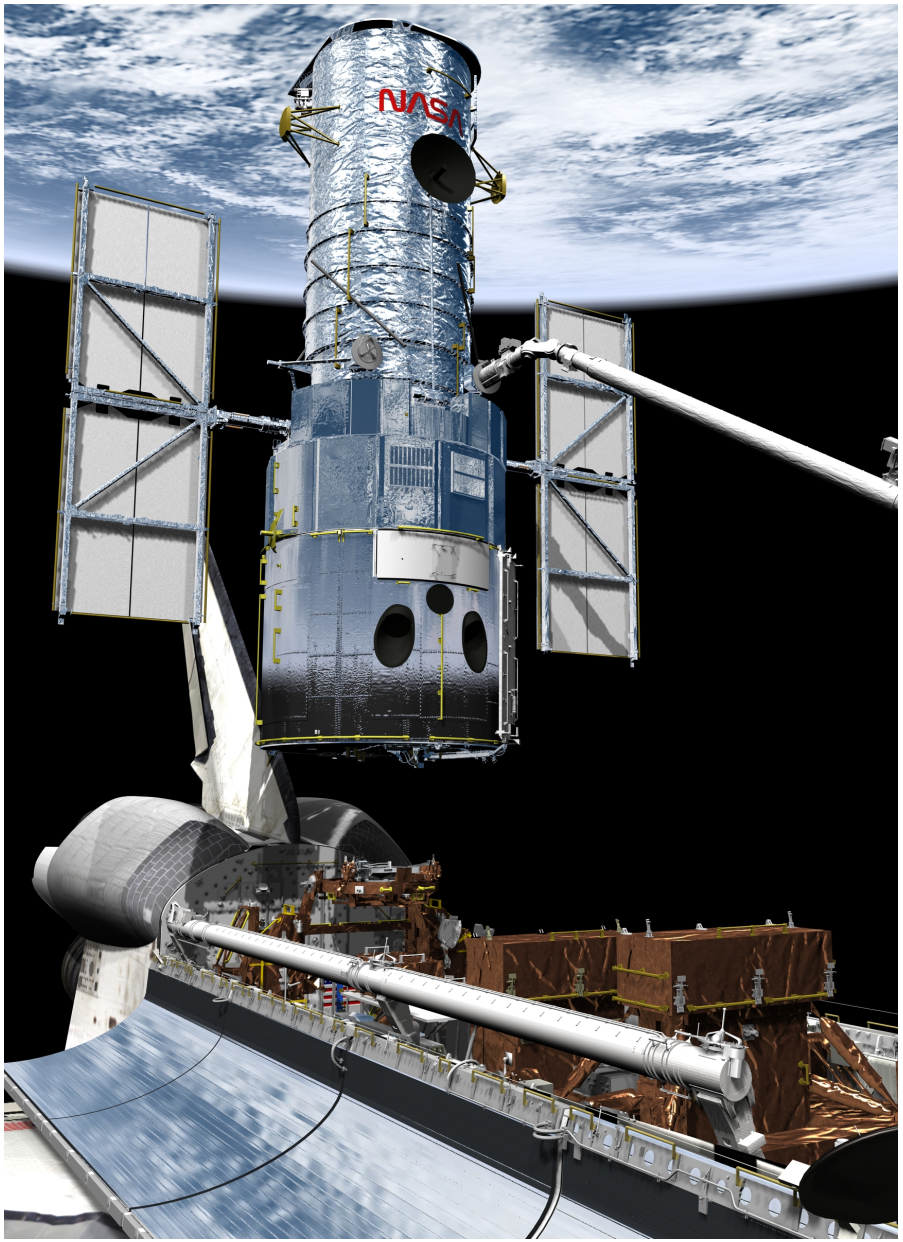
Goddard Space Flight Center



HST/GSFC Project Report

Presentation to: STUC

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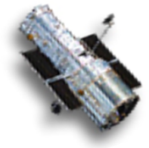
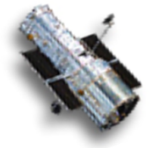
15 November 2011



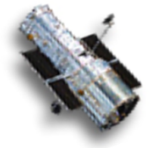
Topics

- Patrick Crouse
  - Recent Anomalies
  - Gyro Status
- Ken Carpenter
  - Forward Management Plan for use of Gyro Assets
  - Automated Operations Update
  - Senior Review of Operating Missions



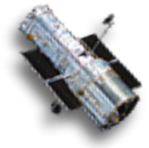
Recent Anomalies

- **Solid State Recorder 1 (SSR-1) anomaly on September 13, 2011**
  - Science playback started at 08:47:58 stopped unexpectedly at 08:58:22 GMT
  - Subsequent opportunities to command the data playback failed and engineering data was not being written to the recorder
  - HST was in the South Atlantic Anomaly (SAA) at the time of the event
  - SSR-1 Interrupt Error log sampled at 08:58:25 showed increased counts; 1773 bus error counts sampled at 09:01:04 showed an increase (retry errors have occurred since installation, this is the first on-orbit SSR anomaly)
  - The SSR design notes identified that 1773 bus errors may cause the SSR software to hang waiting for the Reed Solomon to finish
  - The design notes identified 1773 raw command to clearly diagnose the condition, and the subsequent command to reset the Reed Solomon
  - The team was successful in executing the commands, replaying the data that was in question, and resuming normal operations by late afternoon on September 13
  - Currently in the process of converting the design notes into Contingency Operations Procedures (COPs) in the event of future occurrence.



Recent Anomalies

- **Science Instrument Control and Data Handling (SI C&DH) Lockup**
  - HST Operations Team was paged at ~05:40 am local time on September 27
  - Telemetry confirmed 5th Lock-up event and first since September 9, 2010 (and first in the Automated Operations era)
  - Systems engineers and flight operations teams executed the pre-approved procedure to recover the unit into the fixed format mode
  - A Project briefing was held at 8:45 am
  - Instruments were in the expected state (pseudo boot) with the exception that the Advanced Camera for Surveys was in anneal mode (which was the state it was in at the lockup and is a safe state)
  - Recovery procedures commenced following the briefing and the science timeline was resumed at 6:00 am local on September 28 (just over 24 hours of science observation time was lost)



Attitude Observer Anomaly (AOA) Anomaly Review Board (ARB)

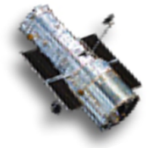
- **The Executive Summary Stated (9/26/11) - *The increasing AOA signature magnitude is believed to be caused by asymmetric corrosion-induced degradation between the 7 flex leads. The orbit terminator heat pulse creates mechanical stresses as it travels through the asymmetrically corroded flex leads, these impose a force on the float.***
  - An AOA signature may occur in *any* gyro
  - There is no identified solution to correct this anomalous behavior
  - The anomalous behavior effects can be mitigated by reducing the Main Bus Voltage transients at the terminators.
  - The thermal pulsing is suspected to contribute to the degradation, but that has not been proven conclusively (***all gyros now configured to operate on the secondary heater controller which operates 10x faster than the primary controller and has demonstrated on orbit to substantially reduce the AOA signature)***

- **The Post SM3B gyro complement had AOA signatures in 4 of the 6 gyros; G2 (2002), G4 (2005) (the subject of an ARB investigation), G6 (2008) and G1 (2008). Only the G4 performance impacted science operations**

- **AOA signatures have been identified in G3 and G4 post SM4. G3 has been removed from the control loop and powered off since March 2011. G4 is currently operating nominally, although *if* it follows the trend of G3, may become problematic as early as first quarter of 2012**

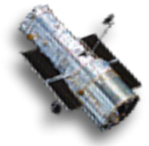
- **Based on a sample size of 2, it is believed that the Enhanced Flex Lead (EFL) gyros (post SM4 G3, G4, and G6) have a greater propensity for the AOA signature to degrade more quickly than the Standard Flex Leads (G3 and G4 reach ~50 arcsec/hr magnitude in ~2 months, compared to SM3B G4 taking 3 years**

- **The Project anticipates to review concepts/impacts to mitigate Main Bus Voltage transients as well as to compensate for the AOA signature in the attitude control law in early December**



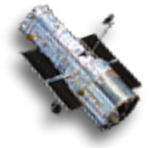
Gyro 4 Status

- **Exhibited the AOA signature on the primary heater controller (operating on the secondary heater controller since DOY 300/2010)**
- **Experienced an ~350 arcsec/hr bias shift over a few orbits on April 29, 2011 and resumed nominal operations**
- **Experienced an increase in motor current on September 7, 2011**
  - Occurred during a vehicle slew between targets
  - Motor current increased from ~120 mA (nominal value) to a peak of 254 mA before decreasing to ~190 mA
  - Motor current has remained consistent at the new 190 mA value
  - The motor will stall around 300 mA
  - Prior experience has indicated that a motor current increase indicates a rotor restriction which is a precursor to gyro failure, but not necessarily an imminent failure (several have run for years after initial event)



Forward Management Plan for Gyros

- **Currently, HST is in 3-gyro control mode (G4, G5, G6)**
  - Maximizes science efficiency while we have full complement of science instruments, two of which are single-string (ACS and STIS)
  - Enables several classes of observations not possible on 1-gyro, e.g., moving targets that require guide-star handoffs, gyro-only observations (e.g., lunar)
  - G1 and G2 are hibernating in a cold, life-preserving state as backups
  - G3 is not reliable (~20% of acquisition were failing at turn-off) – until/if software mitigation of AOA is available
- **Current planned response to losing a gyro is to turn on one of the hibernating gyros (G2) and stay in 3-gyro mode**
- **A proactive switch to 1-gyro mode can extend mission lifetime, at the cost of reduced science efficiency and the loss of some classes of science observation**
- **Long-term strategy is to switch to 1-gyro mode (same performance as 2-gyros) after we lose 4 gyros and have only 2 operational ones left**
  - The Question: is this the optimal strategy or should we switch sooner/later?
  - No final answer today – some thoughts/info follow – study in progress

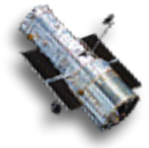


Forward Management Plan for Gyros (con't)

- **Current Gyro Configuration/Status**

Gyro #	Run Hours	Flex Lead	Status
1	7244	Standard	Powered Off Following SMOV4
2	7416	Standard	Powered Off Following SMOV4
3	22353	**Enhanced**	Powered Off Due To Performance (AOA)
4	31025	**Enhanced**	***Running***, AOA, Elevated MC
5	29825	Standard	***Running***, No Issues
6	14113	**Enhanced**	***Running***, No Issues

- **Enhanced flex lead (EFL) gyros have shorter lifetime before AOA**
- **May be able to mitigate AOA via software to**
  - **enable return of G3 to service and extend G4/G6 useful lifetime**
- **Note: G4 may fail due to rotor restriction before AOA limits utility**

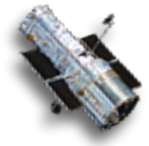


Forward Management Plan for Gyros (con't)

- **Predicted Run Times**

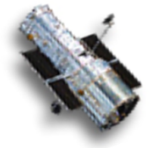
Scenario	Mean	Max	Min	Std Dev	1-σ	2-σ
1 gyro failed (if G3 not recoverable) [3 3 3 1 1] Run Time - years (from 2011.2)	8.5 (2019.7)	15.2 (2026.4)	2.4 (2013.6)	1.9 (---)	6.6 (2017.8) 10.43 (2021.6)	4.6 (2015.8) 12.4 (2023.6)
No Gyro Failed [3 3 3 3 1 1] Run Time - years (from 2011.2)	11.3 (2023)	16.6 (2027.8)	3.4 (2014.6)	2.6 (---)	8.7 (2019.9) 13.8 (2025.0)	6.1 (2017.3) 16.4 (2027.6)

- **The gyro failure/run time database was updated to the last gyro (G2) failure in 2007**
- **Standard Flex Leads (SFLs) and Enhanced Flex Leads (EFLs) have the same failure probabilities assigned**



Forward Management Plan for Gyros (con't)

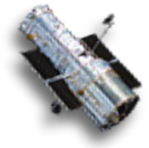
- **Current Plan**
  - Begin assessment of the prospects for extending the useful life of G3 (and other AOA gyros) via software mitigation of the AOA
  - Following the next gyro failure, recover from Kalman Filter Sunpoint Safemode to 3-gyro science mode by powering on hibernating G2 to replace failed gyro (likely G4) in control loop
  - Begin assessment of, and planning for, 1-gyro science mode implementation at subsequent failure (s)
    - Priority over Two Reaction Wheel Science development
    - Begin assessment of improving the efficiency of OGS
  - Investigate optimal time for proactive switch to 1 gyro mode (at a Cycle boundary would be best for maintaining efficient schedule)



Update on HST Automated Operations

- **AO is working as designed. The FOT has been reduced from 35 FTE to 10 FTE as a result of the transition from 24x7 to 8x5 operations**
- **All elements of AO including the observatory, the ground systems, and the staff are operating exactly as planned, except for a single event in which science data lost due to Operator Error (see next page)**
- **There have been no incidences where an Observatory or significant Ground System anomaly has not been detected and alerted by the AO systems**
- **Recovery times from anomalies have been good**
  - could have been longer for SSR1 recovery if reset hadn't work - ready to send folks home overnight before "next step"
- **Automated re-dumps should be in place by end of year**
  - "Monitored auto-re-dumps" running 8x5 starting Nov. 14th
  - Dec. 12th is FRR for 24x7 implementation
- **Science data collection rates are well within our 1% loss margin.**

Date	exposures total	exposures impacted	% exps complete	% exps impacted	visits	orbits	HOPRs received	HOPRs approved	Orbits repeated
2011 Sept	4684	4	99.915%	0.085%	4	6	0	0	0
2011 Aug	4274	4	99.906%	0.094%	4	5	1	0	0
2011 July	5258	4	99.924%	0.076%	4	4	0	0	0

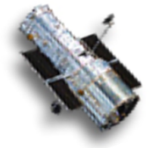


Update on HST Automated Operations (con't)

- **Science Data Loss due to Operator Error**
  - The Tracking Data Relay Satellite System (TDRSS) support schedule for a pass on October 28 was impacted due to the NPP launch, and had been modified into two separate supports
  - Heading into the weekend, HST Flight Operations Team (FOT) recognized that the projected Solid State Recorder (SSR) usage was high and that future data loss was a possibility
  - FOT exercised manual control to turn on the transmitter, dump data, *and turn off the transmitter*
  - Subsequent commanding via the Automated Command Engine (ACE) based on the nominal schedule assumed *the transmitter was still on*
  - Up to 12 exposures were lost; the team is examining how to best update procedures to prevent a similar loss in the future

Goddard Space Flight Center

2012 NASA Astrophysics Division Senior Review of Operating Missions



- **Call for proposals issued in early August**
  - EPO Appendix due Dec 15
  - SR Proposals due: January 18, 2012
  - EPO Review: Jan 23-25, 2012
  - Senior Review Panel Meeting: February 28-March 2, 2012
  - Panel Report/Recommendations expected March 30, 2012
  - The call for proposals and panel recommendations from previous senior reviews available at http://science.nasa.gov/astrophysics/2012-senior-review/
- **Have held several joint STScI/GSFC meetings**
- **Inputs being gathered from STScI and GSFC Teams**
- **Red Team Review and Executive Review being planned at Goddard**
  - December 8th Red Team Review to accommodate the goal of submitting proposal by end of 2011
    - Forward-looking science case
    - Compliance with Call for Proposals
    - Coherence of science story throughout proposal
    - Does the message come across to skimming reader as well as detailed reader?
  - Executive Review is a Goddard management review coordinated by the New Opportunities Office