Technical Consultation of the Hubble Space Telescope (HST) System Health Assessment - Analysis of HST Health

August 24, 2004

Prepared by:
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NESC Principal Engineer

Signature Page

NESC Independent Technical Assessment Team

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EXECUTIVE SUMMARY

On July 13, 2004, the Associate Administrator for the Office of Exploration Systems, Admiral Craig E. Steidle, with concurrence from the Chief Safety & Mission Assurance Officer, Bryan D. O'Connor, and NASA's Chief Engineer, Theron M. Bradley, solicited support from Ralph R. Roe, NESC Director, in the evaluation of the Hubble Space Telescope's (HST) long-term health prospects.

The NESC consultation was one component of an Agency decision on the viability of extending the life of the HST through a robotic service mission (SM). To address the request within the specified parameters, a multi-Center review team of knowledgeable technical specialists was convened to analyze the current and anticipated state of spacecraft subsystems and the parameters that describe the HST health to determine the timeliness of a robotic SM and whether this type of mission is likely to provide the capability to extend the useful scientific life of the HST by 5 years. The NESC team examined numerous HST Program reports and briefings, and the findings from the Independent Program Assessment Office (IPAO) and the Aerospace Corporation Analysis of Alternatives (AOA) as they related to the degradation of the HST's health. The NESC team also examined the state of HST subsystems that will not be serviced under the Goddard Space Flight Center (GSFC) baseline concept (Appendix A) including, but not limited to, the Fine Guidance Sensor (FGS) system, the Data Management Unit, the Multi-Layer Insulation (MLI) blankets, and the main science instrument systems. Appendix F provides HST illustrations.

The technical disciplines used for this assessment were selected based on the consideration of the HST subsystems and included: Guidance Navigation and Control (GN&C), Mechanical Systems, Power and Avionics, Safety and Mission Assurance (S&MA), Scientific Payloads, and Systems Engineering.

The review of the IPAO and AOA documents was supplemented with a significant quantity of HST-related reports, presentations, and other applicable references. A partial listing of these documents is located in Appendix C. In addition, extensive technical discussions were held with the HST Program liaison, numerous HST Operations, Flight Systems Engineering, Systems Management personnel and team technical peers.

By design and circumstances of limited time, the approach was concurrent discipline-based with selective subsystem penetration (audit structure). This assessment method enabled rapid review of the diverse and formidable quantity of HST Program information, while allowing the identification of systemic as well as isolated system characteristics. No specific attempt was made at independent verification of trending information, mathematical models, or performance parameters. Aspects of information transfer from daily operations through HST Program review were included with the data review. This allowed an examination of information flow to ensure

critical performance and health trends were identified and communicated through the decision chain.

In summary, the NESC review team has assessed the HST Program to be:

- organizationally structured to recognize performance deterioration and communicate these system changes through all levels of the Mission Operations, Systems Engineering, and Software (MOSES) team and HST Program Office;
- a highly skilled personnel base to support both operations and sustaining engineering associated with a SM;
- experienced in effective development and implementation of operational workarounds to provide the greatest likelihood of continued science until a SM can be effected (baring a rapid degradation in battery capacity); and
- prepared with contingency plans to perform a power management protocol to maximize HST attitude control until a SM can be effected.

After a thorough review of the information examined and the technical discussions held, it appears there is a high likelihood of having a viable vehicle available for a robotic SM. In addition, following successful equipment and instrument replacement during an optimized SM, the potential for at least five additional years of science discovery is very good.

Recommendations are provided to aid in the decisions that will lead to an optimum SM manifest and to extend the science service life its greatest extent.

NESC Position Paper

Request Number #: 04-060-E	
Requestor Name: Craig E. Steidle	**Requestor Contact Info:** Craig.E.Steidle@nasa.gov 202-358-1523
Short Title: Hubble Space Telescope (HST) System Health Assessment – Analysis of HST Health Degradation	
Description: To evaluate the long-term health of the HST through Year 2013 following a successful robotic servicing mission. Specifically, to provide input on the predicted reliability/expected availability of the major subsystems and instruments. Especially those subsystems and instruments not scheduled for servicing in the baseline concept.	
Date Received: 13 July 2004	**Date Consultation Initiated:** 13 July 2004
Lead Assigned: Steven J. Gentz	**Lead Contact Info:** Steven.J.Gentz@nasa.gov 757-864-9263
Date Consultation Concluded: 12 August 2004	

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In addition to outstanding support provided by the assessment team, the rapid response to this request could not have been accomplished without the exemplary support from the HST Program Office (Dr. Keith Kalinowski), the Lockheed Martin Corporation MOSES team (specifically, Tony Cruz, Mike Wenz, Stan Krol, Dave Haskins, Dan Smith, Mike Myslinski, Christine Cottingham, Greg Goulet, Jessica Regalado, Harry Wynn, Kevin Matthews, and Mike Prior), and the Space Telescope Science Institute representative (Manfred Miebach).

Added appreciation is extended to the NESC Management and Technical Support Office (specifically Lisa McAlhaney, Natasha Herman, and Erin Moran).

Consultation Approach

The NESC conducted an abridged independent examination of available information and personnel interviews to evaluate the current and anticipated state of the spacecraft subsystems and the parameters that describe the HST's health. These examinations included the projected timeliness of a robotic SM and whether the GSFC baseline concept is likely to provide the capability to extend the useful scientific life of the HST by an additional 5 years. The NESC team collected a broad spectrum of pertinent HST Program analyses, reports, briefings, and the results of the IPAO and the Aerospace Corporation AOA assessments as they relate to the degradation of the HST's health. This review included the state of the HST subsystems having the potential to impact the viability of the HST, but will not be serviced under the baseline robotic SM.

The identified documents were distributed to the NESC team for initial independent review and during a Technical Interchange Meeting (TIM) at GSFC (refer to Appendix D for the TIM agenda). Concurrent with these reviews were periodic discussions with the HST Program Liaison for clarifications to information provided and requests for further reference material. The TIM enabled in-depth exchange of information internally to the review team and externally with the HST Program personnel. In the course of these discussions and technical interchanges, additional reports and information were requested for review and evaluation. Finally, the TIM allowed for the consolidation of the various technical discipline observations into a combined package for a stakeholder interim status review (refer to Appendix E).

The following are the major milestones of the NESC assessment:

Milestone	Date
Initial Stakeholder Meeting	13 July 2004
Review Team Formulation	14 - 20 July 2004
Review HST Operations and Performance Data Packages	14 - 26 July 2004
Consultation Scope Definition	19 July 2004

Milestone	Date
Kickoff Teleconference	20 July 2004
Status Teleconference with Stakeholders	23 July 2004
GSFC TIM	28 - 29 July 2004
Interim Status Briefing to Stakeholders	3 August 2004
Final Report Submission	24 August 2004

Data Reviewed

The technical disciplines of GN&C, Mechanical Systems, Power and Avionics, S&MA, Scientific Payloads, and Systems Engineering were assigned review of their respective areas of expertise based on the following HST subsystem divisions:

- Data Management
- Electrical Power
- Mechanisms*
- Instrumentation and Communication
- Optical Telescope Assembly
- Science Instruments
- Pointing Control
- Thermal Control
- Safing

* Mechanisms is not typically listed as a separate subsystem for HST reporting

In addition to the copious volume of information available, the method of information transfer was examined to determine if crucial information on the HST's system health was adequately being disseminated from the MOSES team to the HST Program for review and disposition. This included the procedures used in performance and anomaly identification, reporting, and tracking.

OBSERVATIONS/RECOMMENDATIONS

Following are three main areas pertaining to ***Hardware, Operating Culture,*** and ***Reliability Analysis***. The recommendations are sequentially numbered to aid discussion.

HARDWARE

Observations

- A number of components have longevity exceeding specification life.

  This appears to be a combination of conservative reliability analysis assuming highly

stressed components; quality parts screening (Grade B/NASA PPL-21 Grade 2), fabrication, and test; infant mortality culling; and refined HST operations to minimize degradation (especially to components with known performance concerns).

- The HST architecture appears robust with considerable redundancy and has proven to be adaptable to unforeseen configurations.

- The following components have been identified as having performance issues or require additional emphasis by the HST Program Office:

  - **Nickel Hydrogen Batteries**

    The HST batteries continue to have decreased capacity at a calculated total system rate of -34.2 AmpHour per year (-5.7 Ahr per battery per year). At this projected rate, the system capacity is predicted to fall below the lowest Safemode trigger of 110 Ahr at the end of 2009. Unless changes in the recharging and reconditioning procedures are validated to impede this trend, battery capacity will remain one of the two most likely system limiters for the HST. It is the principal factor in the overall observatory life projections prior to a SM.

  - **Rate Sensor Unit (RSU) Gyroscopes**

    Currently, RSU gyroscopes 3 and 5 have failed with gyroscope 6 held in reserve with known bias instability performance issues. To support nominal pointing control to the desired accuracy requires at least three functional gyroscopes. Reliability estimates are for a greater than 50% probability of having three gyroscopes until the beginning of 2006. The HST Program is developing a two-gyroscope pointing and science scheduling capability in advance of the anticipated loss of three functional gyroscopes. Continued science observations are projected for an additional 12 to 18 months beyond the loss of a three-gyroscope capability using software corrections for the known performance issues of gyroscope 6, and the implementation of a two-gyroscope operational mode. Gyroscope life is the principal factor for observatory useful science life projections and the other most likely system limiter for the HST prior to a SM.

  - **Fine Guidance Sensors (FGSs)**

    Three FGSs provide precise fine-pointing adjustments to tracking guide stars at sub-arcsecond levels with only two functioning FGSs required for nominal science operations. There is concern with the performance of FGS 2R and FGS 3. The effectiveness of FGS 2R is decreasing as a result of a servo-loop gain issue that is most probably due to anomalous Light Emitting Diode (LED).

FGS 3 has significant bearing performance issues that require higher motor torques to overcome, and is being used sparingly to preserve remaining life. Life predictions for adequate FGS control vary, but appear to provide sufficient margin to the projected SM in 2008, but not to the planned end-of-life in 2013. Replacement of the FGSs was in the Orbiter SM, but is not in the baseline GSFC robotic SM.

- **Pointing/Safemode Electronics Assembly (PSEA) Safing Computer**

  Daily temperature monitoring and long-term trending show the PSEA safing computer operating at the yellow high limit (49°C). The mean and maximum temperatures for the first quarter of calendar year 2004 were 40.35 and 48.29°C, respectively. The red high limit for this system is 54.5°C. The HST Program expects to initiate ground testing of a PSEA engineering unit to validate the current yellow and red high limits. The results of this testing may lead to an increase in the warning limits or may require operational controls to preclude limit violations.

- **Space Telescope Imaging Spectrograph (STIS)**

  The STIS was installed on 14 February 1997 during SM 2. In the course of this assessment (3 August 2004), the STIS transitioned into a suspend mode. Preliminary findings by the Failure Review Board indicate a problem with the Side 2 +5 volt Interpoint power converter in the Mechanism Power Supply. This suspected fault is similar to an electrical malfunction that occurred in May 2001 that rendered the Side 1 electronics inoperable.

- The following cross-cutting system aspects have potential concerns:

  - **Total Ionizing Dose (TID) exposure of component electronics.**

    The HST Program provided a technical memorandum on the "Radiation Reliability Assessment of the Hubble Space Telescope Electronics", dated 28 February 1998. This study identified potential TID concerns through 2010. However, this study reveals that only a portion (approximately 64%) of the integrated circuits (ICs) were reviewed from the total of 1120 semiconductor devices contained in the parts list. The study does cite a number of ICs with probable degradation and potential TID issues in a number of electronic devices if not shielded in low dose areas of the vehicle. In general, the report indicates that most devices fabricated during the HST development period are relatively immune to TID effects, but later electronic upgrades may be more susceptible.

Overall, this report provides incomplete evidence to support that the electronics are operating within TID specifications to the intended operational period of 2008 or the end-of-life date of 2013. The HST Parts Control Plan specifies a minimum TID of 15 KRads for generic parts and 5 KRads if generic data is unavailable. Surface dose can exceed a MRad/year, but diminishes rapidly with shielding.

As electronics devices accumulate total dose, device power increases due to transistor parameter shifts and eventually the devices will degrade beyond operational ranges. To date, there are no known HST electronics failures due to this mechanism, but the likelihood increases with TID accumulation.

– **Increasing thermal environment in the HST aft shroud due to higher power consuming equipment and increased instrument utilization.**

This condition appears to be a result of the installation and operation of more capable science instruments that consume more power, and not a result of MLI degradation. The HST Program is performing ongoing analyses and expects to institute operational limitations to manage the thermal load.

The proposed replacement of the Corrective Optics Space Telescope Axial Replacement (COSTAR) with the Cosmic Origins Spectrograph (COS) in the baseline robotic SM will increase thermal loading, as the COS is estimated to generate approximately 200 Watts versus the reported 45 Watts from COSTAR.

– **Review of Failure Modes and Effects Analysis (FMEA) and hazard analyses for identification of single point failures.**

The HST Program reported that in preparation for the Power Control Unit (PCU) replacement during SM 3B, a review of the 1987 FMEA and hazard analyses was completed at the component and system levels. This information was relayed late in the assessment period and represents a considerable quantity of additional reports only available though an internal GSFC document control system. No comprehensive review was performed by the NESC team and will be forwarded as a recommendation to the HST Program for completion prior to a robotics SM Critical Design Review (CDR).

– **B-side electronics has not been exercised since prior to launch and has an assumed reliability of 1 and a failure rate equal to 10% of the operating value.**

The architectural design of the HST does not allow periodic verification of the redundant electronics circuitry without considerable disruption to science

operations and the potential risk to recovery of A-side operations. Ground testing is assumed to have ensured the absence of latent defects in the electrical components and manufacturing. However, the STIS has been the only system that required the use of the redundant electronics. This assumed reliability represents the HST Program's recognized systemic risk. September 2002 is the most recent HST Program assessment of the effort involved to prepare, verify, and implement on-orbit testing of the HST's redundant components. It concluded verification of the B-side electronics was not recommended due to a number of factors that included a small, but non-zero, risk that one of the power-cycled modules would not restart.

– **Continued degradation of the MLI outer ply due to environmental exposure.**

  Prior SMs observed a greater degradation than expected and implemented rudimentary fixes including application of New Outer Blanket Layer (NOBL) material to minimize material and thermal performance loss. Increased damage is predicted during the next several years of solar minimum. The potential for dislodged MLI becoming a contamination concern during future servicing requires assessment and mitigation.

– **A number of components have service exposure greater than design life.**

  The contributing factors that have resulted in the exemplary success of a majority of components are understood from at least a qualitative standpoint. However, electrical and mechanical components cannot be expected to survive indefinitely. Recognition of performance issues will continue to rely on telemetry for long-term health assessment. Graceful failure modes with gradual precursor performance indicators cannot always be expected. A structured Life Extension Initiative defined by the HST Program is a mechanism to explore anomaly detection, fault progression, and failure modes.

Recommendations

1.1 Continue the evaluation of recommendations on life prediction and battery capacity protocol identified in NESC Report, "Technical Consultation of the Hubble Space Telescope (HST) Nickel Hydrogen (N_iH_2) Battery Charge Capacity Prediction", NESC 04-050-E, dated 17 June 2004.

1.2 Assess the augmentation of GSFC baseline robotic SM to include replacement of at least one FGS.

1.3 Complete planned ground testing to determine thermal margin limits of PSEA Safing computer prior to robotic SM CDR. Update thermal warning high limits

or institute operational controls to limit temperature exposure to within allowable operational ranges. If thermal limits can not be successfully raised, then assess potential for augmentation of GSFC baseline robotic SM to include replacement or redundant Safing computer.

1.4 Locate and update, or generate, a comprehensive TID exposure analysis of HST components to identify any elements at risk to performance degradation for the intended operational period of 2008 and to the end-of-life date of 2013. This analysis should be completed or updated prior to the robotic SM CDR.

1.5 Release an operational plan to address aft shroud thermal environment conditions prior to the robotic SM CDR. Update this plan to consider impact of de-orbit module attachment and the replacement instruments and components as part of any SM concept.

1.6 Complete an updated review of the FMEA and hazard analyses for the identification of single point failures prior to the robotic SM CDR. Assess the potential for augmentation of GSFC baseline robotic SM based on this review.

1.7 Confirm thermal margins with respect to expected increased degradation of MLI outer ply prior to the robotic SM CDR.

1.8 Identify contamination control protocol to mitigate risk of degraded MLI migration into internal structure of the HST during a SM.

1.9 Pursue a structured Life Extension Initiative prioritized on component criticality.

OPERATING CULTURE

Observations

- The HST Program appears to be a highly motivated and resourceful team with extensive corporate knowledge that has repeatedly demonstrated the ability to react to and plan for adverse conditions. A number of innovation applications of HST systems to non-traditional roles are considered in fault planning. This team has operations rooted in established procedures and a layered approach to anomaly recognition and disposition.

- The HST Program team appears to practice an iterative SM versus End-of-Life paradigm.

  This manifests as data trending of performance parameters directed towards near-term problem recognition and characterization. The HST team has the prerequisite skills and data available to make these predictions and this observation may be one of nomenclature. However, clarification should be provided to the MOSES team on the

scope of their overall long-term telemetry/performance trending efforts.

Recommendation

2.1 Provide specific direction to HST Systems Engineers to complete end-of-life predictions for major components and subsystems with continuous updates from telemetry data and ground-based Life Extension Initiative results prior to the robotic SM CDR.

RELIABILITY ANALYSIS

Observations

- **The reliability analysis updated by the Aerospace Corporation uses typical assumptions, failure rate updating, and modeling consistent with MIL-HDBK-217 methodology.**
  - Two methods were used to update the 1992 failure rate predictions. First, the methodology (RADC-TR-85-229) developed by the Reliability Analysis Center is used to reduce the failure rate to 60% of the original MIL-HDBK-217 failure rates. This methodology is typically used by current satellite manufacturers. The second update uses operational experience to adjust the HST subsystem failure rates. By using a Bayesian methodology, the "a priori," or original estimate, can be updated. This methodology is also common in reliability engineering and Probabilistic Risk Assessments (PRAs).
- **The current reliability analysis models only electronic failure rates with the exception of the RSU gyroscopes, where a mechanical wear out rate is applied.**
  - The HST has many mechanical systems that should be modeled in the reliability analysis. To perform a Bayesian update to include both HST electrical and mechanical components, shape and scale parameters and gamma distributions are required. These values can be based on hardware experience and engineering estimations. These refined parameters would then be used to adjust component failure rates. Since there are many different types of subsystems in HST, the observed data accumulated over its life may be used to develop different shape parameters for each subsystem and then adjust each failure rate accordingly. Following these failure rate adjustments, the models developed in the original HST Reliability Assessment could be used to more accurately represent the current and expected reliability of the HST.

- **MIL-HDBK-217 unique analyses are intended to be a design trade tool and not an absolute estimate of component field (in-service) failures.**

Recommendations

3.1 Update the reliability model from the August 2003 release to account for HST performance experience to date.

3.2 Perform sensitivity studies on shape and scale parameters of current reliability analysis to determine if there is a change to the HST reliability drivers.

3.3 Update the reliability analysis to incorporate shape and scale parameters and gamma distributions for the electrical and mechanical components using accumulated time and failures experienced during on-orbit operations.

APPENDIX A

Orbiter SM4
Planned Manifest

Cosmic Origins Spectrograph (COS)
Wide Field Camera 3 (WFC 3)
Fine Guidance Sensor (FGS)
Aft Shroud Cooling System
Batteries
Gyroscopes
New Outer Blanket Layer (NOBL)
Data Handling Cross Strap Unit (DSC)

GSFC Baseline
Robotic SM4
Proposed Manifest

Cosmic Origins Spectrograph (COS)
Wide Field Camera 3 (WFC 3)
Batteries
Gyroscopes

APPENDIX B

List of Acronyms

Ahr	AmpHour
AOA	Analysis of Alternatives
CDR	Critical Design Review
COS	Cosmic Origins Spectrograph
COSTAR	Corrective Optics Space Telescope Axial Replacement
DC	Direct Current
DSC	Data Handling Cross Strap Unit
FGS	Fine Guidance Sensor
FMEA	Failure Modes and Effects Analysis
GN&C	Guidance Navigation and Control
GSFC	Goddard Space Flight Center
HQ	Headquarters
HST	Hubble Space Telescope
IC	Integrated Circuit
IPAO	Independent Program Assessment Office
LaRC	Langley Research Center
LED	Light Emitting Diode
JSC	Johnson Space Center
KDDL	Known Data Discrepancy List
MLI	Multi-Layer Insulation
MOSES	Mission Operations, Systems Engineering, and Software
NOBL	New Outer Blanket Layer
NRB	NESC Review Board
PCU	Power Control Unit
PRA	Probabilistic Risk Assessment
PSEA	Pointing/Safemode Electronics Assembly
RSU	Rate Sensor Unit
S&MA	Safety and Mission Assurance
SM	Service Mission
STIS	Space Telescope Imaging Spectrograph
TID	Total Ionizing Dose
TIM	Technical Interchange Meeting
WFC	Wide Field Camera

APPENDIX C

HST Program Reports and Briefings

HST Program Reports and Briefings

- Mission Operations, Systems Engineering, and Software Program Observatory Performance Assessment Quarterly Reports (June 2004, 2003, and 2001)
- 26 July 2004, Mission Operations Snapshot
- 15 July 2004, Mission Operations, Systems Engineering, and Software Program Quarterly Briefing
- 22 June 2004, HST Survivability; Comparison of Servicing Tasks
- 17 June 2004, Technical Consultation of the Hubble Space Telescope (HST) Nickel Hydrogen (N_iH_2) Battery Charge Capacity Prediction, NESC 04-050-E
- 10 June 2004, Known Data Discrepancy List (KDDL)
- 9 June 2004, Comments on RSU being located on the De-orbit Module, EM HST-04-004A
- 2 & 3 June 2004, Status of Hubble Spacecraft
- 2 June 2004, Hubble Science Operations
- 28 April 2004, Effect of WFPC3 Mechanism Disturbances on RGA and PCS, EM HST-04-001A
- 18 December 2003, Limited Life Items and Risk Mitigation List (SM-4)
- 15 July 2003, Anomaly Reporting for HST Operations and Test
- 9 September 2002, Impacts and Risks of On-Orbit Testing of HST's Redundant Modules
- 13 February 2002, HST Cargo Systems Manual
- 2 August 2001, STIS Failure Review Board Final Report
- 13 & 14 May 2004, HST Robotic Servicing Concept Review
- 1 April 1997, HST Parts and Control Plan
- 1991, The Flight Hardware and Ground System for HST Astrometry

Aerospace Corporation Reliability Model

- July 2002, HST Reliability Assessment, Report No. TOR-2003(2154)-2352
- August 2003, Adjusted Reliability Model for Science Operations

Independent Program Assessment Office (IPAO) Briefings

- 21 through 24 June 2004, Briefings
- 20 July 2004, Final Review Briefing

Aerospace Corporation Analysis of Alternatives (AOA) Briefing

- 9 July 2004, Mid Term Briefing
- 3 August 2004, Final Review Briefing

Lockheed Martin Technical Memorandum TM12-97

- 28 February 1998, Radiation Reliability Assessment of the Hubble Space Telescope Electronics

APPENDIX D

Hubble Space Telescope (HST) System Health Independent Technical Consultation
Technical Interchange Meeting
July 28-29, 2004
Proposed Agenda

Wednesday, July 28, 2004
GSFC East, Building 33, Conference Room H118

Time (EST)	Topic/Activity	Presenter/Participants
8:30	Welcome, Safety/Emergency Procedures, Logistics, and Facility Information	Gentz
8:45	Assessment/Meeting Objective	Gentz
9:15	Initial Comments - Reliability - Mechanical Systems - Guidance, Navigation and Control - Power & Avionics - Scientific Payloads - Systems Engineering	Team
11:30	Lunch	
12:30	Travel to Lockheed Martin Corporation Facility 7474 Greenway Center Drive Building 229, Suite 200 301-901-6174	Team
13:00	Mission Operations, Systems Engineering, and Software (MOSES) Program Review	
	- NESC Purpose and Introduction	
	- CHAMP/MOSES HST Role	Gentz
	- Data Management	Cruz
	- Electrical Power	Regalado
	- Mechanisms	Krol
	- Instrumentation & Communication	Mathews

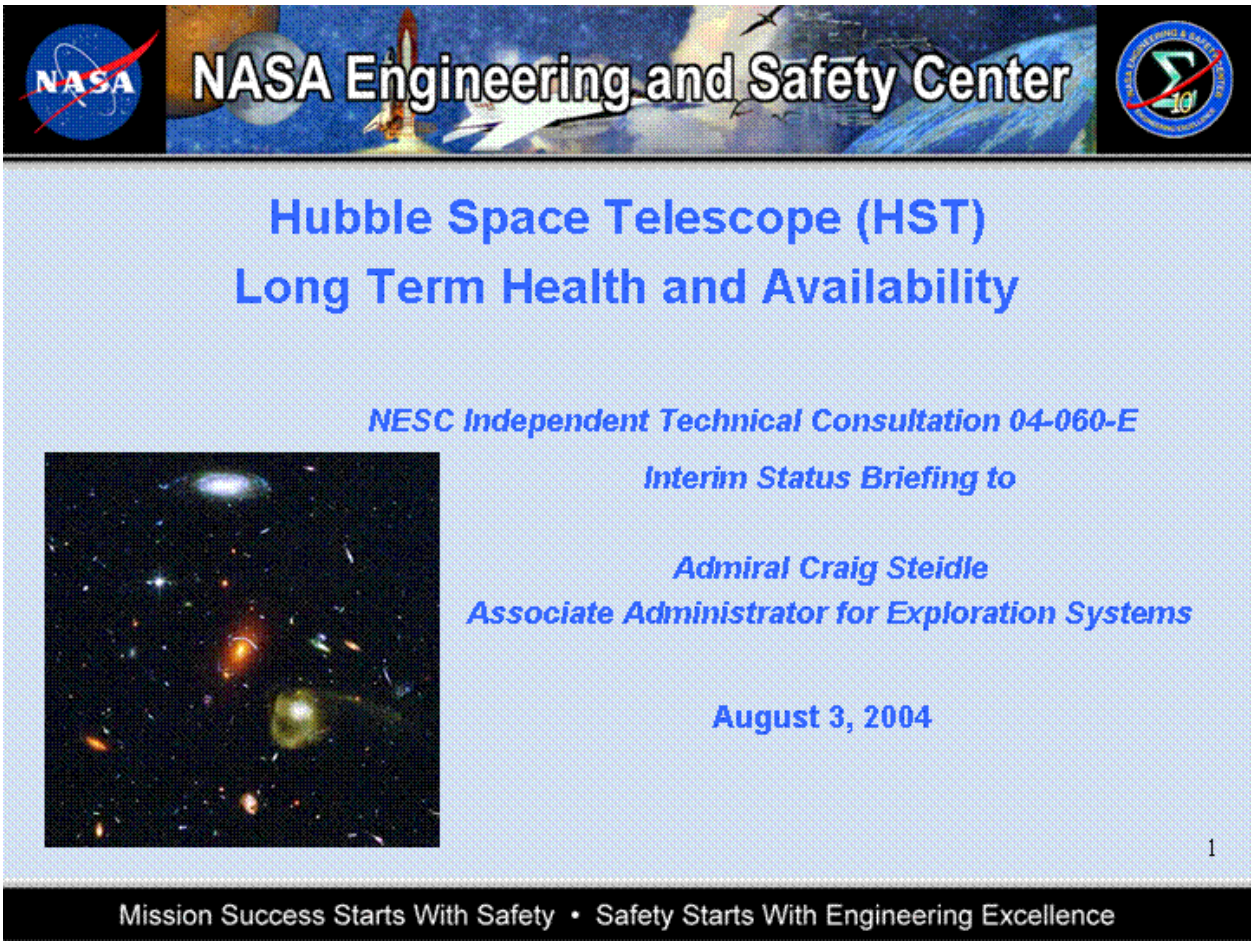
	- Optical Telescope Assembly	Wynn
	- Science Instruments	
	- Pointing Control/Sensor Calibration	Wenz
	- Thermal	Bassford/Heeler
	- Safing	Smith
	- Operations (FOT, HSTARs, Briefings, etc.)	Cottingham
	- Systems Management	Myslinski Goulet
		Haskins
15:30	Travel to GSFC, Building 33	Team
16:00	Working Session and Open Discussion	Team
17:00	Summary/Action Items/ Issues	Gentz
17:30	Adjourn	

Thursday, July 29, 2004
GSFC East, Building 33, Conference Room H118

Time (EST)	Topic/Activity	Presenter/Participants
8:30	Prior Days Review and Current Day Plan	Gentz
9:00	Carryover Topics from Wednesday Document Review and Open Discussion	Team
11:15	HST Program Office Discussion	
12:00	Lunch	
13:00	Code T Status Outline	Team
15:00	Open Discussion	Team
16:30	TIM Summary/Action Items	Gentz
17:30	Adjourn	

APPENDIX E

Interim Status Briefing to Admiral C. Steidle (August 3, 2004)



NASA Engineering and Safety Center

ASSESSMENT APPROACH

- **Documentation Review**
  - Independent Program Assessment Office (IPAO) Briefings
  - Aerospace Corporation Analysis of Alternatives (AOA) Briefing
  - HST Program Reports, Briefings, Plans, and Policies
  - Aerospace Corporation Reliability Modeling
- **Process Review**
  - HST procedures and guidelines
  - HST personnel interviews and discussions
- **Schedule**
  - Task Initiation: 15 July 2004
  - Team Formation: 20 July 2004
  - Technical Interchange Meeting with HST Program: 28 – 29 July 2004
  - *Interim Status Briefing: 3 August 2004*
  - *Final Report: 13 August 2004*

2

Mission Success Starts With Safety • Safety Starts With Engineering Excellence

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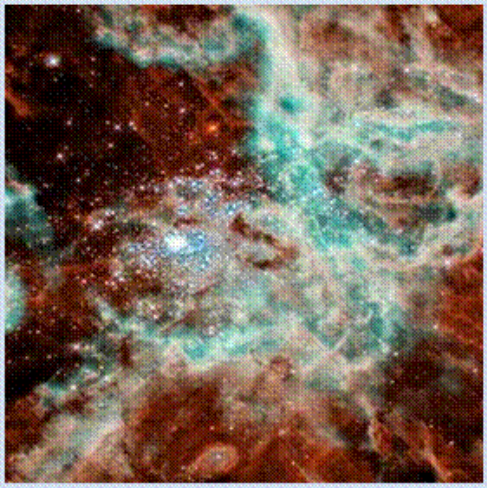
OVERVIEW

Subsystems Examined

- Data Management
- Electrical Power
- Mechanisms
- Instrumentation and Communication
- Optical Telescope Assembly
- Science Instruments
- Pointing Control
- Thermal Control
- Safing



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Mission Success Starts With Safety • Safety Starts With Engineering Excellence

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PRELIMINARY OBSERVATIONS

HARDWARE

- **Component longevity exceeding specification life is a combination of:**
  - Conservative reliability analysis assuming highly stressed components
  - Quality parts screening, fabrication, and test
  - Infant mortality culling
  - Refined operations
- **HST Architecture:**
  - Robust with considerable redundancy
  - Proven to be adaptable to unforeseen configurations
- **Components with performance issues:**
  - Nickel Hydrogen Batteries (service mission baseline augmentation)
  - Rate Sensor Unit Gyroscopes (3, 5, and 6 - service mission baseline augmentation)
  - Fine Guidance Sensors (2R and 3 - **replacement not identified in baseline service mission concept**)
  - Pointing/Safemode Electronics Assembly Safing computer (thermal limits – ***under review****)
  - Space Telescope Imaging Spectrograph (Side 2 operations – ***under review***)

* indicates additional NESC assessment team activities

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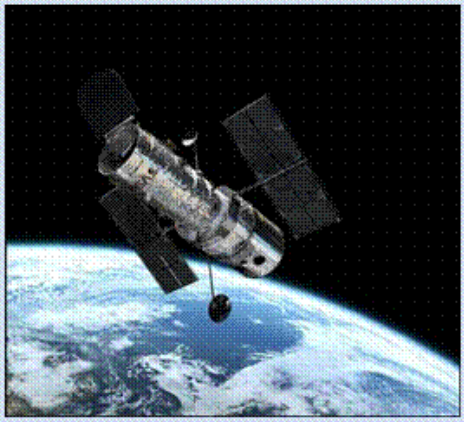
PRELIMINARY OBSERVATIONS (continued)

HARDWARE (continued)

- Crosscutting aspects with potential concerns:
  - Electronics (radiation damage - ***under review***)
  - Thermal environment (operational limitations pre and post service mission - ***under review***)
  - Failure Modes and Effects Analysis (review of single point failures - ***under review***)
  - B side electronics switching (assumed reliability)
  - Multi-layer Insulation (increased degradation during solar minimum and contamination potential during servicing)
  - Number of components with service exposure greater than design life (reliance on telemetry for health assessment)



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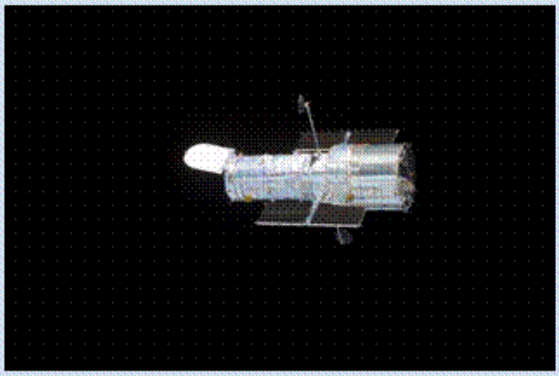
PRELIMINARY OBSERVATIONS (continued)

OPERATING CULTURE

- Demonstrated ability to react to and plan for adverse conditions
  - Innovation in the application of HST systems in non traditional roles
  - Mode of recognize, characterize, and strategize
  - Ground-based Life Extension Initiative
- Practice iterative Service Mission versus End of Life Paradigm
  - Data trending directed towards near term problem characterization
  - Risk mitigation activities versus end of life prediction
  - Represents a culture change for the HST Program Team
- Personnel
  - Highly motivated and resourceful team with extensive corporate knowledge
  - Operations rooted in established procedures



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PRELIMINARY OBSERVATIONS (continued)

RELIABILITY ASSESSMENT

- Updated Aerospace Corporation analysis adheres to MIL-HNBK-217 methodology
- Shape parameter values ***(under review)***
- MIL-HNBK-217 analyses are *intended to be a design trade tool and not an absolute source for field (in-service) failure predictions*

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ADDITIONAL ACTIVITIES

- Receive additional reports, procedures, and data requests
- Complete document and analysis review
- Complete interviews
- Finalize observations, findings, and recommendations
- Submit final report

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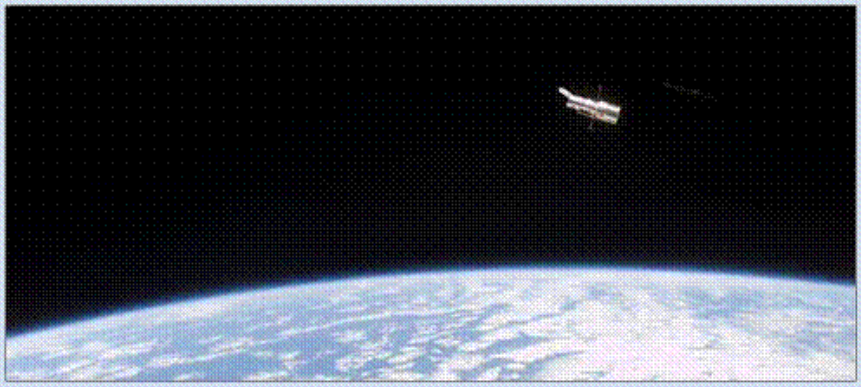
BACKUP INFORMATION



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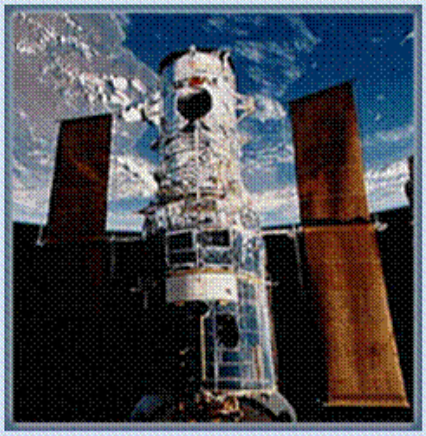
REVIEW TEAM

Name	Emphasis Area
Steve Gentz	NESC Lead
John Azzolini	Systems Engineering
Neil Dennehy	Guidance Navigation and Control
Pete Spidaliere	Systems Engineering
Frank Kirchman	Scientific Payloads
Joe Pellicciotti	Mechanical Systems
Rodger Farley	Mechanical Systems
John Stadler	Systems Engineering
Bob Hodson	Power & Avionics
John Pandolf	Power & Avionics
Brent Heard	S&MA - Reliability
Duane Pettit	S&MA - Reliability
Lisa McAlhaney	Resources Management
Natasha Herman	Administrative Support



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DOCUMENTATION LISTING

HST Program Reports and Briefings

- Mission Operations, Systems Engineering, and Software Program Observatory Performance Assessment Quarterly Reports
- 15 July 2004 Mission Operations, Systems Engineering, and Software Program Quarterly Briefing
- 22 June 2004 HST Survivability; Comparison of Servicing Tasks
- 10 June 2004 Known Data Discrepancy List
- 2 & 3 June 2004 Status of Hubble Spacecraft
- 2 June 2004 Hubble Science Operations
- 13 & 14 May 2004 HST Robotic Servicing Concept Review
- 18 December 2003 Limited Life Items and Risk Mitigation List
- 15 July 2003 Anomaly Reporting for HST Operations and Test
- 13 February 2002 HST Cargo Systems Manual
- 1 April 1997 HST Parts and Control Plan

Aerospace Corporation Reliability Model

- July 2002 HST Reliability Assessment
- August 2003 Adjusted Reliability Model for Science Operations

Independent Program Assessment Office (IPAO) Briefings

- 21 thru 24 June 2004 Briefings
- 20 July 2004 Final Review Briefing

Aerospace Corporation Analysis of Alternatives (AOA) Briefing

- 9 July 2004 Mid Term Briefing
- 3 August 2004 Final Review Briefing

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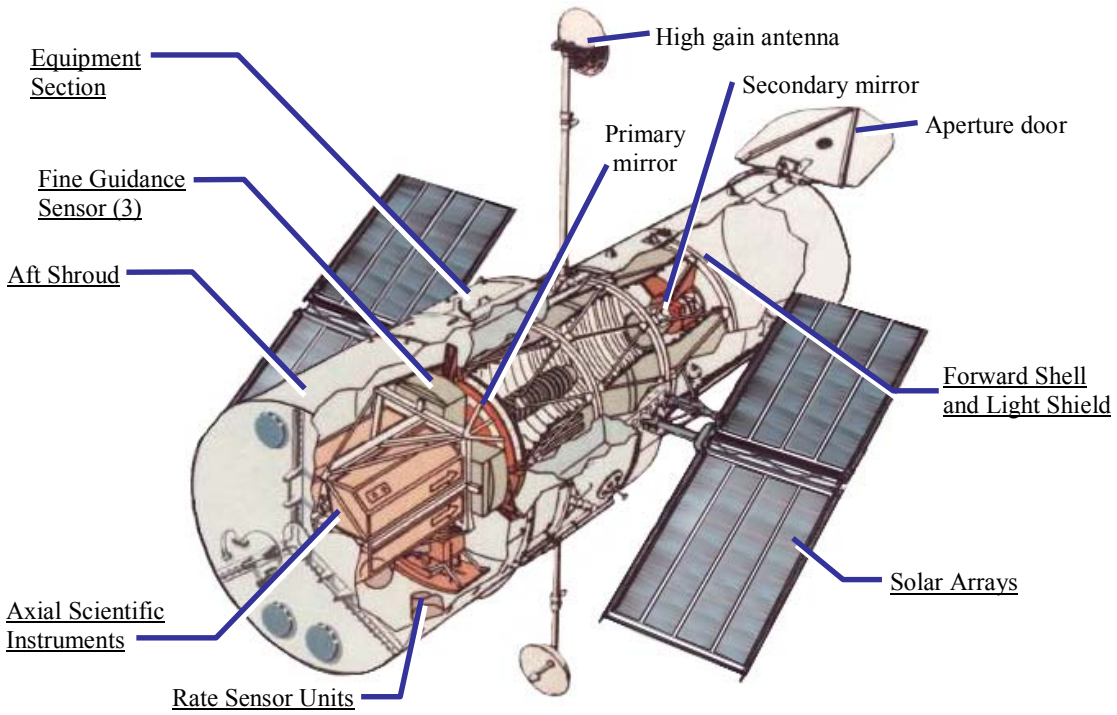
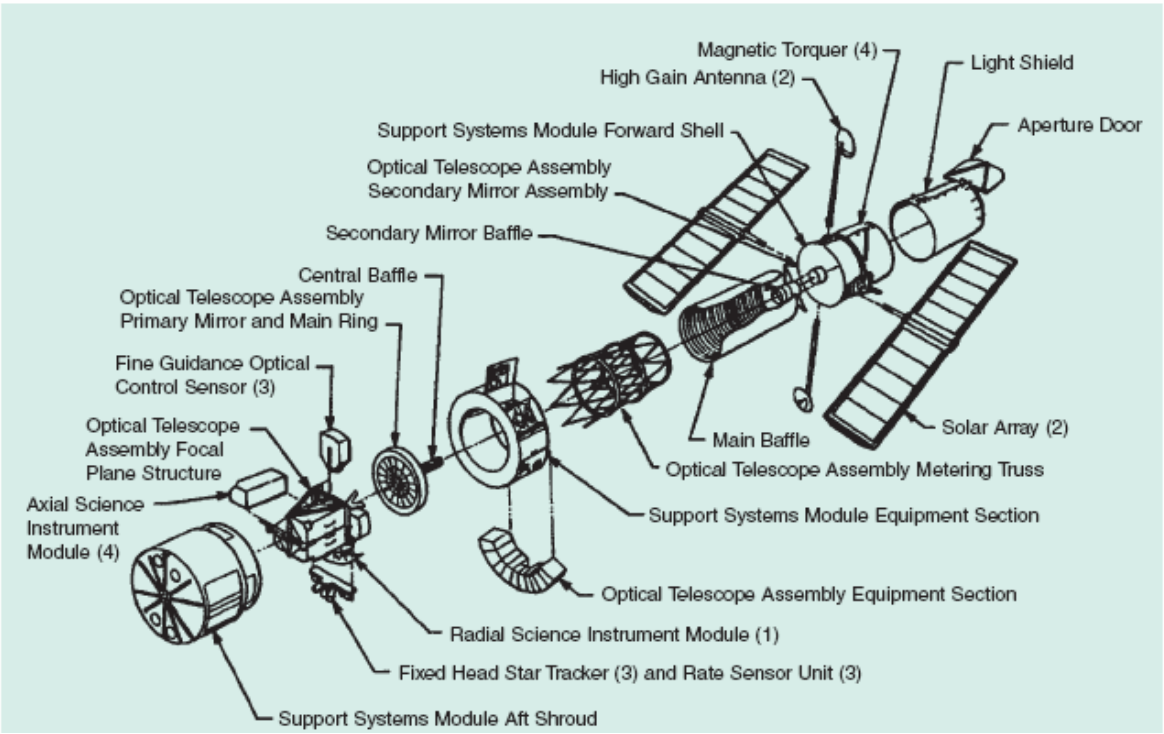
APPENDIX F

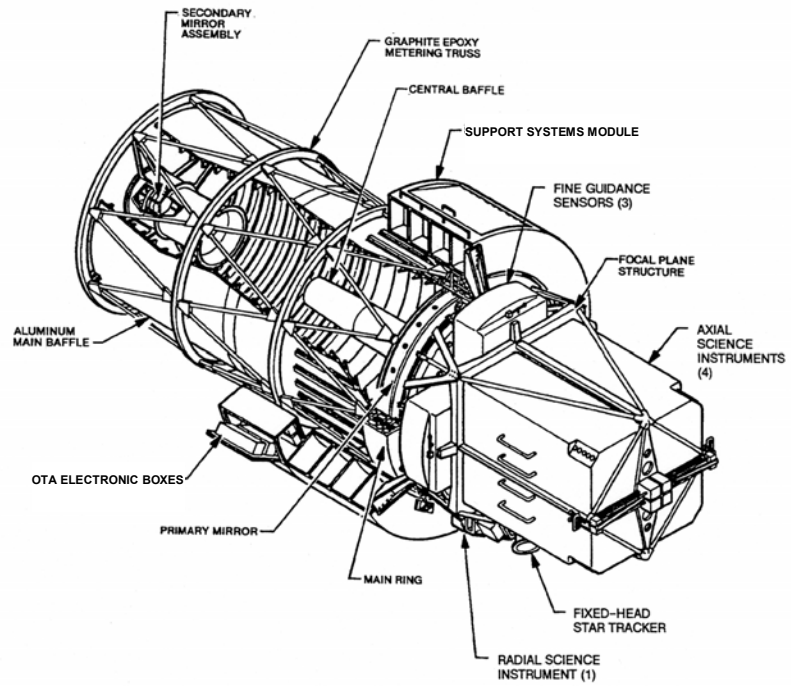
HST Illustrations



Design Features of Support Systems Module



HST - Expanded View



Optical Telescope Assembly Components

Approval and Document Revision History

Approved:	Original signed on file	9/16/04
	NESC Director	Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Principal Engineers Office	08/24/04