balloon ...ormation Data	
OF-330-00-D	Rev – A	Date- 10-27-03	page 1 of 1

Approved by ______Mark Cobble__________ date ____10-27-03____

NOTICE: This sheet is to be attached to Launch Director's Checklist for eventual placement into Flight Folder. Balloon rigging information is captured, transferred to this sheet and sent to the Balloon Engineer. **DOCUMENT FOLLOWS:**

QUALITY CONTROL INFORMATION

TO: **Balloon Engineer**

FM: **Operations Department**

Flight #: ABORT 23

Balloon type: W39.57-2-76 (1066)

Gross lift: 10574 **lbs**

Collar ID: 21

Foam ID: N/A

Collar Location: 166 **Ft. from top**

Was polyethylene used between foam? X **YES** _______ **NO**

Signed: [signature]

Date: 29 APR 2010

K-15 Collar Flight Record

National Scientific Balloon Facility		Collar Flight Record	
OF-328-00-C	Rev – A	Date- 10-27-03	page 1 of 1

Approved by ______Mark Cobble________ date ____10-27-03____

NOTICE: This sheet is to be attached to Launch Director's Checklist for eventual placement into Flight Folder. Collars are to be inspected after each flight according to the above guideline and tagged. Tag is to be removed upon collar installation. Any information on tag should then be transferred to this sheet. **DOCUMENT FOLLOWS:**

COLLAR FLIGHT RECORD

FLIGHT NO. ABORT 23 **LAUNCH DATE** ALICE SPRINGS

INSTALLED BY F. CANDELARIA **COLLAR LOCATION** 166

COLLAR FIT **LOOSE**_____ **MODERATE** X **TIGHT**_____

COLLAR RELEASE ON LAUNCH X **ASCENT**_____

COLLAR RELEASE ANGLE_____ **BALLOON SIZE** W39.57-2

COLLAR SIZE LARGE **COLLAR ID NO.** 21

COLLAR INSPECTION RECORD

COLLAR INSPECTED BY:	DR
COLLAR INSPECTION DATE:	19 APR 2010
CLEAN OF DEBRIS, ETC.:	✓
MATERIAL TEARS REPAIRED:	OK
LINK BELTS CHECK/REPAIR:	REPLACE 1 LINK
TAPE ON BRADS OR ROPE:	OK
BUNGEE CHECKED/REPAIRED:	OK
BUNGEE EYEBOLTS CHECKED:	✓
O RINGS CHECK BURRS/RUST:	✓
CLEVIS PIN ATTACHMENT OK:	✓
VELCRO STRAPS CHECK/REPAIR:	✓

K-16 Flight Operations – Rigging Job Assignments

Columbia Scientific Balloon Facility	CSBF Flt. Ops. - Rigging Job Assignments
OF-318-00-D Rev-B Date: 06-12-2006	Page 1 of 1

Approved by ________Victor M. Davison________ Date ____6/12/2006________

NOTICE: DOCUMENT FOLLOWS

FLIGHT OPERATIONS – RIGGING JOB ASSIGNMENTS

29 APR 2010 ABORT 23

SCIENCE GROUP: BOGGS/NCT UC BERKELEY LAUNCH @ 0700

RELEASE DRIVER: **DON**

Pick up package, Help scientists on line, Connect rip line, Connect parachute, Choke, Pull line cutter pin and check Terminate Safety Cable, Drive on Release

HELIUM TRAILER(S):

Trailer #: **ISO-2** Tubes: **8** **RANDALL**

Trailer #: **ISO-1 / ISO-3** Tubes: **8 / 8** ~~LARRY~~/COBBLE/CANDELARIA/RH

(Larry drive prime mover) (Mark monitor helium)

BALLOON VEHICLE: Balloon # **1066** **ROBIN**

Drive balloon to pad and during layout. Inflate balloon and Pick up red poly.

GROUND CLOTH VEHICLE: Bubble + **8** **LARRY**

Drive to pad, Drive for layout, Inflate balloon, drive on cloth pick up

LAUNCH SPOOL: Pibal **1000** ft **RANDALL**

Drive to pad, inflate & position tethered pibal, Raise bubble
Drive during inflation. Release balloon from spool

LIGHT PLANT(S): (1) _______ (2) **X** (BOTH BY SPOOL) **ROBIN**

SPECIAL EQUIPMENT: **KAWASAKI MULE/CHUTE CART** **MARK**

RECOVERY CREW: Show Time: N/A **SULLIVAN**

SAO Show Time: N/A __________

****

1. Mark Cobble 2. Victor Davison 3. Frank Candelaria 4. Keith Parkes 5. Randall Henderson
6. Marty Crabill 7. Joe Masters 8. Robin Whiteside 9. Derek Dolbey 10. Nathan McCabe
11. Don Roberts 12. Curtis Frazier 13. Reid Chambers 14. Larry Fox

K-17 Rigging Weight Sheet

Flight Folder

RIGGING FLIGHT REQUEST RESPONSE

Flight Request Number
C1000-09 Revised

Scientist
Steven Boggs/Un. Cal Berkeley (NCT)

Desired Float	Minimum Float	Desired Alt.	Minimum Alt.	Valving Required
			120 kft (day)	
4 days	24 hours	130 kft	100 kft (nite)	no

Flight Profile
evening launch desired

Float Stability
Desired: 10 kft Minimum: 20 kft

Payload		3100
Electronics		356
Parachute Size	130	500
Misc.		225
Sustaining Ballast		157
Sunset Ballast		677
Drive Up Ballast	morning	366
SUSP. WEIGHT		5381
Est. Balloon Wt.		4124
GROSS LOAD		9505
Free Lift %	10	951
GROSS INFLATION		10456
CU FT. HELIUM		158924

Location
Australia 2010

Ballast Type	Total Ballast
SAND	1200

Balloon Size W39.57-2 0

Max Payload 6000 Min Payload 100

Alt w/Ballast 128 kft Alt w/o Ballast 130.5 kft

Comments:

APPENDIX L: WEATHER DOCUMENTATION

L-1 Davis Weather Station 8 Hour

L-2 Flight Forecast Data

L-3 Pilot Balloon (PIBAL) Data

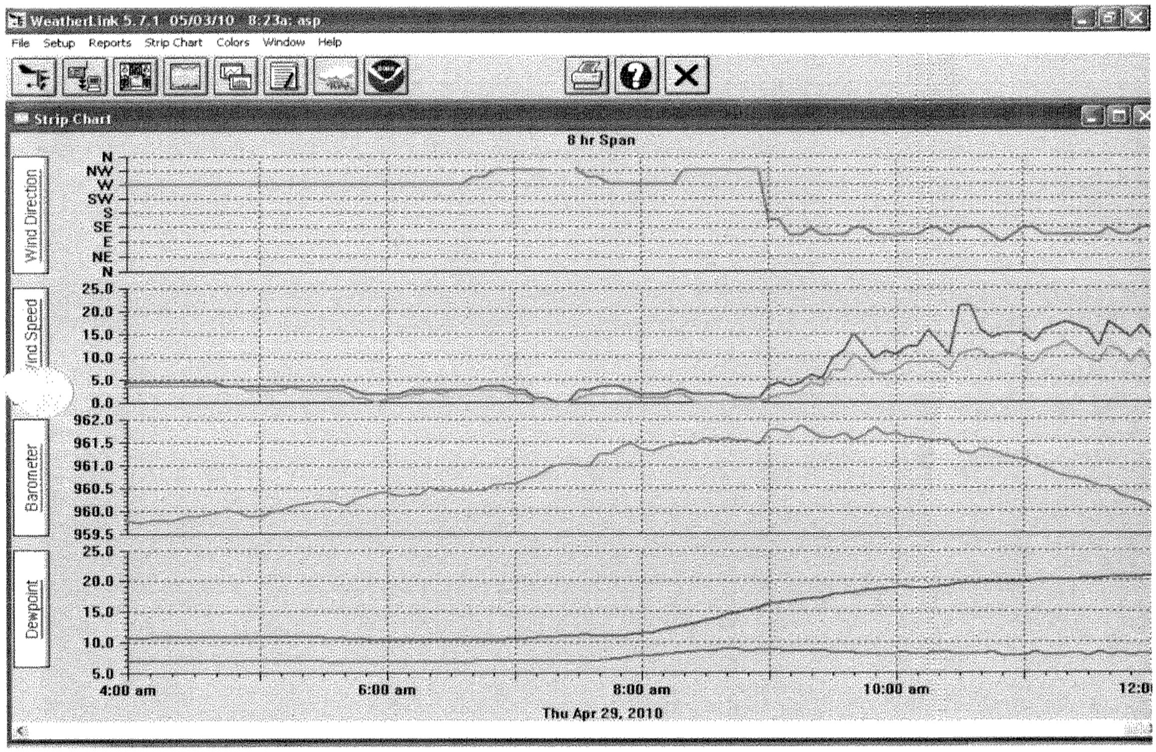
L-4 Climbout and Descent Trajectory Forecast

L-5 ABORT 23 Meteorologist Observation Report

L-6 Rawinsonde Data (radiosonde systems that measure winds, along with pressure, temperature and humidity)

L-7 Surface Observations

L-1 Davis Weather Station 8 Hour



L-2 Flight Forecast Data

<u>Flight Forecast Data</u>

Group: NCT

Launch Date/Time(UTC):28 Apr 2010/2200Z
Launch Data/Time(Local):29 Apr 2010/0730L

<u>Synopsis</u>
High pressure to the south will continue to dominate.

<u>Launch Conditions</u>
Surface Winds: ESE-SE 2-5 kts, G9 kts by 0820-0850L
Low Level Winds:
400ft:100-120/8-10 kts
700ft:090-110/12-14 kts
1000ft:090-110/13-15 kts
1300ft:090-110/14-16 kts
Clouds and Weather: 50 SCT

<u>Climbout and Enroute</u>
Tropopause: -76.0C @ 51.9kft **Min Temp: TROP**
Max Wind: 270 deg/55 kts at 45kft
Initial Position at Float: 085/20nm from Alice Springs
Estimated Time at Float: 27 hrs staying at 105kft minimum,
Clouds and Weather: 60 SCT 100 SCT 300 SCT-BKN

<u>Impact Conditions</u>
Forecast Descent Vector: 080 deg/10 nm
Estimated Impact Position: 150nm E of Longreach
Clouds and Weather: 50 SCT 100 SCT 300 SCT
Surface Winds: VRBL 5-10 kts

<u>Remarks</u>
Fri AM: Sfc: VRBL 2-5 kts, L/L winds..080-100/12-14 kts
Estimated float time: 21-28 hours (depending on min alt)
Sat AM: Sfc: VRBL 1-3 kts, L/L winds..070-090/10-12 kts
Estimated float time: 24-30 hours (depending on min alt)
Sunday..increasing easterly flow

L-3 Pilot Balloon (PIBAL) Data

20100428161050.txt

```
Starting PiBall Run 2010/04/28 16:10:50
   150ft   3.2 knots from 90.1 deg
   450ft   10.7 knots from 82.4 deg
   750ft   14.6 knots from 91.0 deg
   1050ft 12.4 knots from 99.2 deg
   1350ft 11.6 knots from 101.2 deg
   1650ft 10.3 knots from 109.9 deg
   1950ft 10.7 knots from 112.5 deg
   2250ft 11.2 knots from 117.4 deg
   2550ft 9.1 knots from 129.1 deg
   2850ft 9.8 knots from 147.0 deg
   3150ft 9 knots from 156.6 deg
   3450ft 10 knots from 169.3 deg
   3750ft 10.5 knots from 155.0 deg
   4050ft 12.7 knots from 126.2 deg
```

01 / 01:41 ACST (L)

[redacted]

Page 1

20100428164807.txt

```
Starting PiBall Run 2010/04/28 16:48:07
   150ft   1.9 knots from 80.6 deg
   450ft   9.7 knots from 81.7 deg
   750ft   12.5 knots from 93.5 deg
   1050ft 11.9 knots from 98.3 deg
   1350ft 9.7 knots from 111.0 deg
   1650ft 10.9 knots from 112.5 deg
   1950ft 11.2 knots from 116.7 deg
   2250ft 11.5 knots from 125.1 deg
   2550ft 12.6 knots from 128.3 deg
   2850ft 12.9 knots from 133.3 deg
   3150ft 12.7 knots from 127.6 deg
   3450ft 9.4 knots from 121.1 deg
   3750ft 9.5 knots from 130.6 deg
   4050ft 11.3 knots from 135.5 deg
```

02/ 02:18(b)

Page 1

20100428172841.txt

```
Starting PiBall Run 2010/04/28 17:28:41
   150ft    2.2 knots from 128.7 deg
   450ft    6.7 knots from 80.1 deg
   750ft    11.3 knots from 101.7 deg
   1050ft 11.2 knots from 113.3 deg
   1350ft 12.5 knots from 114.5 deg
   1650ft 11.9 knots from 118.3 deg
   1950ft 13.5 knots from 117.1 deg
   2250ft 12.6 knots from 117.6 deg
   2550ft 12.3 knots from 119.2 deg
   2850ft 12.4 knots from 116.1 deg
   3150ft 13.4 knots from 114.9 deg
   3450ft 14.2 knots from 122.7 deg
   3750ft 12.5 knots from 136.8 deg
   4050ft 12.5 knots from 136.6 deg
```

03| 02:59 (W)

Page 1

20100428175847.txt

```
Starting PiBall Run 2010/04/28 17:58:47
   150ft   1.2 knots from 230.4 deg
   450ft   5.7 knots from 92.3 deg
   750ft   8.5 knots from 109.6 deg
   1050ft 10.9 knots from 118.4 deg
   1350ft 12.5 knots from 117.9 deg
   1650ft 13.8 knots from 118.4 deg
   1950ft 13.2 knots from 119.0 deg
   2250ft 9.1 knots from 116.0 deg
```

04 | 03:32 (L)

20100428183651.txt

```
Starting PiBall Run 2010/04/28 18:36:51
   150ft   0.9 knots from 209.2 deg
   450ft   4.5 knots from 113.2 deg
   750ft   10.1 knots from 120.5 deg
   1050ft 10.5 knots from 119.6 deg
   1350ft 11.4 knots from 121.5 deg
   1650ft 11.4 knots from 118.6 deg
   1950ft 12.9 knots from 119.6 deg
   2250ft 12.7 knots from 118.6 deg
   2550ft 13.8 knots from 120.6 deg
   2850ft 14 knots from 123.7 deg
   3150ft 14.3 knots from 125.5 deg
   3450ft 13.6 knots from 136.6 deg
```

05/04:18(L)

Page 1

20100428191755.txt

```
Starting PiBall Run 2010/04/28 19:17:55
   150ft   4.3 knots from 249.0 deg
   450ft   4.3 knots from 101.5 deg
   750ft   8.9 knots from 113.9 deg
   1050ft 10.3 knots from 118.3 deg
   1350ft 10.9 knots from 122.3 deg
   1650ft 12.2 knots from 118.5 deg
   1950ft 11.8 knots from 123.0 deg
   2250ft 14 knots from 121.0 deg
   2550ft 14.9 knots from 123.1 deg
   2850ft 14.7 knots from 119.0 deg
   3150ft 15.3 knots from 123.5 deg
   3450ft 13 knots from 128.4 deg
   3750ft 15.8 knots from 138.7 deg
   4050ft 13 knots from 131.3 deg
```

06/04:48(L)

20100428194757.txt

```
Starting PiBall Run 2010/04/28 19:47:57
   150ft   2.7 knots from 252.4 deg
   450ft   4.3 knots from 93.6 deg
   750ft   8.4 knots from 108.4 deg
   1050ft 10.3 knots from 119.6 deg
   1350ft 12.1 knots from 117.3 deg
   1650ft 11.7 knots from 118.4 deg
   1950ft 11.7 knots from 121.0 deg
   2250ft 11.7 knots from 118.8 deg
   2550ft 13.2 knots from 118.4 deg
   2850ft 13.6 knots from 118.6 deg
   3150ft 16.3 knots from 120.0 deg
   3450ft 34.2 knots from 124.7 deg
   3750ft 55.5 knots from 119.4 deg
```

07/0518(L)
Delayed NOTAM

Page 1

20100428202336.txt

```
Starting PiBall Run 2010/04/28 20:23:36
   150ft   3.4 knots from 235.3 deg
   450ft   3.1 knots from 120.7 deg
   750ft   9 knots from 111.5 deg
   1050ft 10.5 knots from 116.5 deg
   1350ft 11.8 knots from 114.3 deg
   1650ft 12 knots from 115.9 deg
   1950ft 11.8 knots from 114.6 deg
   2250ft 12.3 knots from 115.2 deg
   2550ft 12.5 knots from 118.2 deg
   2850ft 13.6 knots from 117.6 deg
   3150ft 15.1 knots from 125.6 deg
   3450ft 16.2 knots from 131.2 deg
   3750ft 13.9 knots from 138.6 deg
   4050ft 12.7 knots from 131.7 deg
```

08/05:54(4)
Balloon layout

Page 1

20100428205943.txt

```
Starting PiBall Run 2010/04/28 20:59:43
   150ft   2.7 knots from 229.2 deg
   450ft   5.1 knots from 111.9 deg
   750ft   10.8 knots from 109.6 deg
   1050ft 12.8 knots from 111.6 deg
   1350ft 14.4 knots from 112.6 deg
   1650ft 14 knots from 116.3 deg
   1950ft 14.4 knots from 120.0 deg
   2250ft 14.8 knots from 120.7 deg
   2550ft 13.1 knots from 122.9 deg
   2850ft 13.7 knots from 122.6 deg
   3150ft 15.1 knots from 129.2 deg
   3450ft 15.3 knots from 128.9 deg
   3750ft 12.6 knots from 129.2 deg
   4050ft 12.6 knots from 122.6 deg
```

09/ 06:30 (L)

20100428211230.txt

```
Starting PiBall Run 2010/04/28 21:12:30
   150ft   2 knots from 246.3 deg
   450ft   4.6 knots from 115.4 deg
   750ft   10.6 knots from 109.8 deg
   1050ft 12.9 knots from 115.2 deg
   1350ft 15.1 knots from 116.3 deg
   1650ft 14.6 knots from 117.1 deg
```

10| 06:43(L)
Go for inflation

Page 1

20100428220956.txt

```
Starting PiBall Run 2010/04/28 22:09:56
   150ft   2.9 knots from 199.0 deg
   450ft   7.5 knots from 121.6 deg
   750ft   11.6 knots from 114.9 deg
   1050ft 13 knots from 113.6 deg
   1350ft 12.6 knots from 114.6 deg
```

11 | 07:40 (L)
Inflation check

```
Starting PiBall Run 2010/04/28 22:40:23
   150ft   0.7 knots from 187.5 deg
   450ft   8.1 knots from 110.8 deg
   750ft   12.2 knots from 110.6 deg
   1050ft 13.4 knots from 111.2 deg
   1350ft 13.6 knots from 109.9 deg
   1650ft 13.5 knots from 109.6 deg
   1950ft 14.4 knots from 109.4 deg
   2250ft 15.2 knots from 111.9 deg
   2550ft 17.2 knots from 112.8 deg
   2850ft 19.1 knots from 125.3 deg
```

12/08:10 (L)
Post launch

L-4 Climbout and Descent Trajectory Forecast

Flight Folder

Climb_20100428_153802.txt

Science Group: NCT
Balloon Type: ZP
Balloon Size: 39.5
Chute Size: 130
Weight with Ballast: 5489
Weight without Ballast: 3289

Trop
-73C
@ 94.8kft

Calculations based on the following ascent rates:
Surface-50kft: 1050.
50kft-70kft: 600.
Above 70kft: 675.

altitude	dir	spd	bearing	distance(nm)	time(min)
3.	100	14	280.	0.2	1.0
6.	135	11	305.	0.7	3.8
9.	185	7	323.	0.9	6.7
12.	240	5	338.	0.9	9.5
18.	290	5	8.	0.7	15.2
24.	275	11	62.	1.3	21.0
30.	280	14	81.	2.5	26.7
34.	280	18	87.	3.6	30.5
39.	265	31	86.	6.0	35.2
45.	275	46	90.	10.4	41.0
53.	245	30	80.	16.7	54.3
60.	205	12	74.	18.1	66.0
70.	85	8	73.	15.9	82.6
80.	90	15	68.	12.4	97.4
90.	100	15	56.	9.5	112.2
100.	270	5	59.	10.6	127.1
110.	270	15	67.	13.9	141.9
120.	270	20	73.	18.5	156.7
128.	270	35	78.	25.2	168.5

Min Temp
TROP

Descent Vectors Without Ballast

altitude	dir	spd	bearing	distance(nm)	time(min)
3.	100	14	280.	0.2	0.9
6.	135	11	305.	0.7	3.6
9.	185	7	323.	0.9	6.3
12.	240	5	336.	0.9	8.8
18.	290	5	3.	0.7	13.8
24.	275	11	56.	1.0	18.3
30.	280	14	78.	1.9	22.8
34.	280	18	85.	2.8	25.7
39.	265	31	85.	4.7	29.4
45.	275	46	89.	7.8	33.5
53.	245	30	84.	9.8	37.7
60.	205	12	81.	10.1	40.7
70.	85	8	81.	9.6	44.0

Page 1

Climb_20100428_153802.txt

80.	90	15	80.	9.0	46.7
90.	100	15	79.	8.5	48.8
100.	270	5	79.	8.6	50.4
110.	270	15	79.	8.9	51.6
120.	270	20	80.	9.2	52.5
128.	270	35	80.	9.6	53.2

Descent Vectors With Ballast

altitude	dir	spd	bearing	distance(nm)	time(min)
3.	100	14	280.	0.2	0.7
6.	135	11	305.	0.5	2.8
9.	185	7	323.	0.7	4.9
12.	240	5	336.	0.7	6.8
18.	290	5	3.	0.5	10.7
24.	275	11	56.	0.8	14.2
30.	280	14	78.	1.5	17.6
34.	280	18	85.	2.1	19.9
39.	265	31	85.	3.6	22.8
45.	275	46	89.	6.0	25.9
53.	245	30	84.	7.6	29.2
60.	205	12	81.	7.8	31.5
70.	85	8	81.	7.5	34.1
80.	90	15	80.	6.9	36.1
90.	100	15	79.	6.6	37.8
100.	270	5	79.	6.7	39.0
110.	270	15	79.	6.9	39.9
120.	270	20	80.	7.1	40.6
128.	270	35	80.	7.4	41.2

L-5 ABORT 23 Meteorologist Observation Report

Campaign Meteorologist Observation Report for Abort #23

I was the campaign meteorologist on duty during this abort during the 2010 Australia Campaign. Weather conditions at time of balloon release from the spool were as follows:

Surface wind: 290 deg/2 kts (note that during inflation surface winds were 250-300 deg/1-4 kts)
Pressure: 961.4 mb
Temperature: 11.7C
Sky Condition: Clear
Layout direction: 110 degrees

Pilot Balloon measurement taken 2209Z:

150ft: 199 deg/2.9 kts
450ft: 122 deg/7.5 kts
750ft: 115 deg/11.6 kts
1050ft: 114 deg/13 kts
1350ft: 115 deg/12.6 kts

Pilot Balloon measurement taken after abort at 2240Z:

150ft: 188 deg/0.7 kts
450ft: 111 deg/8.1 kts
750ft: 111 deg/12.2 kts
1050ft: 111 deg/13.4 kts
1350ft: 110 deg/13.6 kts

I have also separately sent YBAS radiosonde data taken by the Alice Springs Met Office (from 12Z 28 Apr and 00Z 29 Apr), Flight Forecast Data Sheet, and emergency terminate descent corridor data. Please note that the emergency terminate descent corridor data was based on the 12Z 28 Apr YBAS radiosonde up to 80kft.

L-6 Rawinsonde Data (radiosonde systems that measure winds, along with pressure, temperature and humidity)

```
SNPARM = PRES;TMPC;DWPC;DRCT;SKNT;HGHT;HGFT

STID = YBAS          STNM =    94326   TIME = 100428/1200
SLAT = -23.80     SLON =   133.88   SELV =   546.0
STIM =  1100
```

PRES	TMPC	DWPC	DRCT	SKNT	HGHT	HGFT
961.00	15.60	7.60	130.00	6.99	546.00	1791.00
1000.00	-9999.00	-9999.00	-9999.00	-9999.00	204.00	669.00
955.00	18.80	7.80	128.25	10.50	599.65	1967.00
950.00	19.00	7.00	126.77	13.45	644.88	2116.00
944.00	18.57	6.81	125.00	17.00	699.32	2294.00
925.00	17.20	6.20	125.00	16.01	874.00	2867.00
863.00	11.78	4.89	120.00	12.00	1458.19	4784.00
850.00	10.60	4.60	125.00	12.00	1586.00	5203.00
818.00	7.60	4.00	133.39	10.33	1904.48	6248.00
812.00	8.00	4.40	135.00	10.00	1965.30	6448.00
805.00	10.40	-14.60	138.21	9.65	2037.08	6683.00
799.00	12.60	-36.40	140.98	9.35	2099.50	6888.00
775.00	12.40	-33.60	152.28	8.12	2354.73	7725.00
707.00	8.00	-31.00	186.31	4.40	3117.11	10227.00
700.00	7.40	-25.60	190.00	4.00	3199.00	10495.00
659.00	3.60	-22.40	238.29	2.86	3692.58	12115.00
617.00	2.40	-35.60	290.98	1.62	4226.22	13866.00
566.00	-2.73	-36.73	0.00	0.00	4913.93	16122.00
542.00	-5.30	-37.30	323.31	1.74	5259.30	17255.00
523.00	-5.90	-41.90	293.09	3.18	5539.39	18174.00
500.00	-8.90	-44.90	255.00	4.99	5890.00	19324.00
474.00	-11.50	-53.50	257.90	6.45	6300.12	20670.00
416.00	-19.96	-51.96	265.00	10.00	7276.58	23873.00
400.00	-22.50	-51.50	275.00	10.99	7570.00	24836.00
398.00	-22.82	-51.62	275.00	10.99	7606.71	24956.00
390.00	-24.10	-52.10	270.67	11.69	7755.43	25444.00
354.00	-28.94	-58.71	250.00	15.00	8446.84	27713.00
313.00	-35.10	-67.10	278.92	12.52	9325.62	30596.00
305.00	-36.69	-68.08	285.00	12.00	9505.29	31185.00
300.00	-37.70	-68.70	285.00	13.00	9620.00	31562.00
279.00	-42.14	-70.92	290.00	16.01	10114.71	33185.00
272.00	-43.70	-71.70	286.53	16.93	10287.92	33753.00
250.00	-48.10	-73.10	275.00	20.01	10850.00	35597.00
239.00	-50.30	-74.30	266.46	22.56	11145.16	36565.00
225.00	-53.25	-73.97	255.00	25.99	11535.98	37848.00
222.00	-53.90	-73.90	256.95	26.97	11622.88	38133.00
210.00	-54.96	-73.37	265.00	31.00	11978.11	39298.00
200.00	-55.90	-72.90	260.00	38.00	12290.00	40322.00
191.00	-56.48	-75.13	255.00	37.00	12580.55	41275.00
160.00	-58.70	-83.70	273.32	45.06	13698.12	44941.00
156.00	-59.90	-84.90	275.94	46.21	13856.40	45461.00
150.00	-61.50	-9999.00	280.00	48.00	14100.00	46260.00
149.00	-61.73	-9999.00	280.00	48.00	14141.15	46395.00
133.00	-65.70	-9999.00	274.95	42.44	14839.99	48688.00
119.00	-68.21	-9999.00	270.00	37.00	15507.59	50878.00
107.00	-70.62	-9999.00	245.00	31.99	16145.59	52971.00
102.00	-71.70	-9999.00	245.00	28.67	16432.83	53913.00
101.00	-71.50	-9999.00	245.00	27.99	16491.12	54105.00

100.00	-71.70	-9999.00	250.00	25.99	16550.00	54298.00
96.80	-72.70	-9999.00	260.00	24.01	16740.98	54924.00
88.50	-71.30	-9999.00	260.00	26.82	17267.91	56653.00
88.00	-70.88	-9999.00	260.00	27.00	17301.63	56764.00
86.00	-69.18	-9999.00	255.00	29.00	17438.44	57213.00
84.30	-67.70	-9999.00	242.42	23.97	17557.26	57603.00
82.00	-67.88	-9999.00	225.00	17.00	17722.85	58146.00
79.00	-68.12	-9999.00	220.00	8.00	17945.96	58878.00
76.00	-68.37	-9999.00	235.00	15.00	18177.71	59638.00
72.00	-68.72	-9999.00	205.00	12.00	18501.37	60700.00
70.00	-68.90	-9999.00	200.00	12.00	18670.00	61253.00
68.00	-69.54	-9999.00	200.00	15.00	18843.30	61822.00
67.50	-69.70	-9999.00	193.82	14.26	18887.42	61967.00
66.00	-68.63	-9999.00	175.00	12.00	19022.70	62410.00
62.60	-66.10	-9999.00	97.79	11.33	19341.07	63455.00
61.00	-66.67	-9999.00	60.00	10.99	19497.54	63968.00
58.00	-67.79	-9999.00	45.00	10.99	19802.29	64968.00
57.20	-68.10	-9999.00	29.03	8.61	19886.22	65244.00
57.00	-67.84	-9999.00	25.00	8.00	19907.48	65313.00
54.30	-64.30	-9999.00	281.62	4.66	20202.01	66280.00
53.00	-63.66	-9999.00	230.00	2.99	20350.87	66768.00
51.90	-63.10	-9999.00	222.80	4.08	20479.70	67191.00
50.00	-62.10	-9999.00	210.00	6.00	20710.00	67946.00
48.00	-61.20	-9999.00	145.00	10.00	20963.14	68777.00
47.00	-60.74	-9999.00	110.00	10.00	21093.70	69205.00
46.50	-60.50	-9999.00	104.32	9.52	21160.02	69423.00
44.70	-62.50	-9999.00	83.38	7.71	21404.60	70225.00
44.00	-62.13	-9999.00	75.00	6.99	21502.76	70547.00
43.00	-61.60	-9999.00	85.00	13.00	21645.72	71016.00
41.00	-60.49	-9999.00	55.00	10.99	21941.91	71988.00
39.00	-59.32	-9999.00	80.00	12.00	22252.91	73008.00
38.30	-58.90	-9999.00	67.96	12.00	22365.54	73378.00
37.00	-58.73	-9999.00	45.00	12.00	22582.41	74089.00
36.00	-58.59	-9999.00	60.00	6.99	22754.48	74654.00
35.00	-58.45	-9999.00	130.00	8.00	22931.40	75234.00
34.00	-58.30	-9999.00	-9999.00	-9999.00	23113.45	75832.00

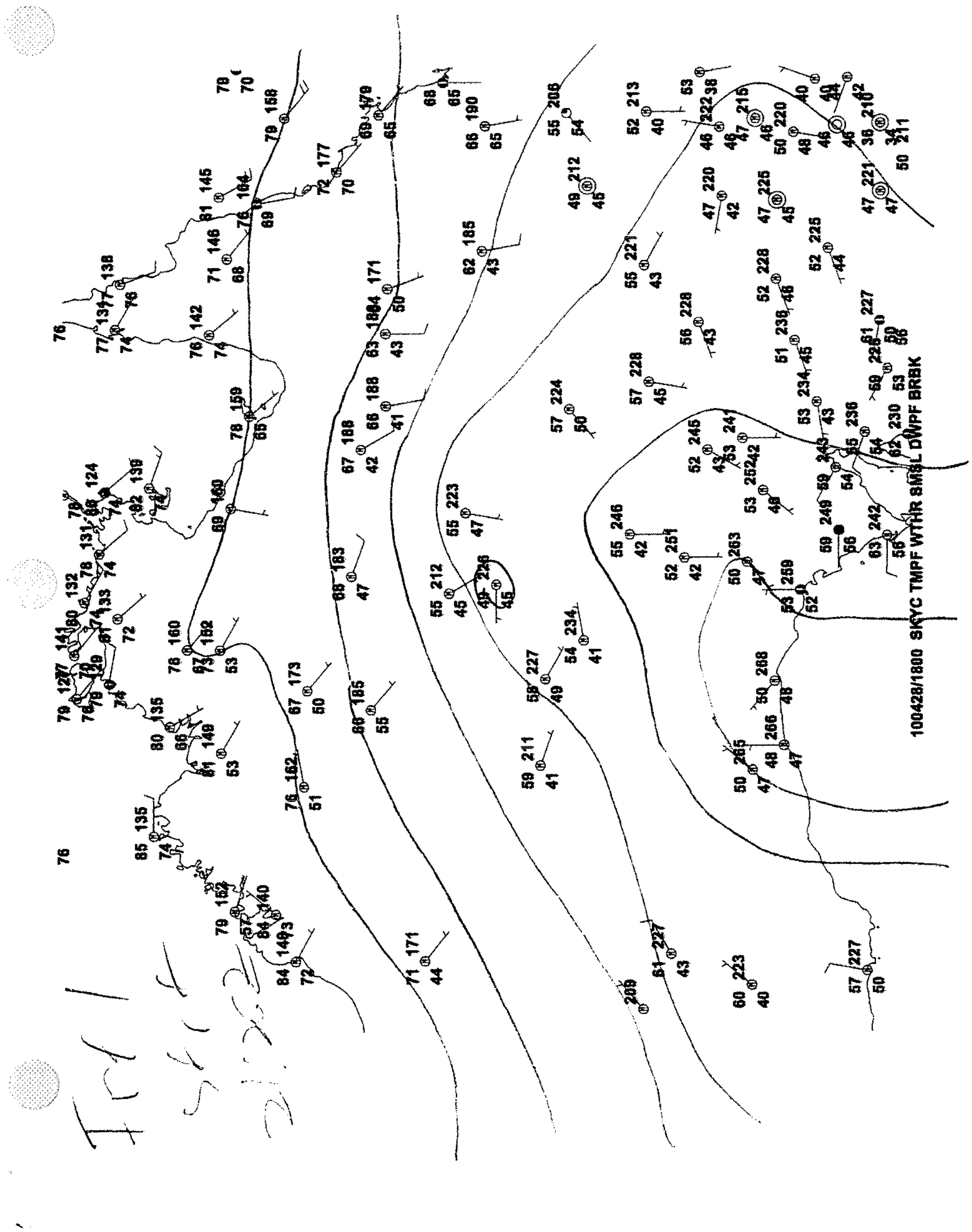
SNPARM = PRES;TMPC;DWPC;DRCT;SKNT;HGHT;HGFT

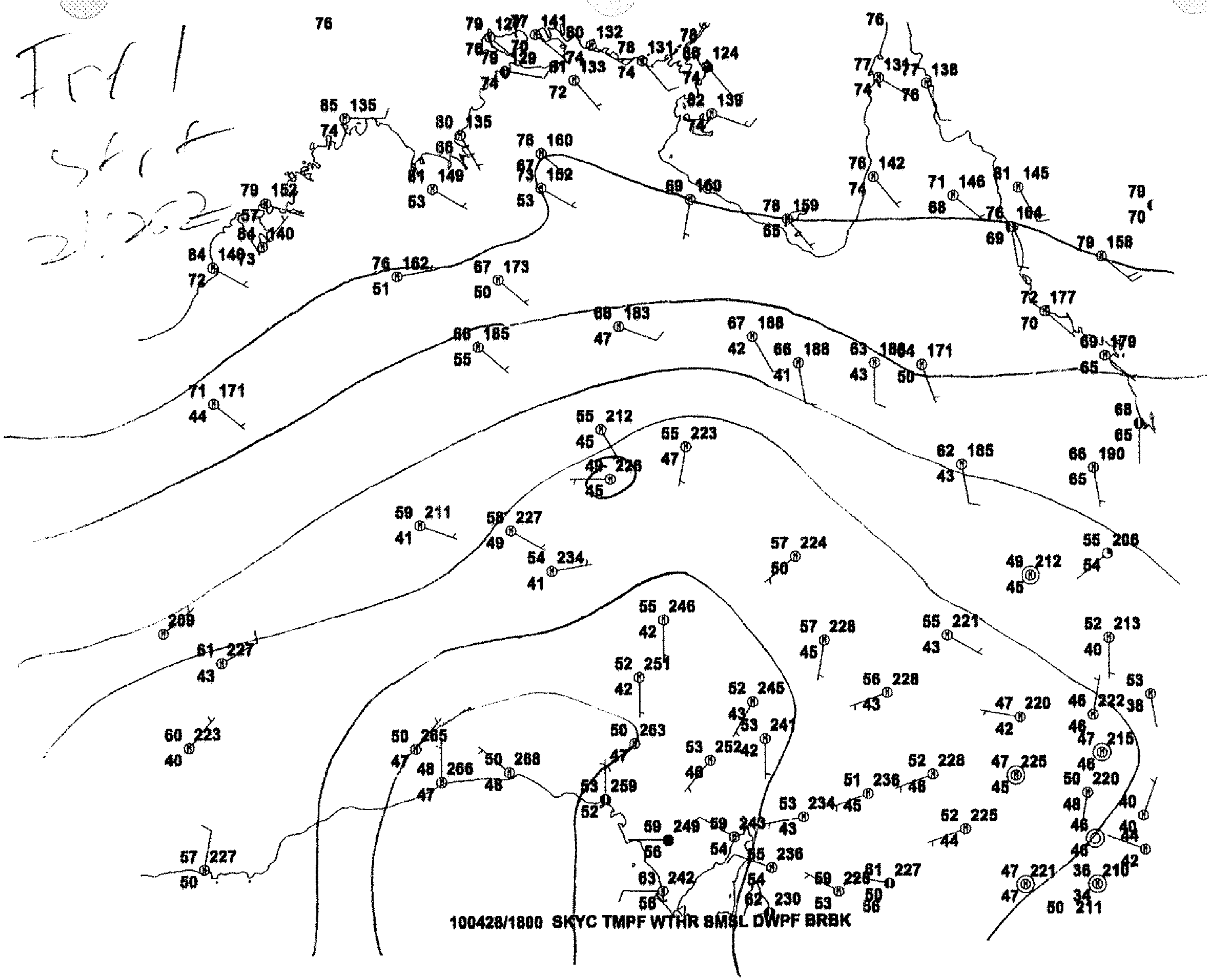
STID = YBAS STNM = 94326 TIME = 100429/0000
SLAT = -23.80 SLON = 133.88 SELV = 546.0
STIM = 2300

PRES	TMPC	DWPC	DRCT	SKNT	HGHT	HGFT
962.00	14.80	8.80	0.00	0.00	546.00	1791.00
1000.00	-9999.00	-9999.00	-9999.00	-9999.00	214.00	702.00
954.00	13.80	7.80	25.55	2.98	616.24	2022.00
940.00	15.00	7.00	70.78	8.26	740.61	2430.00
925.00	14.20	6.20	120.00	14.01	876.00	2874.00
914.00	13.41	5.96	120.00	14.01	976.16	3203.00
863.00	9.60	4.80	130.00	17.00	1456.85	4780.00
855.00	9.60	3.60	133.07	16.39	1534.17	5033.00
850.00	11.60	-4.40	135.00	16.01	1583.00	5194.00
847.00	12.60	-16.40	135.45	15.47	1612.59	5291.00
840.00	14.00	-23.00	136.49	14.21	1682.27	5519.00
824.00	14.20	-21.80	138.92	11.30	1844.19	6050.00
817.00	13.95	-23.29	140.00	10.00	1915.83	6286.00
780.00	12.60	-31.40	154.99	7.90	2305.04	7562.00
709.00	6.80	-22.20	185.87	3.57	3096.19	10158.00
700.00	6.60	-19.40	190.00	2.99	3201.00	10502.00
629.00	3.20	-33.80	334.05	0.46	4072.28	13361.00
617.00	2.26	-35.15	0.00	0.00	4226.25	13866.00
546.00	-3.70	-43.70	308.99	7.85	5203.43	17072.00
528.00	-6.06	-44.16	295.00	10.00	5464.94	17930.00
508.00	-8.78	-44.68	300.00	10.00	5766.17	18918.00
500.00	-9.90	-44.90	280.00	10.99	5890.00	19324.00
495.00	-10.45	-44.35	270.00	12.00	5967.10	19577.00
491.00	-10.90	-43.90	270.55	12.00	6029.34	19781.00
460.00	-13.92	-51.06	275.00	12.00	6521.04	21394.00
435.00	-16.50	-57.20	230.00	15.00	6942.35	22777.00
413.00	-18.90	-62.90	217.25	18.19	7333.64	24060.00
401.00	-20.93	-64.01	210.00	20.01	7551.55	24775.00
400.00	-21.10	-64.10	210.00	20.01	7570.00	24836.00
362.00	-27.07	-64.17	215.00	16.01	8281.31	27170.00
346.00	-29.77	-64.20	235.00	18.01	8603.44	28227.00
300.00	-38.30	-64.30	230.00	19.00	9620.00	31562.00
293.00	-39.90	-65.90	234.48	20.79	9781.93	32093.00
270.00	-43.61	-68.58	250.00	27.00	10332.08	33898.00
250.00	-47.10	-71.10	240.00	23.00	10850.00	35597.00
248.00	-47.34	-71.31	240.00	22.01	10902.19	35768.00
226.00	-50.18	-73.72	255.00	27.00	11505.82	37749.00
200.00	-53.90	-76.90	240.00	31.99	12300.00	40354.00
185.00	-57.30	-78.30	231.06	37.81	12798.51	41990.00
168.00	-58.61	-82.33	220.00	45.01	13406.64	43985.00
155.00	-59.70	-85.70	220.00	39.32	13914.77	45652.00
150.00	-60.70	-9999.00	220.00	37.00	14120.00	46325.00
119.00	-67.89	-9999.00	215.00	27.99	15518.90	50915.00
100.00	-73.30	-9999.00	230.00	21.00	16570.00	54364.00
97.30	-73.90	-9999.00	225.00	24.01	16729.10	54885.00
82.00	-71.30	-9999.00	190.00	16.01	17730.48	58171.00
78.00	-70.54	-9999.00	125.00	10.00	18023.21	59131.00
77.80	-70.50	-9999.00	123.23	10.00	18038.23	59181.00

71.00	-71.54	-9999.00	60.00	10.00	18576.52	60947.00
70.00	-71.70	-9999.00	55.00	8.00	18660.00	61220.00
68.70	-72.10	-9999.00	9.73	4.76	18770.71	61584.00
68.00	-70.19	-9999.00	345.00	2.99	18831.80	61784.00
67.10	-67.70	-9999.00	318.42	5.06	18911.27	62045.00
65.00	-68.30	-9999.00	255.00	10.00	19102.70	62673.00
61.90	-64.50	-9999.00	232.29	13.03	19399.19	63646.00
59.00	-65.14	-9999.00	210.00	16.01	19691.59	64605.00
55.00	-66.08	-9999.00	150.00	13.00	20119.39	66009.00
53.30	-66.50	-9999.00	140.12	11.68	20310.72	66636.00
50.00	-64.70	-9999.00	120.00	8.99	20700.00	67913.00
41.00	-59.17	-9999.00	75.00	12.00	21927.14	71939.00
40.90	-59.10	-9999.00	72.80	11.96	21942.24	71989.00
39.00	-58.97	-9999.00	30.00	10.99	22240.56	72968.00
37.00	-58.82	-9999.00	80.00	10.00	22570.71	74051.00
35.50	-58.70	-9999.00	-9999.00	-9999.00	22830.25	74902.00

L-7 Surface Observations




100428/1800 SKYC TMPF WTHR SMSL DWPF BRBK

APPENDIX M: Quest for Quotation

M-1 – Request for Quotation

M-2 – Crane Selection Process

M-3 – Purchase Order

BALLOON LAUNCHING STATION – ALICE SPRINGS AIRPORT
UNIVERSITY OF NEW SOUTH WALES

CRANE HIRE FOR BALLOON LAUNCHING STATION, ALICE SPRINGS

REQUEST FOR QUOTATION

Description:

The University of New South Wales is seeking to hire a crane for the purpose of launching a series of stratospheric balloon flights carrying scientific instruments, from the Balloon Launching Station, Alice Springs Airport. The balloon launch is a specialised procedure requiring the involvement of a highly trained professional team, one of whom will drive the crane during the launch process. The launches are carried out from the secured area of Alice Springs airport runway 17/35. Up to eight balloon flights will take place between approximately mid-March and end of May 2010. The maximum suspended payload for any flight will be 3.5 tonnes. Because of stringent weather condition requirement, several attempts are sometimes necessary before a successful launch is achieved. Because of the sporadic nature of balloon launches, it is envisaged that the crane will be operated only for short periods. However, it will be required to be on-site for the whole duration of the hire period. The launch area is 600 metres away from the Balloon Launching Station. The picture below shows a DEMAG AC265J crane used in a previous launch from Alice Springs airport.

It will be necessary to fit two pieces of hardware (a) a pair of stabiliser bars, and (b) a launch head unit, to the hired crane to modify it for the launch process. These pieces of hardware were previously constructed to be fitted to a DEMAG AC265J crane without the need for welding or bolting into the chassis of the hired crane. These pieces of hardware will be supplied by the University of NSW, and the fitting will be carried out at the Balloon Launching Station. However, if the existing units do not fit the hired crane, they will be altered or new ones will be fabricated on site. They are described below:

1. **Stabiliser bars:** The hired crane will be fitted with two stabiliser bars with swivel wheels, one bar on each side and parallel to the crane body. A stabiliser bar is shown in the picture below.

The stabiliser bar is designed so that it can be clamped to the outriggers of the hired crane as shown in the pictures below. The existing stabiliser bars were fabricated for outriggers of cross-section dimensions as follows:

- **Front outrigger** 225 mm wide, 450 mm high, 950 mm distance from top of outrigger to ground;
- **Rear outrigger** 250 mm wide, 600 mm high, 1250 mm distance from top of outrigger to ground. Distance between mid-points of front and rear outrigger: 8520 mm.

2. **Launch head unit**: A specially designed launch head unit is fitted to the end of the boom of the crane. It is designed to be pinned to the crane head using the existing pins and pin holes used for the light boom extension. It has a launch pin at the end pointing away from the crane boom, from which the scientific payload is suspended. It also has a release arm mechanism to release the payload from the launch heat unit at launch. The complete unit is shown (on its side) in the pictures below.

The launch head unit is shown in the pictures below in the orientation in which it will be mounted on the boom of the hired crane (left hand picture looking along the boom towards the crane cab, right hand picture looking towards the end of the crane boom).

The stabiliser bars and the launch head unit will be available for inspection at the Balloon Launching Station as per the schedule given below.

Crane vehicle Specifications:

- The crane vehicle must be in very good mechanical condition, and must have good acceleration.
- Vehicle wheelbase length from front axle to rear axle: 6130 mm minimum
- Total vehicle weight: 50 tonnes minimum
- Crane lifting capability: 59 tonnes
- Crane boom: The boom must extend out at least 3.2 metres from the front of the vehicle when at a height of 12.2 metres from the ground
- Period of hire: 1 March 2010 to 15 May 2010, with the option of an extension of hire to 15 June 2010, and of early termination of contract in the event of early completion of the campaign.

- Crane/vehicle operation: A crane/vehicle operator will not be required. The crane will be operated and driven by suitably qualified NASA personnel.
- Amount of anticipated usage: A total crane operation time of 150 hours is anticipated for the hire period, with an average usage of 1.5 hours a day.

Payment terms:

Payment will be made on the submission of fortnightly invoices.

Selection criteria:

Criterion no.	Description	Weighting
1.	Total cost of hire, including delivery to and pickup from site, and options for extending the hire period or for early termination of hire contract	60%
2.	Crane/vehicle technical details, including acceleration and capability	10%
3.	Crane/vehicle history (age, past use, service history)	10%
4.	Maintenance requirements and availability of local technical support in Alice Springs during the hire period.	10%
5.	Ability to use existing stabiliser bars and launch head unit without modification	10%

Quotation Process Schedule:

DATE	ACTIVITY
26 Oct 09	Issue of limited Request for Quotation
9 Nov 09	Meeting from 9.00 a.m. to 10.00 a.m. at the Balloon Launching Station, Alice Springs for questions and any further required clarification, with the opportunity to inspect the stabiliser bars and launch head unit on-site.
20 Nov 09	Deadline for Quotation to be received at UNSW@ADFA
27 Nov 09	Award of contract to successful vendor

Address for site of balloon operations and for delivery of crane:

Balloon Launching Station
Off Maryvale Road
Alice Springs Airport
Alice Springs NT 0870
Phone: 08 8952 6315
Fax: 08 8955 5007

Contact for further information and for delivery of your quotation:

Associate Professor Ravi Sood
Station Director, Balloon Launching Station
School of PEMS
UNSW@ADFA
Northcott Drive
Canberra ACT 2600

Phone: 02 6268 8765
Fax: 02 6268 8786
Mobile: 0420 278 508
Email: r.sood@adfa.edu.au (preferred mode of contact)

R. Sood
26 October 2009

MEMORANDUM

TO: MARK VAN POPPEL
MANAGER, FINANCIAL SERVICES
UNSW@ADFA

FROM: RAVI SOOD
SCHOOL OF PEMS

SUBJECT: **HIRE OF LAUNCH CRANE FOR BALLOON LAUNCHES**

27 NOVEMBER 2009

Five companies (see Attachment A) were each invited to quote for the supply of a crane to carry out a series of eight balloon launches from the Balloon Launching Station, Alice Springs during the NASA/CSBF campaign which will take place from Feb to May 10. The specifications, selection criteria and the timetable that were sent out to each company are shown in Attachment B.

Two quotes were received by the deadline of 22 November 09. These were assessed by the selection committee which consisted of the following:

1. Ravi Sood (UNSW@ADFA)
2. Erich Klein (CSBF)
3. Frank Candelaria (CSBF)
4. Jim Rotter (CSBF)
5. Danny Ball (CSBF).

The selection process included a one hour long teleconference on 25 Nov 09. A summary of the submissions is shown as Attachment C.

The DEMAG AC100/4 crane proposed by Tasmanian Heavy Lift was **rejected** due to its insufficient wheel base length (5791 mm vs. 6130 mm minimum specified length)

The LTM 1080/1 proposed by Wanna Lift Crane Hire was **rejected** due to its insufficient wheel base length (5700 mm vs. 6130 mm minimum specified length)

The LTM 1100/2 proposed by Wanna Lift Crane Hire was **accepted** because the crane meets all the requirements for wheel base length, gross vehicle weight and acceleration performance.

I would appreciate it if a Purchase Order could be raised to Wanna Lift Crane Hire as per the attached Request for Purchase Order. Insurance cover for the hire will be provided by CSBF and a copy will be submitted to your office prior to the commencement of the hire period. We will need to wait for the crane details from the supplier before the insurance cover is established.

Thank you for your assistance in this matter.

ATTACHMENT A

CRANE HIRE AT THE BALLOON LAUNCHING STATION, ALICE SPRINGS

A. COMPANIES THAT HAVE EXPRESSED AN INTEREST IN BIDDING:

National Crane Hire / McAleese Transport[1]
P: 08 8347 4322 08 8347 4602
M: 0418 600 450
19 Opala St, Regency Pk, SA, 5010
Ron Holman [Ron.Holman@mcaleese.com.au]

Wanna Lift? Crane Hire
Russell Dehne Enterprise
19 Price St, Alice Springs NT 0870
(08) 8953 5900; 0418 899 916
rdehne@bigpond.net.au

Freo Cranes
1 Mandurah Road
Kwinana WA 6167
NW Area Manager
Ben Pieyre; 08 9419 5444
ben.pieyre@freomachinary.com.au

B. OTHER COMPANIES IN ALICE SPRINGS THAT HAVE THE CAPABILITY OF RESPONDING TO OUR REQUEST FOR QUOTE/TENDER

Sitzler Bros[2]
52 Smith Street
Alice Springs NT 0870
Tel: +61 8 8952 1855
Email: admin@sitzlerbros.com.au
Managing Director: Michael Sitzler
General Manager: Trevor Jacobs

C. OTHER COMPANIES IN ALICE SPRINGS THAT MAY HAVE THE CAPABILITY OF RESPONDING TO OUR REQUEST FOR QUOTE/TENDER

R & D NT Crane Hire
4 Goyder St
Alice Springs NT 0870
0402 336 516; 08 8953 1907

Ross Engineering[3]
46 Elder St Alice Springs NT 0870
Ph: (08) 8952 1132
Neil Ross [neil.ross@rossengineering.com.au]

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[1] This company supplied the crane previously
[2] This company was an unsuccessful bidder for Project 2008/4962
[3] This company won the contract for Project 2008/4962

ATTACHMENT B

BALLOON LAUNCHING STATION – ALICE SPRINGS AIRPORT
UNIVERSITY OF NEW SOUTH WALES

CRANE HIRE FOR BALLOON LAUNCHING STATION, ALICE SPRINGS

REQUEST FOR QUOTATION

Description:

The University of New South Wales is seeking to hire a crane for the purpose of launching a series of stratospheric balloon flights carrying scientific instruments, from the Balloon Launching Station, Alice Springs Airport. The balloon launch is a specialised procedure requiring the involvement of a highly trained professional team, one of whom will drive the crane during the launch process. The launches are carried out from the secured area of Alice Springs airport runway 17/35. Up to eight balloon flights will take place between approximately mid-March and end of May 2010. The maximum suspended payload for any flight will be 3.5 tonnes. Because of stringent weather condition requirement, several attempts are sometimes necessary before a successful launch is achieved. Because of the sporadic nature of balloon launches, it is envisaged that the crane will be operated only for short periods. However, it will be required to be on-site for the whole duration of the hire period. The launch area is 600 metres away from the Balloon Launching Station. The picture below shows a DEMAG AC265J crane used in a previous launch from Alice Springs airport.

It will be necessary to fit two pieces of hardware (a) a pair of stabiliser bars, and (b) a launch head unit, to the hired crane to modify it for the launch process. These pieces of hardware were previously constructed to be fitted to a DEMAG AC265J crane without the need for welding or bolting into the chassis of the hired crane. These pieces of hardware will be supplied by the University of NSW, and the fitting will be carried out at the Balloon Launching Station. However, if the existing units do not fit the hired crane, they will be altered or new ones will be fabricated on site. They are described below:

1. **Stabiliser bars:** The hired crane will be fitted with two stabiliser bars with swivel wheels, one bar on each side and parallel to the crane body. A stabiliser bar is shown in the picture below.

The stabiliser bar is designed so that it can be clamped to the outriggers of the hired crane as shown in the pictures below. The existing stabiliser bars were fabricated for outriggers of cross-section dimensions as follows:

- **Front outrigger** 225 mm wide, 450 mm high, 950 mm distance from top of outrigger to ground;
- **Rear outrigger** 250 mm wide, 600 mm high, 1250 mm distance from top of outrigger to ground. Distance between mid-points of front and rear outrigger: 8520 mm.




2. **Launch head unit**: A specially designed launch head unit is fitted to the end of the boom of the crane. It is designed to be pinned to the crane head using the existing pins and pin holes used for the light boom extension. It has a launch pin at the end pointing away from the crane boom, from which the scientific payload is suspended. It also has a release arm mechanism to release the payload from the launch heat unit at launch. The complete unit is shown (on its side) in the pictures below.

The launch head unit is shown in the pictures below in the orientation in which it will be mounted on the boom of the hired crane (left hand picture looking along the boom towards the crane cab, right hand picture looking towards the end of the crane boom).

The stabiliser bars and the launch head unit will be available for inspection at the Balloon Launching Station as per the schedule given below.

<u>Crane vehicle Specifications:</u>

- The crane vehicle must be in very good mechanical condition, and must have good acceleration.
- Vehicle wheelbase length from front axle to rear axle: 6130 mm minimum
- Total vehicle weight: 50 tonnes minimum
- Crane lifting capability: 59 tonnes
- Crane boom: The boom must extend out at least 3.2 metres from the front of the vehicle when at a height of 12.2 metres from the ground
- Period of hire: 1 March 2010 to 15 May 2010, with the option of an extension of hire to 15 June 2010, and of early termination of contract in the event of early completion of the campaign.

- Crane/vehicle operation: A crane/vehicle operator will not be required. The crane will be operated and driven by suitably qualified NASA personnel.
- Amount of anticipated usage: A total crane operation time of 150 hours is anticipated for the hire period, with an average usage of 1.5 hours a day.

Payment terms:

Payment will be made on the submission of fortnightly invoices.

Selection criteria:

Criterion no.	Description	Weighting
1.	Total cost of hire, including delivery to and pickup from site, and options for extending the hire period or for early termination of hire contract	60%
2.	Crane/vehicle technical details, including acceleration and capability	10%
3.	Crane/vehicle history (age, past use, service history)	10%
4.	Maintenance requirements and availability of local technical support in Alice Springs during the hire period.	10%
5.	Ability to use existing stabiliser bars and launch head unit without modification	10%

Quotation Process Schedule:

DATE	ACTIVITY
26 Oct 09	Issue of limited Request for Quotation
9 Nov 09	Meeting from 9.00 a.m. to 10.00 a.m. at the Balloon Launching Station, Alice Springs for questions and any further required clarification, with the opportunity to inspect the stabiliser bars and launch head unit on-site.
20 Nov 09	Deadline for Quotation to be received at UNSW@ADFA
27 Nov 09	Award of contract to successful vendor

Address for site of balloon operations and for delivery of crane:

Balloon Launching Station
Off Maryvale Road
Alice Springs Airport
Alice Springs NT 0870
Phone: 08 8952 6315
Fax: 08 8955 5007

Contact for further information and for delivery of your quotation:

Associate Professor Ravi Sood
Station Director, Balloon Launching Station
School of PEMS
UNSW@ADFA
Northcott Drive
Canberra ACT 2600

Phone: 02 6268 8765
Fax: 02 6268 8786
Mobile: 0420 278 508
Email: r.sood@adfa.edu.au (preferred mode of contact)

R. Sood
26 October 2009

ATTACHMENT C

SUMMARY OF CRANES OFFERED BY VENDORS

Tasmanian Heavy Lifts Pty Ltd: DEMAG AC100

- Wheel base: 5740 mm compared to 6130 mm minimum requirement
- Vehicle weight: 48 tonnes min (12 tonnes per axle); can be loaded to 72 tonnes
- Cost: $2143 per day
- Mob/demob cost: $36,000
- History of crane: Date of manufacture ranges from 2001 to 2006. Three cranes available.
- Service and Maintenance : Not included (extra if needed)
- Minimum crane hire period: Hire duration quoted 1 Mar to 15 May, i.e. 76 days. Therefore minimum cost will be $198,868, plus service costs, plus insurance
- Extension of hire period: not addressed.

Wanna Lift Crane Hire Liebherr LTM1100/2

- Wheel base: 7240 mm compared to minimum 6130 mm
- Vehicle weight: 60 tonnes minimum, 12 tonnes per axle, can be loaded to > 70 tonnes
- Cost: $2200 per day
- Mob/demob cost: $60,000
- History of crane: Average age of 4 years, hired from Melbourne
- Maintenance: day to day check-up included. Service not required during hire period
- Minimum hire: 8 weeks. Therefore, minimum cost for 8 weeks (56 days) would be $183,200. Comparative cost for 76 days would be $227,200.

Wanna Lift Crane Hire Liebherr LTM1080/1

- Wheel base: 5700 mm compared to minimum required 6130 mm
- Vehicle weight: 48 tonnes (12 tonnes per axle), can be loaded to > 55 tonnes
- Cost: $2000/day
- Mob/demob costs: $48,000
- History of crane: Average age of 4 years, hired from Melbourne
- Maintenance: day to day check-up included. Service not required during hire period
- Minimum hire: 8 weeks. Therefore, minimum cost for 8 weeks (56 days) would be $160,000. Comparative cost for 76 days would be $200,000.

M-3 – Purchase Order

27-Nov-09 Rev. 4

University of New South Wales @ Australian Defence Force Academy
ABN: 57 195 873 179

Date 27 Nov 09
PO # ________ **Online App**________
Technical enquiries: R. Sood

Ref: Number ________
Voucher # ________
Phone: +61 2 6268 8765
Fax: +61 2 6268 8786

Attention: Russell Dehne
Company: Wanna Lift? Crane Hire
Address: 19 Price Street
Alice Springs NT 0870
P O Box 7801
Alice Springs NT 0871

Fax Number: **08 8953 2372**
Phone Number: 08 8953 5900
Vendor No:

DELIVERY INSTRUCTIONS
Please include our reference number and mark to the attention of:
Deliver to Balloon Launching Station, Alice Springs on 1 Mar 2010

C/O MAIN STORE
University of New South Wales at
Australian Defence Force Academy
Northcott Drive, Campbell. ACT 2600 Australia

Item.	Please Supply the Following Description	Unit of Measure	Qty	Unit Cost (excl. GST)	Total Cost (excl. GST)	GST Amount	Purchase Total (Incl. GST)
1	Liebherr LTM 1100/2 Mobile Crane with total weight reduced to 50 tonnes. Crane to be delivered on 1 March 2010. Hire for a period of eight weeks, with an option to extend for upto a further four weeks. Delivery address: BALLOON LAUNCHING STATION OFF MARYVALE ROAD, ALICE SPIRNGS AIRPORT Contact: R. Sood; 08 8952 6315; 0420 278 508			183,200.00:	183,200.00:	18,320.00	201,520.00
				:	:	:	:
				:	:	:	:
				:	:	:	:
				:	:	:	:
				:	:	:	:
				:	:	:	:
				:	:	:	:
				:	:	:	:
				:	:	:	:
Comments:				Totals (AUD $)	183,200.00:	18,320.00	201,520.00

Please Send Tax Invoice to Cardholder

Address for tax invoice:
School of PEMS
University of New South Wales
Australian Defence Force Academy

Method of Payment: Westpac Visa Purchasing Card

Cardholder: ________________ Phone No.: + 61 2 6268 ______

27-Nov-09 Rev. 4
CANBERRA ACT 2600

Card Number: ________________ Expires: ____/____ Signature: ________________

27-Nov-09 Rev. 4

Requested By: R. Sood   Date Requested: 27 Nov 09   Room number: 110 Phone Extn: 88765

Job Number: ____________   Budget No: ____________   Supervisors signature: ____________

Availability: Ex Stock______Days/Weeks   Delivery Date: 1 Mar 2010   Are Material Safety Data Sheets Required YES ☐ NO ☒ ____________ (signature required)

QUOTATIONS (PER PURCHASING GUIDELINES)			If quotation procedures haven't been met per UNSW Accounting Manual Section 11.2.4 please tick reason(s)
Supplier	Price	Date	☐ Sole Supplier
1.See attached Memo.			☐ Goods Under Contract
2.			☐ Service Agreement
3.			☐ Match Existing Product/Equipment
Other			☐ Other (please explain)

Brief justification for purchase when quotation procedures haven't been met:

Item	Business Unit	Account Code	Fund Source	Dept ID	Program	Class	Budget Yr.	Project/Grant	
1	UNSWA		RE949	Z7001	0 0 0 0	0 0	2009	RM01538	
2					0 0 0 0	0 0			
3					0 0 0 0	0 0			
4					0 0 0 0	0 0			
5					0 0 0 0	0 0			
6					0 0 0 0	0 0			
7					0 0 0 0	0 0			
8					0 0 0 0	0 0			
9					0 0 0 0	0 0			
10					0 0 0 0	0 0			

Comments:

FUNDING APPROVAL This request approved and declared free of any conflict of interest (as defined in the UNSW Staff Code of Conduct and quotation requirements have been met:	**Asset**: YES ☐ NO ☒	**Location**:
	Build in to existing asset:	**Disposal of asset**:
Delegates Signature:	Location:	Asset Description
Surname (Print):	Tag #	Serial #
Date:	Comments:	Tag # NB: Asset Disposal form to be lodged

FUNDING: Tick one box only

☐ Central ☐ Admin ☐ Education ☒ Research ☐ Other

Name: R. Sood

Appendix N: Evidence Listing

ITEM	LOCATION	ACTION	DATE	Reason
TM GSE CONFIGURED FOR NCT	OLD PAYLOAD BUILDING	Released		Video shows functional/DBR
MINI-SIP WORKSTATION	OLD PAYLOAD BUILDING	Released		Video shows functional
85' BI-FILAR FLIGHT CABLE LADDER (STEEL)	NEW PAYLOAD BUILDING	Released		Video shows functional
TRUCK PLATE ASSEMLBY W/PARTIAL SAFETY CABLE	NEW PAYLOAD BUILDING	Send to Goddard		
SAFETY CABLE PEAR RING AND CABLE REMNANTS	LAUNCH CRANE HEAD	Send to Goddard		
LAUNCH CRANE W/SAFETY CABLE PEAR RING ATTAC	SECURE YARD AS BLS	Send to Goddard		
TRI-PLATE (ATTACHMENT TO SCI ROTATOR)	NEW PAYLOAD BUILDING	Released		
BALLOON COLLAR AND RECEIVER	NEW PAYLOAD BUILDING	Released		
120 PARACHUTE (INTACT)	NEW PAYLOAD BUILDING	Released		
REMOTE FIRING UNIT UTP)	PARACHUTE TOP	Released		Video shows functional
MINI-SIP (SUPPORT INSTRUMENT PACKAGE)	NEW PAYLOAD BUILDING	Released		Video shows functional
UNIVERSAL TERMINATE PACKAGE (UTP)	NEW PAYLOAD BUILDING	Released		Video shows functional
PARACHUTE CUTAWAY MECHANISM	NEW PAYLOAD BUILDING	Released		Video shows functional
GONDOLA AUTOMATIC PARACHUTE RELEASE (GAPR)	NEW PAYLOAD BUILDING	Released		
EXTERNAL CABLING (UTP/MINI SIP/CIP/PARACHUTE	NEW PAYLOAD BUILDING	Released		
VIDEO DATA TRANSMITTER (CSBF)	NEW PAYLOAD BUILDING	Released		
SCIENCE DATA TRANSMITTER (CSBF)	NEW PAYLOAD BUILDING	Released		
CONSOLIDATED INSTRUMENT PACKAGE (CIP)	NEW PAYLOAD BUILDING	Released		
ACCELOROMETER (TOP PAYLOAD MOUNTED)	NEW PAYLOAD BUILDING	Find data		
BATTERIES: UTP/M-SIP/CIP	NEW PAYLOAD BUILDING	Determine damage		
PV PANELS (2EA) PIGGYBACK FOR MPT CHG. CONT.	NEW PAYLOAD BUILDING	Released		
3 HELIUM TUBE RACK UNITS W/HEISE GAUGES	SECURE YARD AS BLS	Released		Readings verified
NCT INSTRUMENT COMPONENTS	SEA CONTAINER AS BLS	Released		
NCT GONDOLA REMNANTS	NEW PAYLOAD BUILDING	Released		
DOCUMENT - DAVIS WX SURF. OBS.	WX FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - SURFACE CHARTS	WX FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - PIBAL READINGS (1-4)	WX FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - WX FORECAST & METEOROLOGIST OBS	WX FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - (MECHANICAL) RIGGING RECORDS	OPERATIONS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - RECOVERY INSTRUCTIONS	OPERATIONS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - RECOVERY FORM	OPERATIONS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - ADD'L RIGGING DATA	OPERATIONS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - POST FLIGHT HELIUM TRAILER MEASUI	OPERATIONS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - POST FLIGHT GAGES & SCALES CHECK	OPERATIONS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - 01 CIP PACKING LIST & COMPAT CHEC	ELECTRONICS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - 02 ELECTRONICS PRE-FLIGHT CHECK L	ELECTRONICS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - 03 TM GSE CONFIGURATION SHEET	ELECTRONICS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - 04 FLIGHT LINE CHECKLIST	ELECTRONICS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - 05 UTP PACKING / CHECK LIST	ELECTRONICS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - 06 UTP/GAPR PRE-FLIGHT CHECK LIST	ELECTRONICS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - 07 UTP/RFU ENVIRONMENTAL RECORD	ELECTRONICS FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - REVISED FLIGHT PLAN	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - PRE-FLIGHT MINIMUM SUCCESS	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - LOAD ALTITUDE CURVE	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - GONDOLA CERTIFICATION	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - FLIGHT REQUIREMENTS	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - ELECTRONIC CERTIFICATION	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - RISK ANALYSIS REVIEW	CAMPAGIN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - BALLOON SPECIFICATION (AEROSTAR)	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - LAUNCH EQP. CONFIG. CERT. (LECC)	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - QUICK LOOK REPORT - POST ABORT	CAMPAIGN MANAGER FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - AUSTRALIA CONTACT / WITNESS LIST	BPO FILES FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - GROUND SAFETY PLAN	BPO FILES FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - PROCEDURES, ELECTRONICS FAILURE	BPO FILES FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - KEY PERSONNEL LIST	BPO FILES FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - BALLOON MISHAP APPOINTMENT MEMO	BPO FILES FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - NCT MISSION PROJECT PLAN	BPO FILES FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - NCT QUICK LOOK REPORT (POST ABOR	BPO FILES FOLDER	Send to Goddard	5/15/2010	
DOCUMENT - FLIGHT APPLICATION, NCT	BPO FILES FOLDER	Send to Goddard	5/15/2010	
VIDEO DOCUMENT - ALL AVAILABLE VIDEO FILES	VIDEO FOLDER	Send to Goddard	5/15/2010	
STILL PHOTOS - ALL AVAILABLE PHOTOGRAPH FILES	PICTURES FOLDER	Send to Goddard	5/15/2010	
WITNESS STATEMENTS (UP TO 5/7/10)	SECURE FOLDER	Send to Goddard	5/15/2010	

Appendix O: Export Control Evaluation

Export Control Review

August 26, 2010

Columbia Scientific Balloon Facility
1510 E FM 3224, Palestine, Texas 75803, 903-729-0271

The Columbia Scientific Balloon Facility (CSBF), located in Palestine, Texas, is a NASA facility managed by the Physical Science Lab of New Mexico State University. The contract to manage the facility is administered by the Balloon Program Office at Wallops Flight Facility of Goddard Space Flight Center (GSFC).

CSBF provides the services of launching large (400 ft. diameter), unmanned, high altitude (120,000 ft.), research balloons; tracking, and recovering the scientific experiments suspended beneath them, for NASA centers and universities from all over the world. Scientists use scientific data collected during balloon flights to help answer important questions about the universe, atmosphere, the Sun and the space environment. Questions such as "How did the universe, galaxies, stars, and planets form and evolve?" and "Are there Earth-like planets beyond our solar system?" are being answered by NASA with the help of experiments flown on these scientific balloons.

Standard NASA scientific balloons are constructed of polyethylene film; the same type material used for plastic bags. This material is only 0.002 centimeters (0.0008 inches) thick, about the same as an ordinary sandwich wrap. The film is cut into banana-peel shaped sections called gores and heat sealed together to form the balloon. Up to 180 gores are used to make NASA's largest balloons. These standard, zero-pressure, balloons are open to the atmosphere at the bottom to equalize the internal pressure with the surroundings. The balloon system includes the balloon, the parachute and a payload that holds instruments to conduct scientific measurements.

Helium, the same gas used to fill party balloons, is used in NASA balloons. These very large balloons can carry a payload weighing as much as 3,600 kilograms (8,000 pounds), about the weight of three small cars. They can fly up to 42 kilometers (26 miles) high and stay there for up to two weeks. The balloon is launched by partially filling it with helium and launched with the payload section suspended beneath it. As the balloon rises, the helium expands, filling the balloon until it reaches float altitude in two to three hours.

The CSBF contracted with the University of New South Wales to operate the Alice Springs Balloon Launching Centre at the Alice Springs International Airport. The balloon launch campaign in question was conducted in April 2010. The payload for the launch attempt on April 29th, 2010 was the Nuclear Compton Telescope (NCT). The NCT is a balloon-borne soft gamma-ray (0.2-15 MeV) telescope designed to study astrophysical sources of nuclear line emission and gamma-ray polarization. The NCT Program was sponsored by NASA and by

NSPO of Taiwan in collaboration with the Space Science Laboratory of University of California (UC) Berkeley.

Analysis

These scientific balloons are expansive balloons filled with helium and are not listed under the ITAR (Category VIII) or under any specific ECCN on the CCL; they are therefore classified as EAR 99. They are commercially available products. The NASA Sounding Rocket Program contracts with the Columbia Scientific Balloon Facility (CSBF) in Texas, which purchases these balloons for NASA. CSBF manages the balloon launching operations and contracted with the University of New South Wales (NSW) in Australia for the launch operations for the Nuclear Compton Telescope (NCT). NSW manages the balloon launch facility in Australia and provided the commercially available crane that was used for this balloon launch. The interface between the balloon, the payload, and the crane was provided by the CSBF. The payload was provided by the University of California at Berkley under a NASA Grant. The Grant stipulated no pre-review requirements and encourages the public distribution of the science from these missions, without controls. The payload was developed with international students and extensive information concerning the payload has been published in the open literature. The balloon launch operations are conducted in an open forum and the public is able to photograph these operations. In fact, a documentary on the balloon launch operations that shows the details of the launch operations was shown in 2006/2007 on the Discovery Channel.

Summary

These balloons are commercially available, the crane is commercially available, the scientific payload was developed at a university in a publicly available forum, and the launch operations are not secluded and are available for public viewing. There is minimal information about the balloons, the crane, and the NCT in this report; there is far more extensive information publicly available on the NCT than is included in this report. The interface between the crane, the payload, and the balloon uses standard industrial design, involving a pin and cables, with no high technology involved. The report details launch operations and procedures, which have been extensively documented and photographed, with both still photography and videos.

Therefore, I do not believe that there is any export control concerns with this Mishap Investigation Board (MIB) Report. I recommend that from an export control perspective that this report is approved for public release; this only speaks to the export control concerns and does not address other reasons that the report may be limited in its distribution, which must be addressed separately. Proprietary information must be protected and only released upon approval of the owner.