



Goddard Space Flight Center

HST/GSFC Project Report



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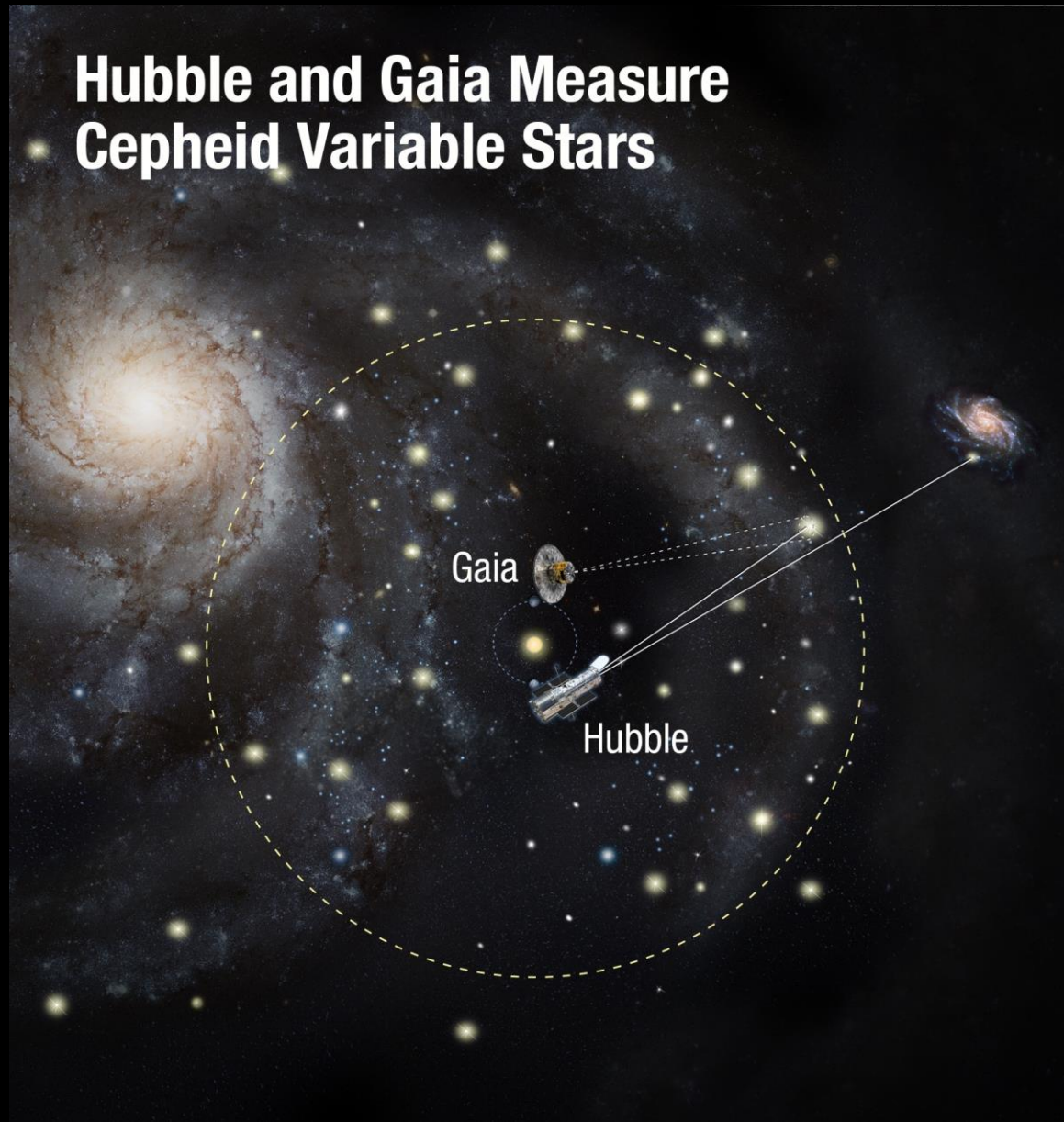
Science Operations Manager

**Space Telescope
Users Committee
Meeting
November 13, 2018**

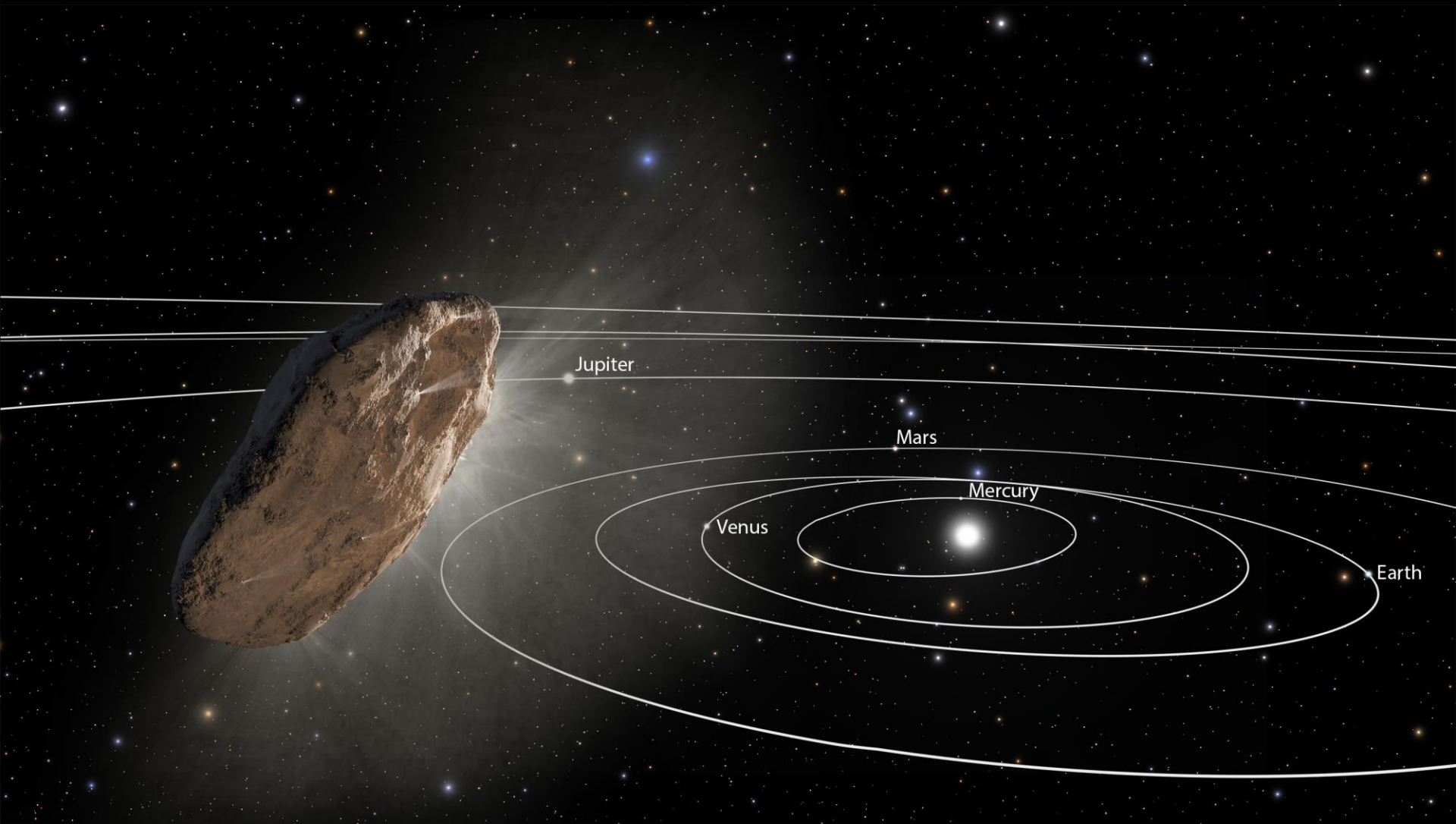
Agenda

- **Science highlights**
- **Senior Review**
- **Observatory Status (Gyros!)**
- **Budget Status**

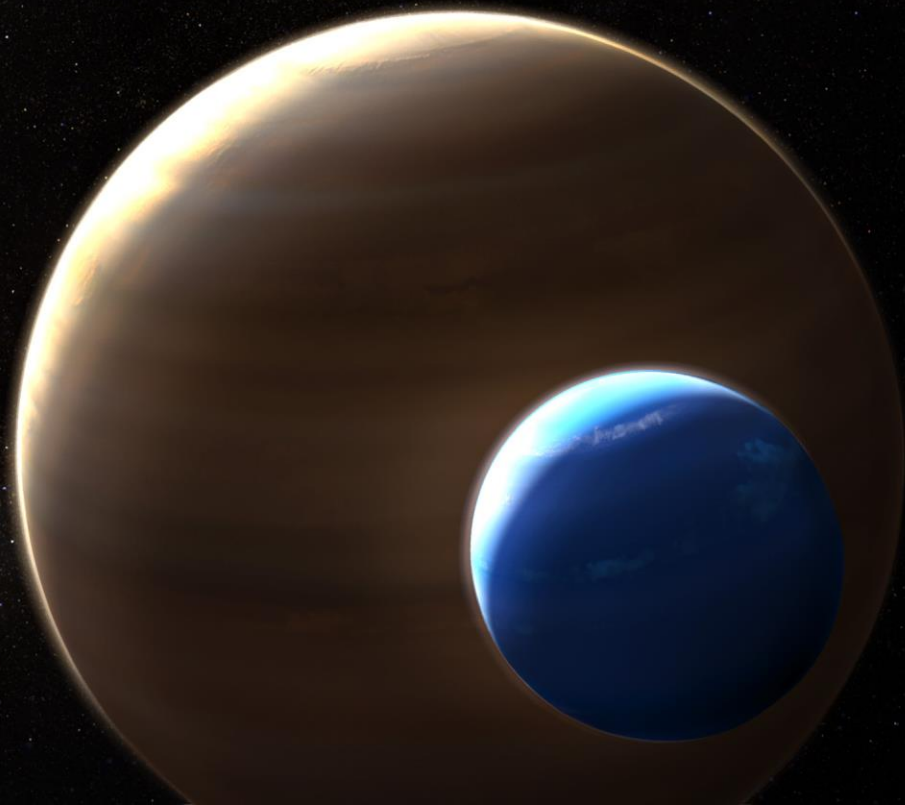
The Hubble Constant: High Precision Measurements Fuel A Cosmic Conundrum



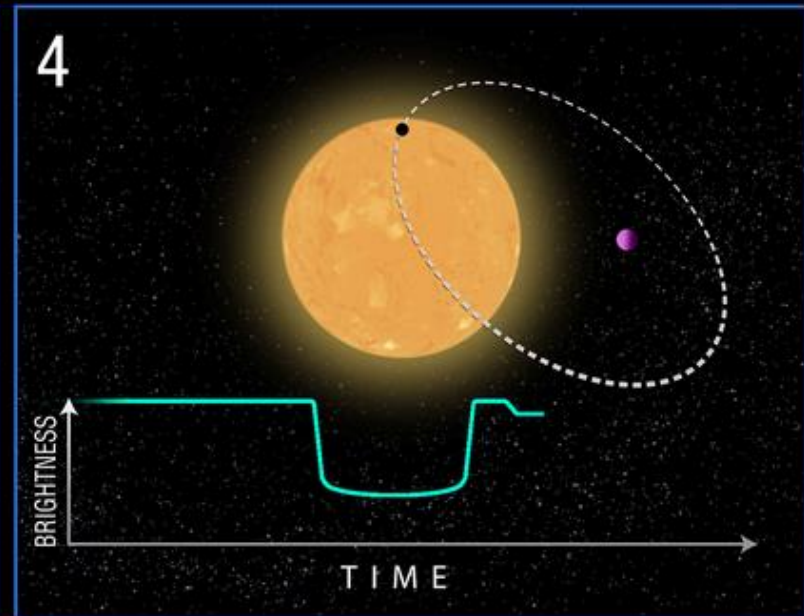
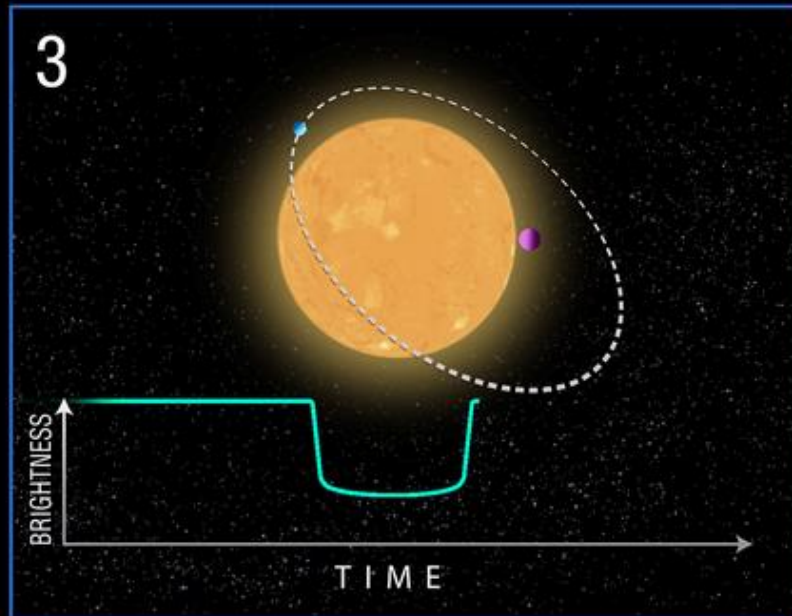
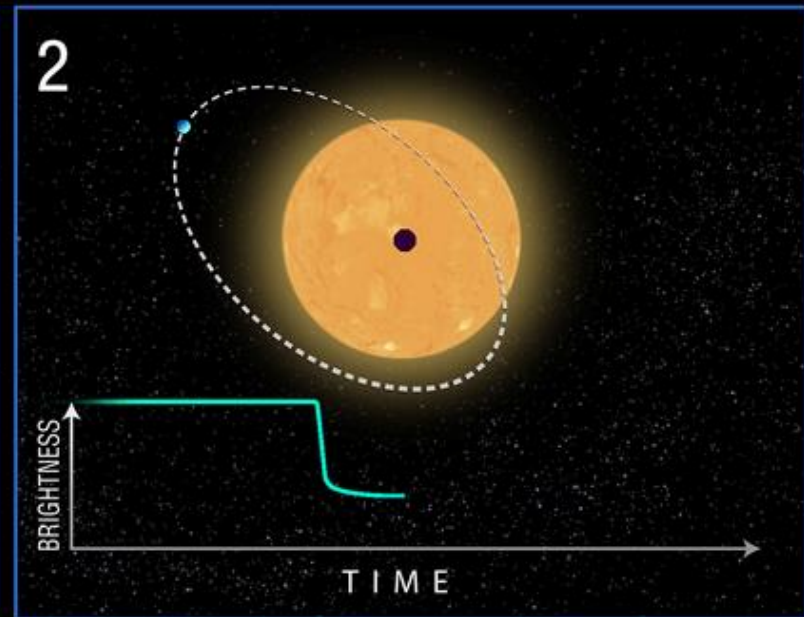
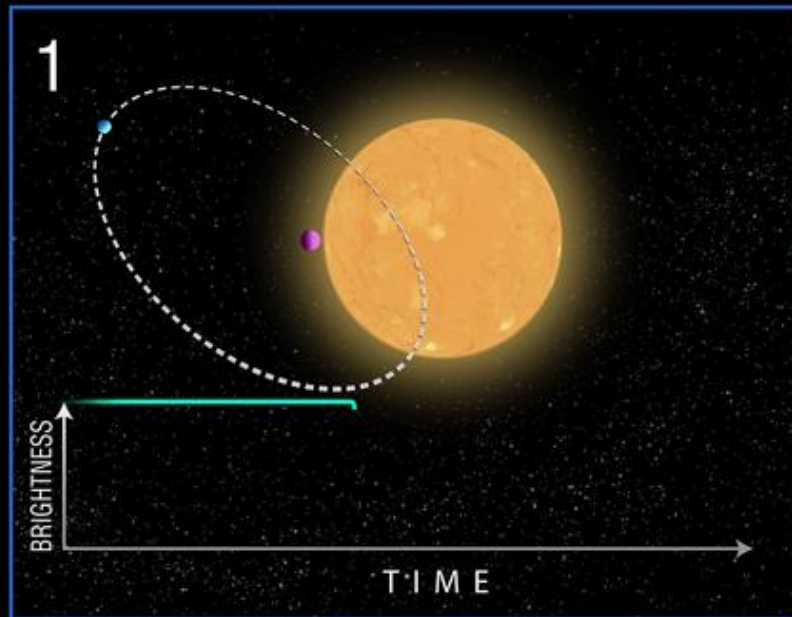
Interstellar Object Passing Through Solar System Gets Unexpected Boost



First detection of an Exomoon?



Transit of Kepler-1625b and Suspected Moon



Agenda

- **Science highlights**
- **Senior Review**
- **Observatory Status (Gyros!)**
- **Budget Status**

Agenda

- **Senior Review**

Senior Review

“These reviews of operating missions are NASA’s highest form of peer review, as the subject is not a single science investigation, or even a single space mission, but rather a portfolio of operating missions.”

NASA will use the findings from the Senior Review to:

- Prioritize the operating missions and projects
- Define an implementation approach to achieve astrophysics strategic objectives
- Provide programmatic direction to the missions and projects for FY20, FY21 and FY22
- Issue initial funding guidelines for FY23 and FY24 (revisited in the 2022 Senior Review).

Separate panels for Hubble, Chandra, and “rest of missions” (Fermi, NICER, NuSTAR, Swift, TESS, XMM-Newton)

Senior Review Subcommittee will merge the findings from the Chandra, Hubble, and Rest-of-Missions Panels and rank all missions on the basis of their scientific merit, their relevance and responsiveness to the division’s strategic goals, and their technical capability and cost reasonableness.

Schedule Highlights:

December 14th: Red Team Review of Hubble Senior Review Proposal, GSFC

February 1st: Proposals due to NASA HQ

February 25-27th: Hubble Panel Meeting, STScI

April-May: Mtgs of Senior Review Subcommittee, and APAC;

May-June: HQ Direction to Projects

HST Observatory Status

10/31/18

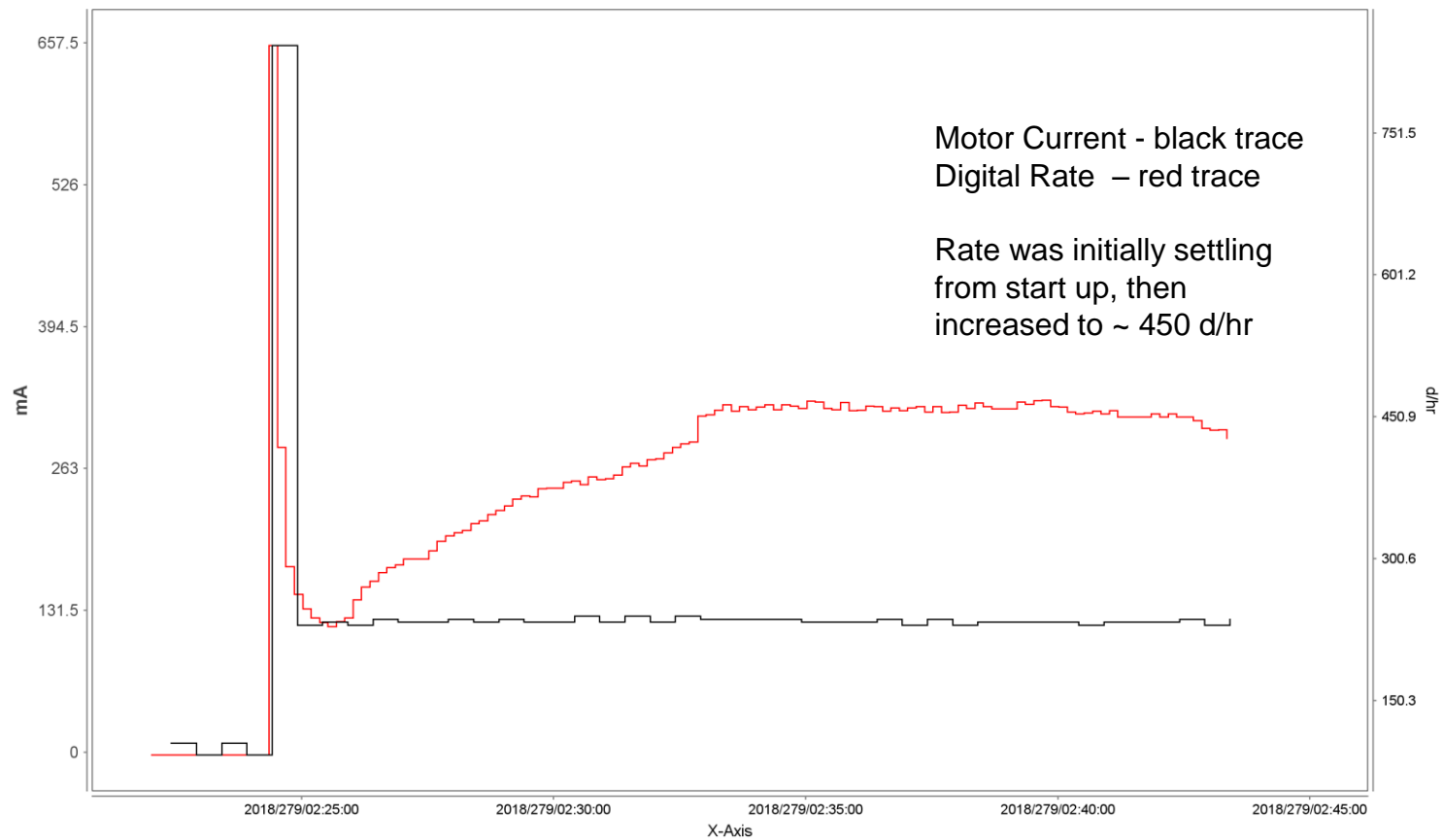
Subsystem		Summary
Science Instruments (SI)	G	<ul style="list-style-type: none"> WFC3 performance excellent; Channel Select Mechanism (CSM) movements significantly reduced without science impact; appearance of dust particles on the optic being monitored – 6 in 2018; no impact to science; No new recommendations from January 2018 Tiger Team meeting COS <ul style="list-style-type: none"> Moved to 4th position 10/2017; COS 2025 initiatives should extend 4th lifetime to ~2023 FUV detector sensitivity loss continues as expected; Sensitivity ARB closure 4/2011 ACS and STIS repaired instruments (SM4) performing nominally NICMOS in standby following decision to not restart following Cycle 19 proposal evaluations
Electrical Power System	G	<ul style="list-style-type: none"> Excellent battery performance; 510 Amp hour benchmark; raised voltage temperature cutoff 80mV on March 1 Solar Array 3 performance remains excellent Solar Array Drive Electronics (SADE) investigation following 2/15/13 SWSP completed; no further actions
Pointing Control System	G	<ul style="list-style-type: none"> <u>3 powered on 10/6/2018 – high output rates, normal performance 10/19/2018; significant AGyro 2 failed on 10/5/2018; Gyro OA signature ~100 as/hr at Enter Orbit Day</u> Gyro 1 failed on 4/21/2018; Gyro 6 powered on 4/21/2018 Gyro 5 failed on 3/7/14; Gyro 6 powered off 3/13/14 Gyro 3 removed from control loop/powered off 2011; Gyro 6 powered on; gyros on secondary heater controller Motor current increases: G4 120 mA to 190 mA in 9/2011, currently ~170 mA Attitude Observer Anomaly (AOA) (ARB report 10/2011) mitigation completed 11/2012 FGS-3 bearings degraded (~10% duty cycle to preserve life); FGS-2R2 Clear Filter operations began 1/2015
Data Management System	G	<ul style="list-style-type: none"> SI Control and Data Handling (C&DH) has had 12 lockup recoveries since 6/15/09; most recent was 1/19/18 SI FSW enhanced to protect detectors from SI C&DH lock up events Solid State Recorders (SSRs) 1&3 each experienced lock up in 2011 in the South Atlantic Anomaly (SAA); SSR3 experienced another lockup in SAA on 1/9/18; Alert monitors detect condition to minimize data loss
Communications	G	<ul style="list-style-type: none"> Multiple Access Transponder 2 (MAT2) coherent mode failed (12/24/2011); Two-way tracking unavailable Joint Space Operations Center (JSpOC) now the source for the operational ephemeris via Conjunction Avoidance Risk Assessment (CARA) team and the Flight Dynamics Facility
Thermal Protection System	G	<ul style="list-style-type: none"> New Outer Blanket Layers (NOBLs) installed on Bays 5,7, and 8 during SM4 Thermal performance is nominal

Hubble Gyros

- **Hubble Kalman Filter Sun Point (KFSP) safe mode and gyro issues**
 - Gyro 2 Failure
 - On October 5 at 6:02 pm EDT, the Low Mode Body Rate test failed followed ~1.4 minutes later by failure of the Two Gyro test and entry into Kalman Filter Sun Point safe mode
 - Gyro 2 motor current increased to ~ 313 mA and rate output from the gyro had ceased, both indicative of a stall
 - The Running Restart Autonomous Command Routine performed as expected, but failed to prevent the stall
 - An additional restart commanded from the ground at 10:12 pm was unsuccessful and Gyro 2 was considered failed
 - Gyro 3 high output rate
 - Gyro 3 was powered on at 10:23 pm EDT on October 5, exhibiting nominal motor current; digital high mode rates were ~ 450 deg/hr (~90x normal rates)
 - Formed Anomaly Review Board, initial meeting was held on October 9

Hubble Gyros

GYRO 3
Start Up Signature



Mnemonic			Pts	Min	Max	Mean	StdDev	Axis
G333 GRG2_3MC	mA	(TLM: RGA 2-3 Motor C)	43	-2.80000E+00	655.200E+00	122.614E+00	90.1681E+00	1
Q423 QRGCGCTS	d/hr	(TLM: RGA 3 Gyro Coun)	129	92.3948E+00	844.261E+00	374.396E+00	125.420E+00	2

— GRG2_3MC — QRGCGCTS

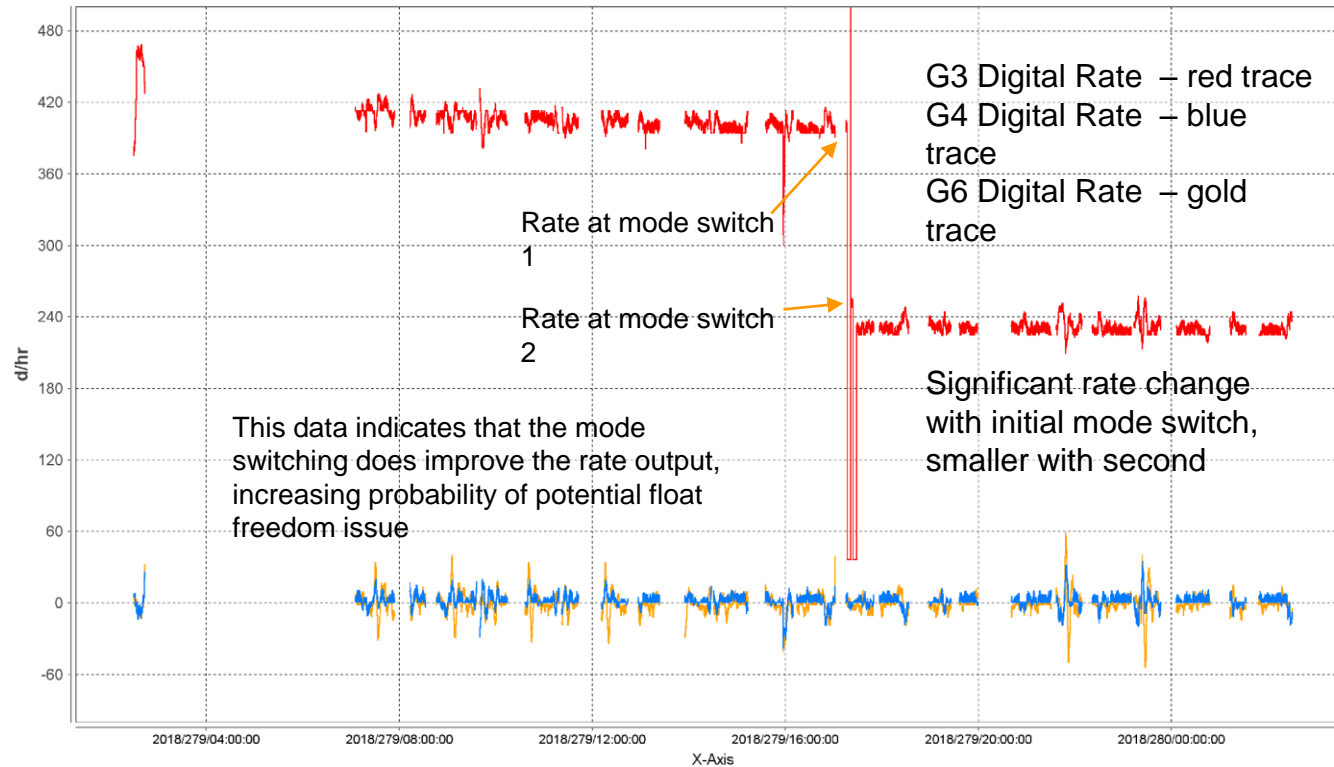
Hubble Gyros

Start time: 2018/279/02:30:00.000
Stop time: 2018/280/02:30:00.000
Untitled
Untitled

Datasource: Best Good Only
Filtering: All Data
Constraint Label: None

G3,4,6 Rates

Rate shifts with mode switching during failed KFSP recovery



Mnemonic	Pts	Min	Max	Mean	StdDev	Axis
Q423 QRGCCTS	5027	36.2191E+00	2.25108E+03	323.365E+00	95.3556E+00	1
Q433 QRGDGCTS	5032	-38.0273E+00	34.8135E+00	1.78696E+00	5.75192E+00	1
Q453 QRFGGCTS	5032	-54.1738E+00	59.0612E+00	-8.24786E-01	8.80636E+00	1

— QRGCCTS — QRGDGCTS — QRFGGCTS

Job Id: GURO_PLOTS_PLOT_153616514

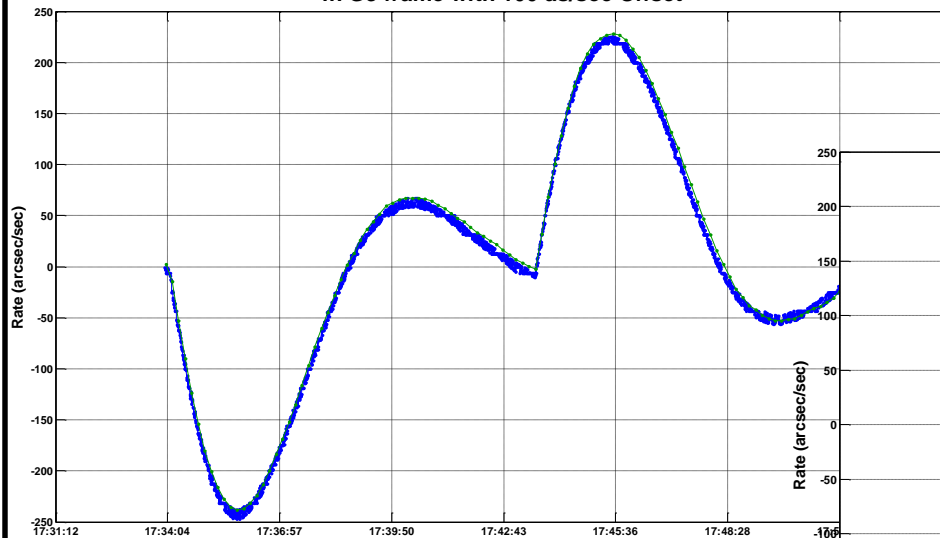
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Hubble Gyros

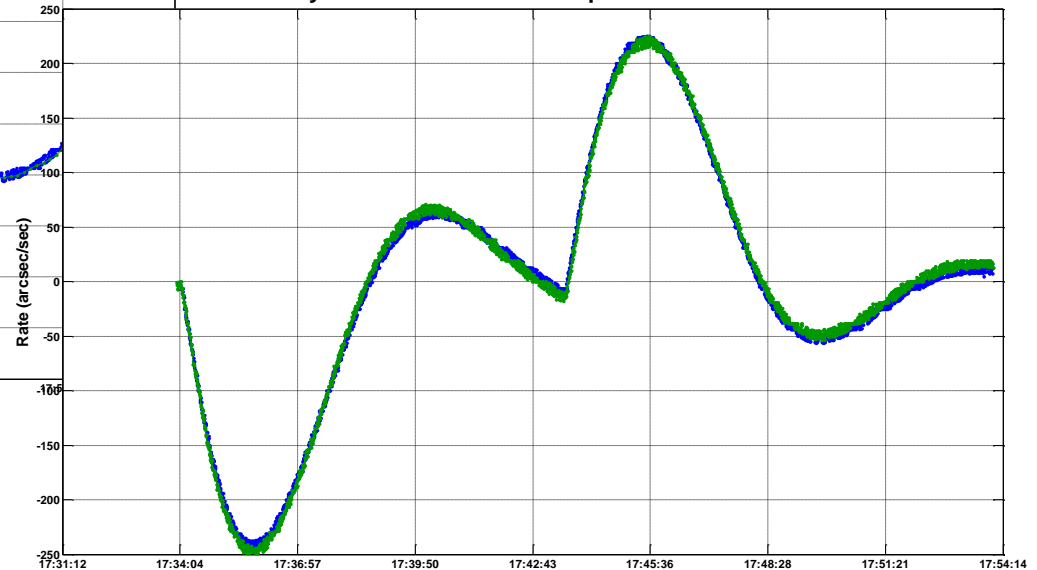
- **Gyro 3 recovery**

- Toggling the gyro mode (High to Low) multiple times between October 6 and October 10 reduced the bias from ~ 450 to ~ 100 deg/hr.
- KFSP offset test conducted on October 10 showed that Gyro 3 accurately followed vehicle rates in high mode and low mode data acquired during the transition through lower rates was also valid

Gyro 3 Measured Rate compared to Vehicle Rate
in G3 frame with 100 as/sec Offset



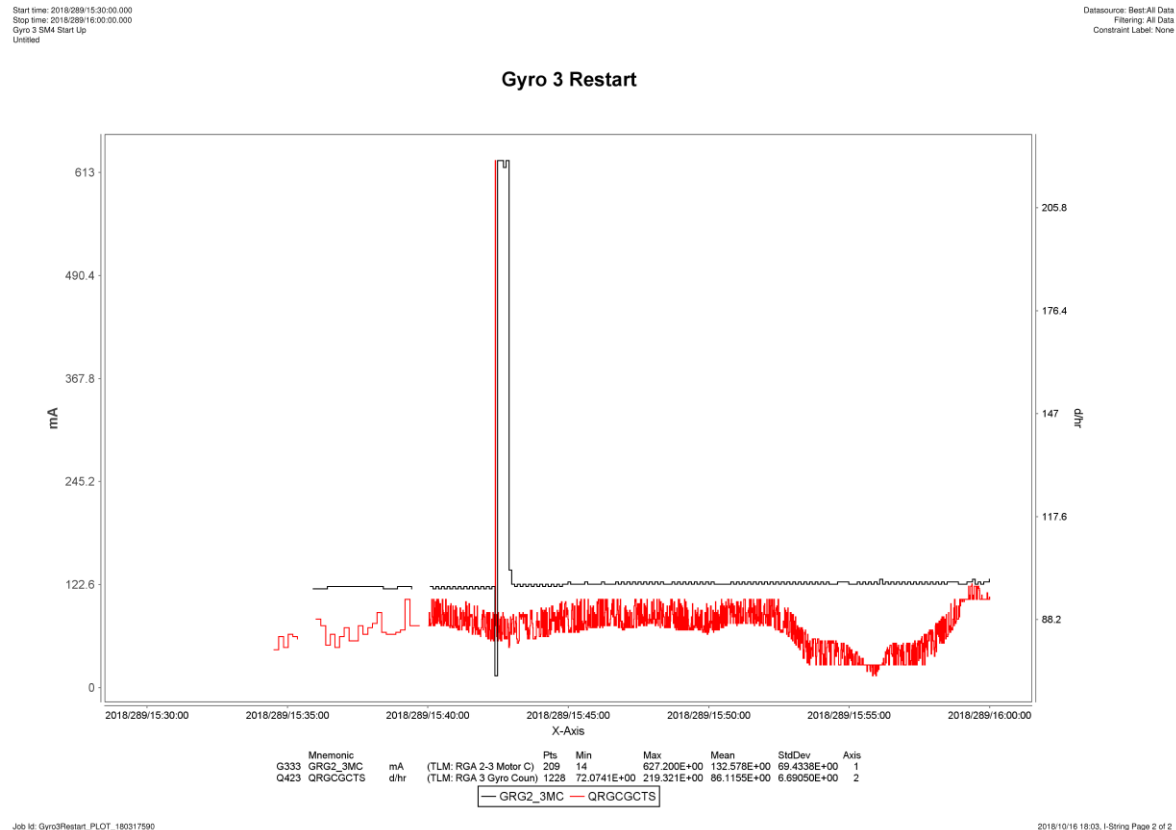
Gyro 3 Measured Rate compared to G4 Rate



Hubble Gyros

- **Gyro 3 recovery**

- Additional mode toggles appeared to have little effect, although the bias slowly drifted down to ~85 deg/hr by October 16
- A running restart of Gyro 3 was performed on October 16; no change observed

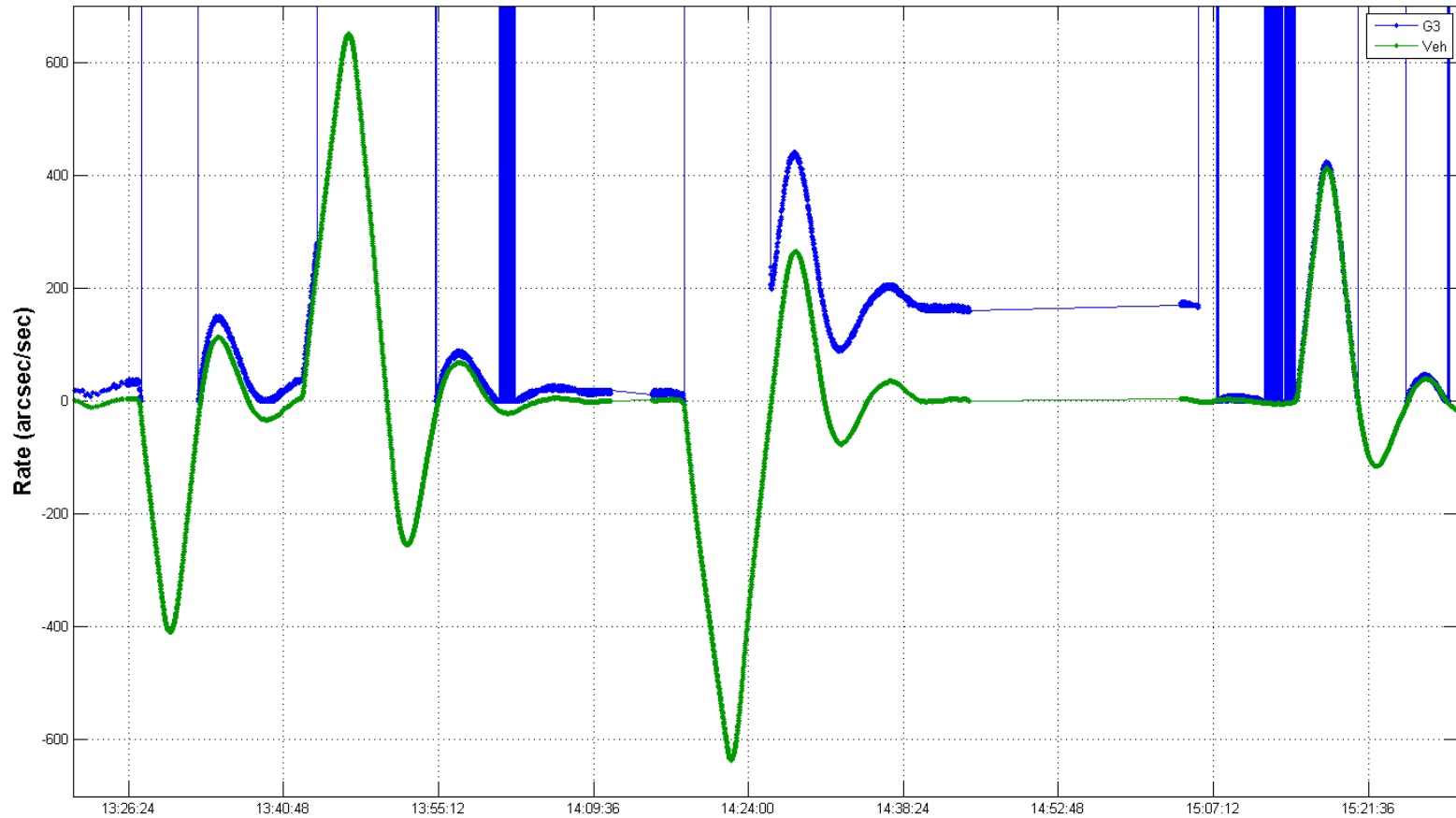


Hubble Gyros

- **Gyro 3 recovery**
 - On October 18, a set of maneuvers about the Gyro 3 input axis in combination with toggling to low mode during at maximum rate output, reduced the high mode output rate from ~ 85 deg/hr to ~ 34 deg/hr
 - A repeat of the same maneuvers on October 19 reduced the bias rate down to operational levels
 - An increase in the output was observed following the third of 4 segments. Toggling to low mode removed the bias, and the final segment was completed in high mode with no adverse indications

Hubble Gyros

Gyro 3 High Mode Measured Rate
compared to Vehicle Rate in G3 frame



Hubble Gyros

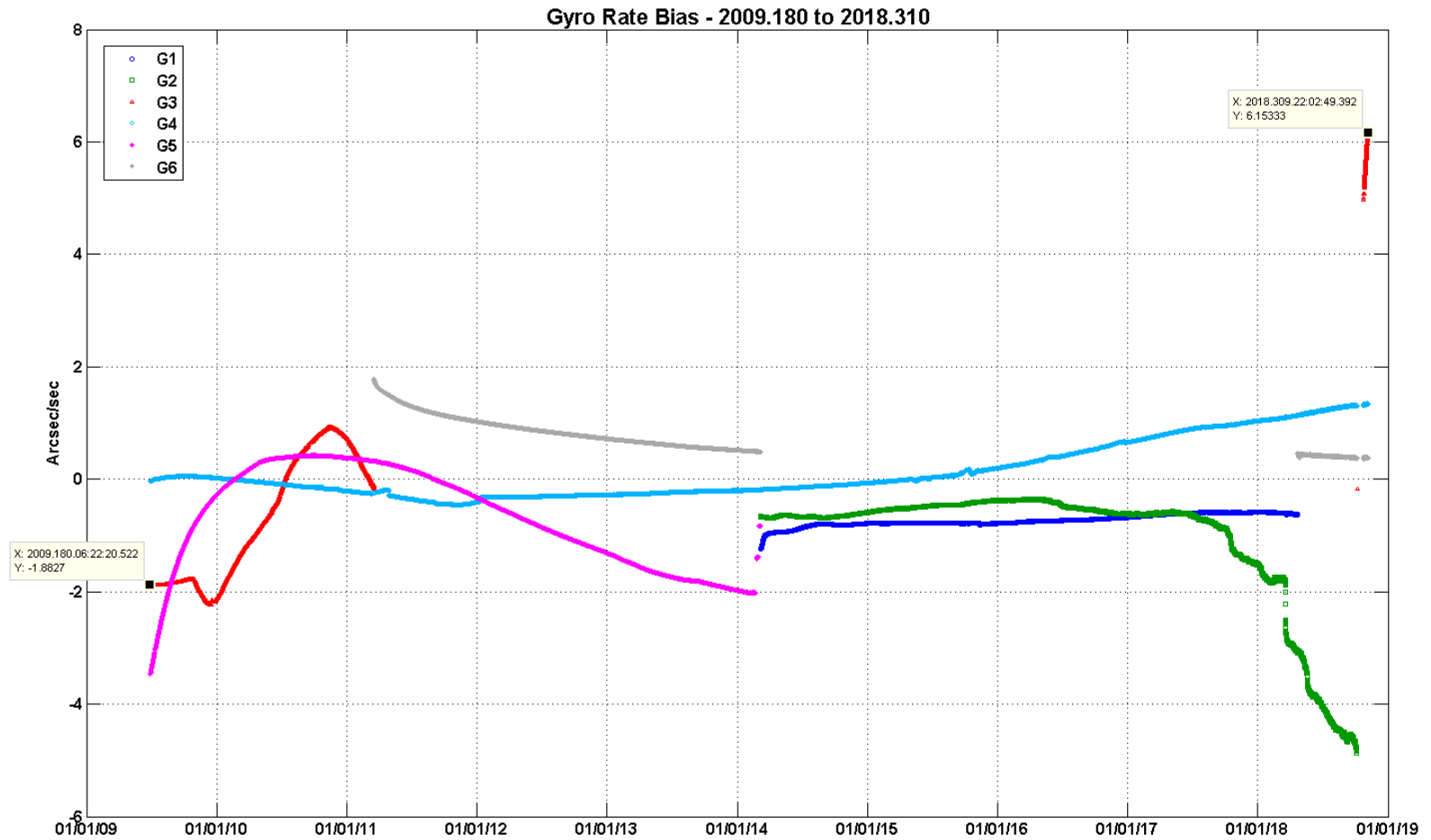
- **Recovery to Science Operations**

- Quiet periods and additional maneuver sequences indicated the bias was remaining stable
- Hubble was promoted to normal mode for 8-10 hour periods daily on October 24-26 to obtain data to calculate new Gyro 3 bias and perform gyro calibration maneuvers
- Following nominal performance and an onboard software update to provide additional protection against an unexpected sudden large bias shift, Hubble initiated a return to science timeline on Friday evening, October 26
- Wide Field Camera 3 successfully completed the first set of exposures at 2:10 am EDT on October 27, completing the first science observations since October 5
- Targets this first weekend were scheduled greater than 90 degrees from the Sun; last week was constrained to greater than 62 degrees, with exception for New Horizons program ~60 degrees (real-time monitoring was employed)
- Team will continue to work toward getting back toward nominal 50 degree constraint

Gyro 3 Performance

- **Early performance assessment**
 - Gyro 3 has a significant bias drift
 - Gyro 3 exhibiting ~100 as/hr spike at Enter Orbit Day, sinusoidal variation throughout the remainder of the orbit
 - Jitter reduced from ~15 to ~8 mas

Gyro 3 Performance

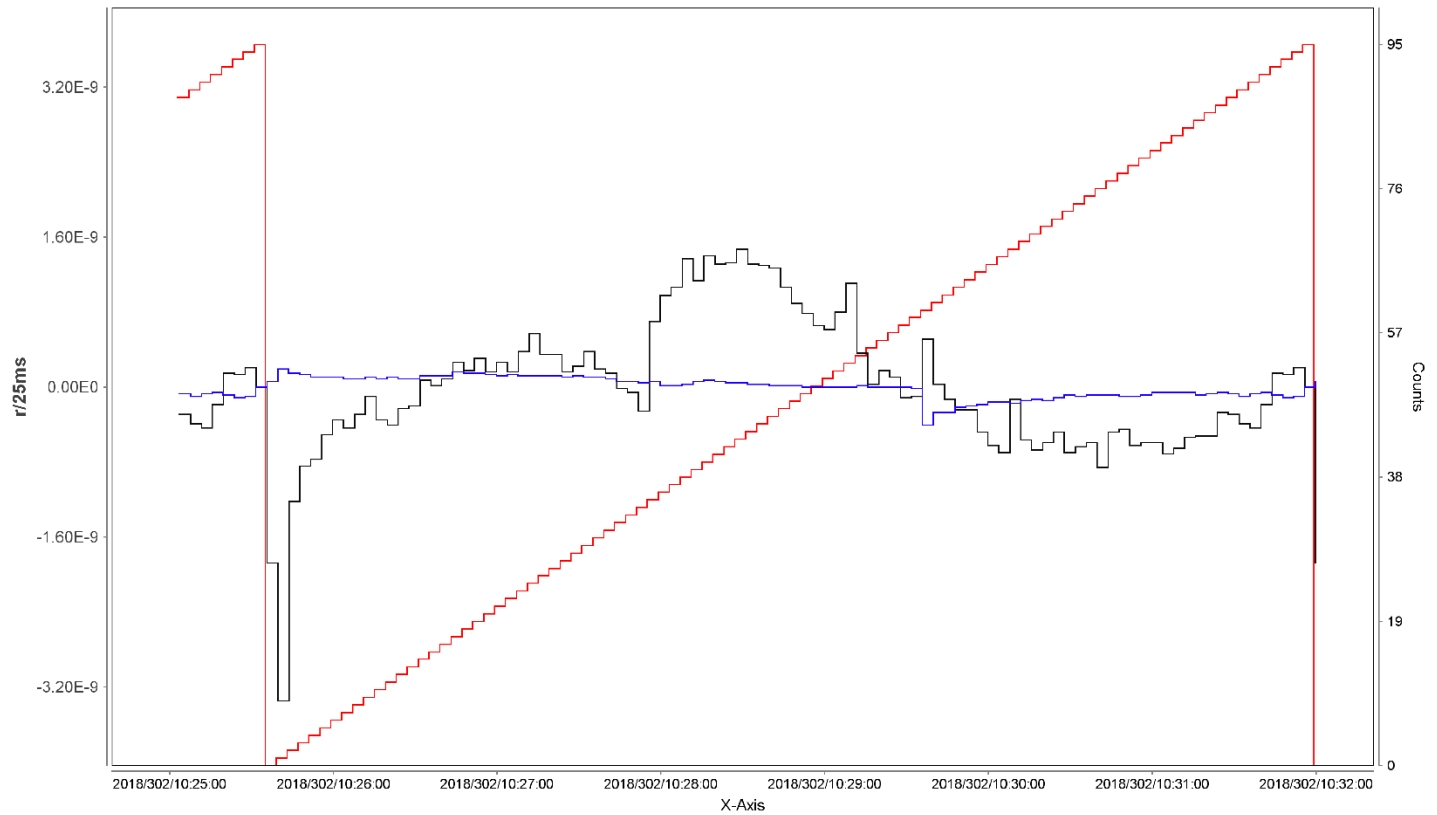


Hubble Gyros

Start time: 2018/302/10:25:00.000
Stop time: 2018/302/10:32:00.000
Historical Observer
Untitled

Datasource: BestGood Only
Filtering: All Data
Constraint Label: None

Historical Observer (+/- 120 as/hr)



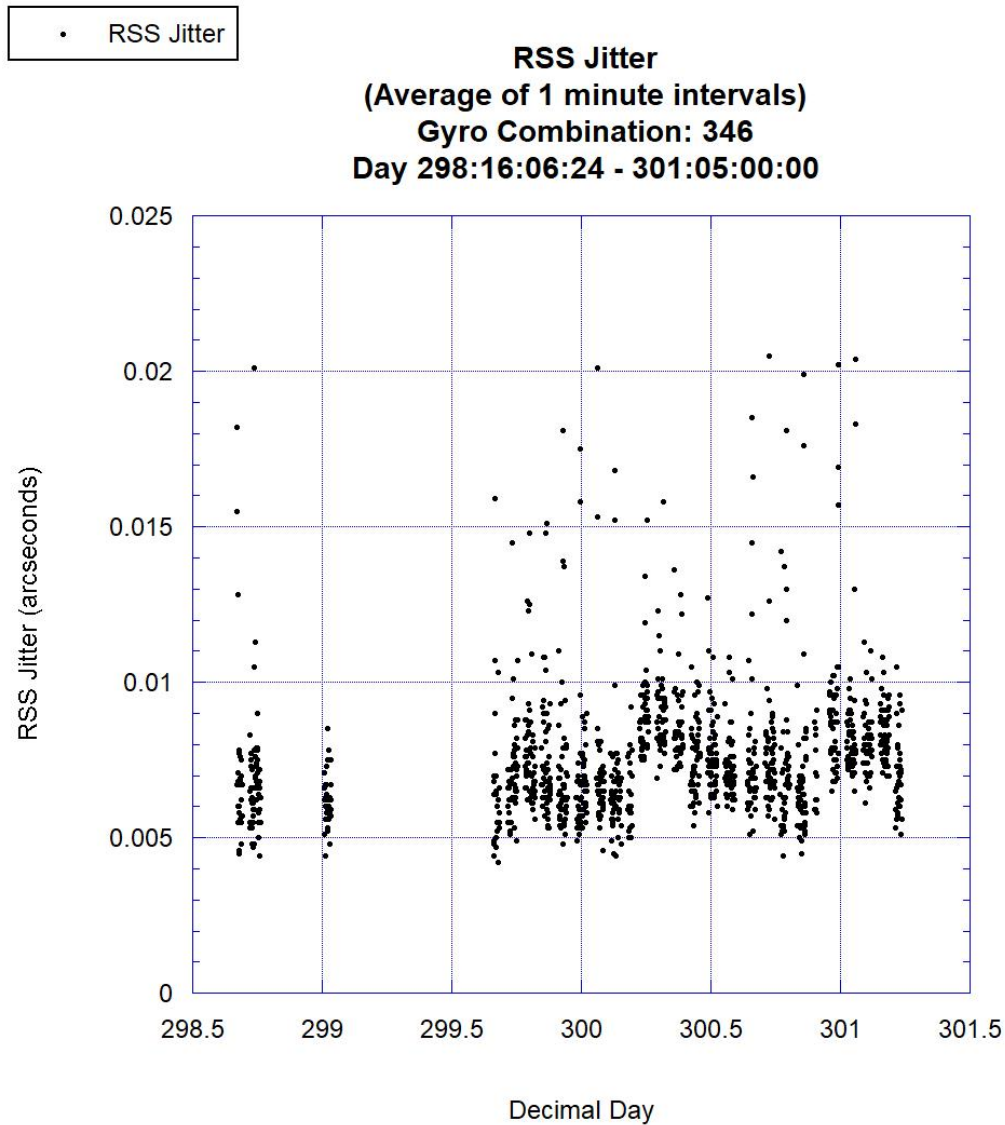
Mnemonic		Pts	Min	Max	Mean	StdDev	Axis
Q112 QHOV2CP	r/25ms (TLM: HOV2Compensatio)	105	-4.07454E-10	1.89174E-10	-6.51382E-12	1.10548E-10	1
Q113 QHOV3CP	r/25ms (TLM: HOV3Compensatio)	105	-3.34694E-09	1.46974E-09	-2.59169E-11	7.36852E-10	1
Q111 QHOBIN	(TLM: HO TelemetryBin)	105	0	95	50.4000E+00	29.5191E+00	2

— QHOV2CP — QHOV3CP — QHOBIN

Job Id: HO_PLOT_111550340

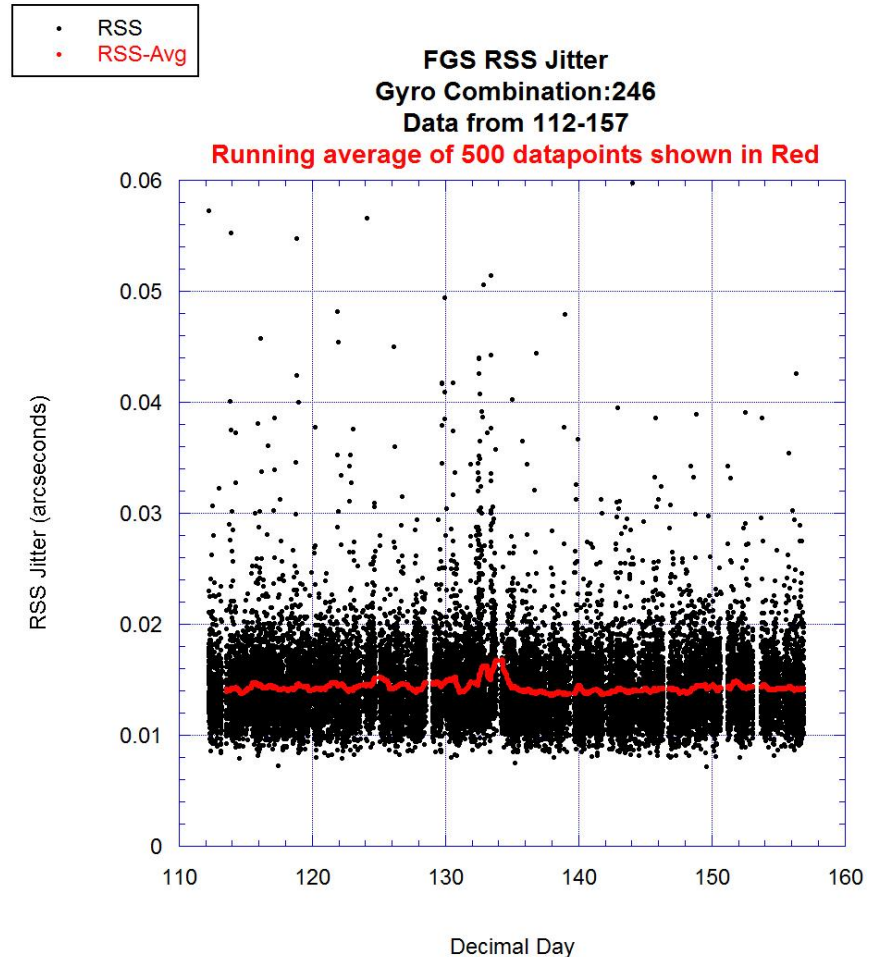
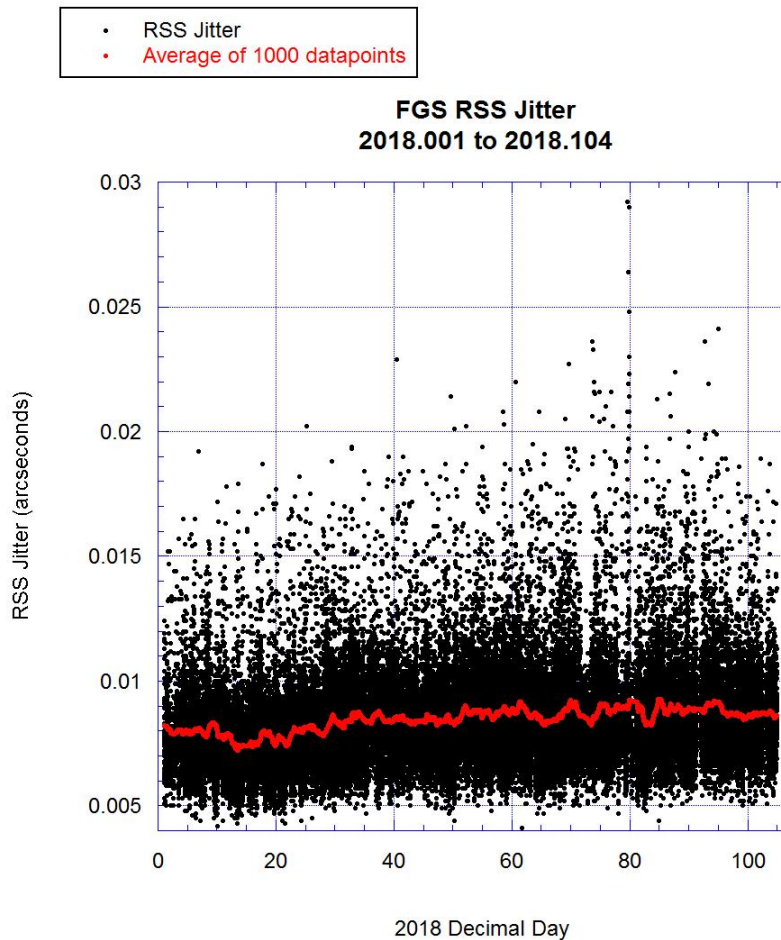
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Gyro 3 Jitter Performance



Gyro-2 performance and Jitter

- HST boresight jitter due to gyro-2 high frequency noise had increased from early 2017 to early 2018 where it appeared to flatten at average ~ 9 mas rss
- The new gyro complement after the failure of Gyro 1 shifted the performance to ~ 15 mas



Mission Operations – Gyro Run Time Performance

10/31/18

Current Gyro Runtimes

Post SM4 RGA	Status	Flex Lead	Total Hours 2018/304
G1	Failed April 2018	Standard	43359
G2	Failed October 2018	Standard	47550
G3	On	Enhanced	22975
G4	On	Enhanced	93473
G5	Failed March 2014	Standard	51497
G6	On	Enhanced	40587

Previous Flex Lead Failure Runtimes

Date of Failure	Gyro	Flex Lead	Total hours at failure
1992.281	G6	Standard	34825
1997.099	G4	Standard	31525
1998.295	G6	Standard	46276
1999.110	G3	Standard	51252
1999.317	G1	Standard	38470
2007.243	G2	Standard	58039
2014.066	G5	Standard	51497
2018.111	G1	Standard	43359
2018.278	G2	Standard	47550

Maximum runtime hours (current G4) 93,473

Minimum runtime hours (SM3A G5, rotor restriction) 13,857

Mean runtime hours for 6 current onboard gyros 49,907

Mean runtime hours for all 22 HST operational gyros 43,698

Mean runtime hours for the 9 HST flex lead failure gyros 44,755

Budget Status

- **Budget Outlook (New Obligation Authority (NOA))**

- FY17 appropriated budget was \$97.3M

\$M	FY18	FY19	FY20	FY21	FY22	FY23	FY24
PPBE-18	\$98.3	\$98.3	\$98.3	\$98.3	\$98.3	\$98.3	
PPBE-19	\$83.3	\$88.3	\$88.3	\$93.3	\$98.3	\$98.3	
PBR-19	\$83.3	\$78.3	\$88.3	\$93.3	\$98.3	\$98.3	
PPBE-20	\$98.3	\$78.3	\$88.3	\$93.3	\$98.3	\$98.3	\$98.3

- Expected to manage \$35M reduction by utilizing the existing large uncosted carryover associated with awarded grants; have adjusted the grants funding profile going forward
- Erosion of uncosted carryover will result in need to reduce costs FY21-24

- **General Observer / Archival Research Outlook**

- Cycle 24 and Cycle 25 were awarded the value recommended by the Financial Review Committee (FRC); expect to award FRC recommendation for Cycle 26
- *Budget guideline will require cost reductions within the Senior Review budget horizon, including potential impacts to the GO/AR as early as Cycle 27*

Discussion

- **Questions?**