Goddard Space Flight Center

HST/GSFC Project Report

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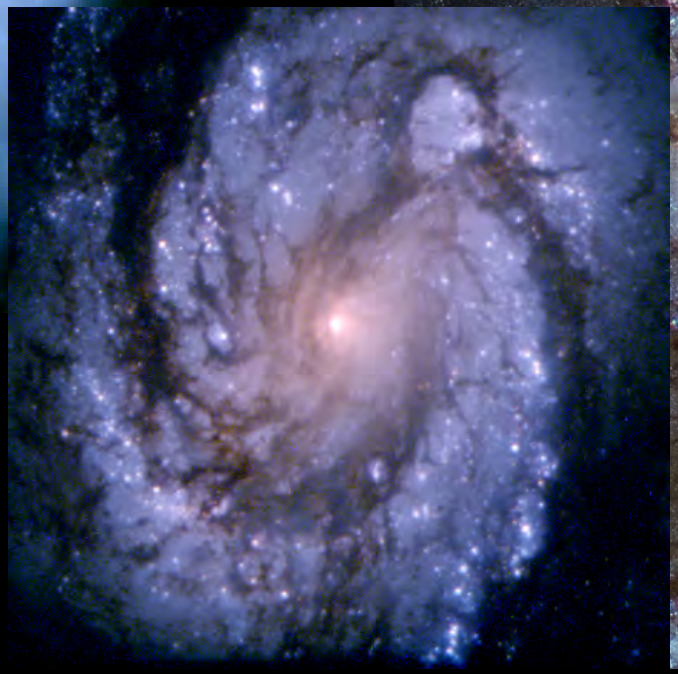
Space Telescope Users Committee Meeting
May 13, 2019

Celebrating Hubble Servicing: 25th Anniversary of HST Servicing Mission 1

WFPC1

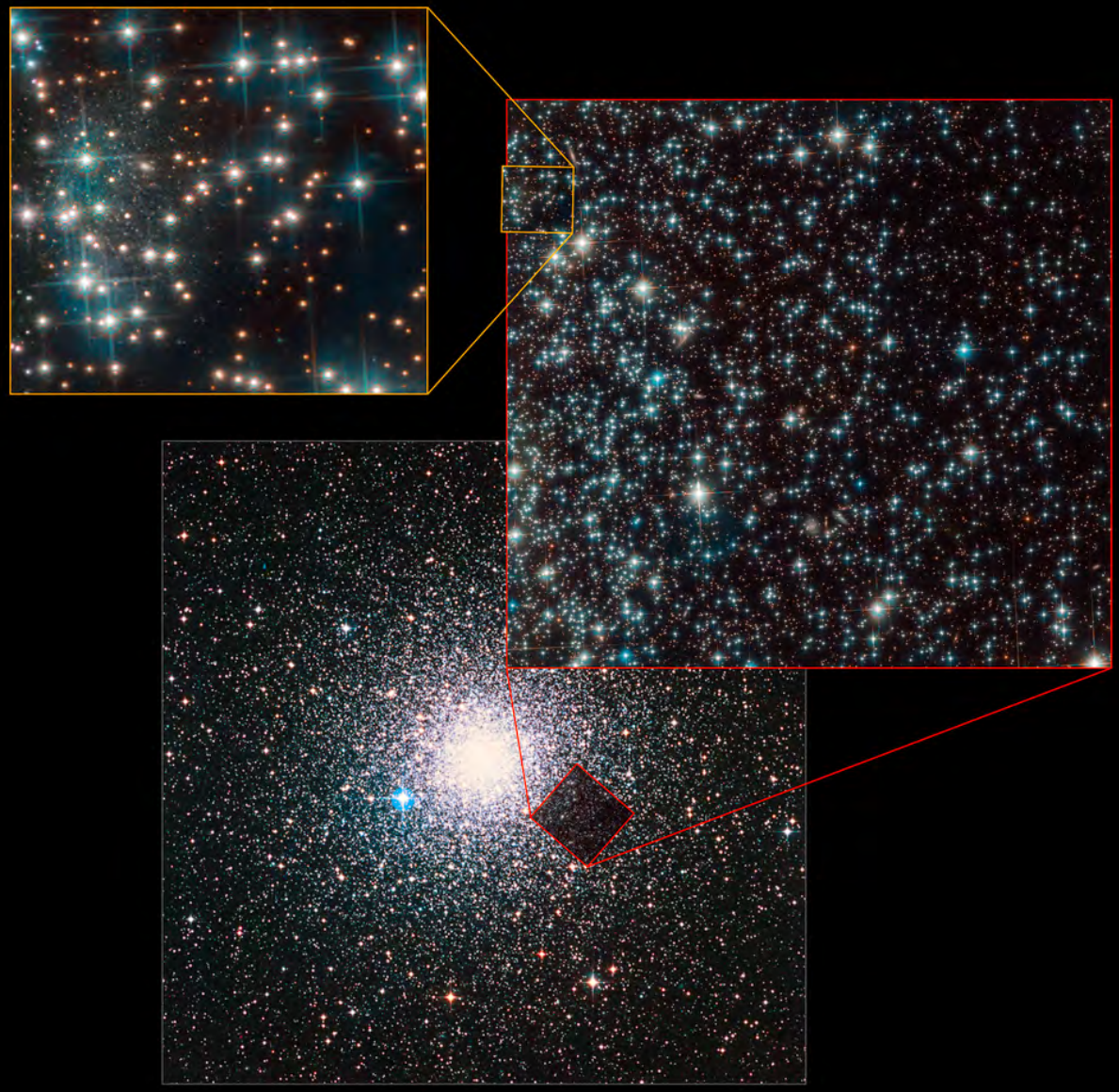


WFPC2

WFC3

Galaxy M100

Hubble still surprises us: Unexpected neighbor dwarf galaxy hiding behind Milky Way globular cluster



NASA, ESA, and L. Bedin (Astronomical Observatory of Padua, Italy)

Asteroid sprouting dust “tails” as it slowly spins up

NASA, ESA, K. Meech and J. Kleyna (University of Hawaii), and O. Hainaut (European Southern Observatory)

Agenda

- **Science highlights**
- **Senior Review**
- **Observatory Status**
- **Budget Status**

Senior Review 2019

"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 (delays due to federal government shutdown):

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

~~February 1st~~: March 15th: HST Senior Review Proposal submitted to NASA HQ

~~February 25-27th~~: May 6-8th: HST Panel Mtg with Mission Presentations/Discussions, STScI

~~April-May~~: June-July?: Mtgs of Senior Review Subcommittee, and APAC;

~~May-June~~: June-Aug?: HQ Direction to Projects

The panel was reminded that no full (flagship, multi-wavelength) Hubble follow-on mission is even possible until at least the 2030's…

Healthy Science Instruments

Subsystem		Summary
Science Instruments (SI)	G	• ACS entered suspend mode on 2/28/2019 due to failed checksum during return to normal science mode following routine anneal cycle; returned to normal operations status on 3/6 following assessment • ACS experienced same checksum suspend on 4/3, recovered that day; Tiger Team investigation identified EEPROM chip exhibiting a temperature dependence – successful mitigation implemented for May 3 anneal • WFC3 January 2019 suspend attributed to Single Event Upset within onboard telemetry collection circuitry • WFC3 performance excellent; Channel Select Mechanism movements significantly reduced without science impact; appearance of dust particles on the optic being monitored – 7 in 2018; no impact to science • COS moved to 4th position 10/2017 began COS 2025 initiative; investigating potential 5th lifetime position • STIS repaired instruments (SM4) performing nominally • NICMOS in standby
Data Management System	G	• SI Control and Data Handling (C&DH) has had 12 lockup recoveries since 6/15/09; most recent was 1/19/18 • Operations Concept and Requirements Review for a rapid recovery from lockup events completed on April 4; anticipate operational availability May 31,2019 • SI FSW enhanced to protect detectors from SI C&DH lock up events

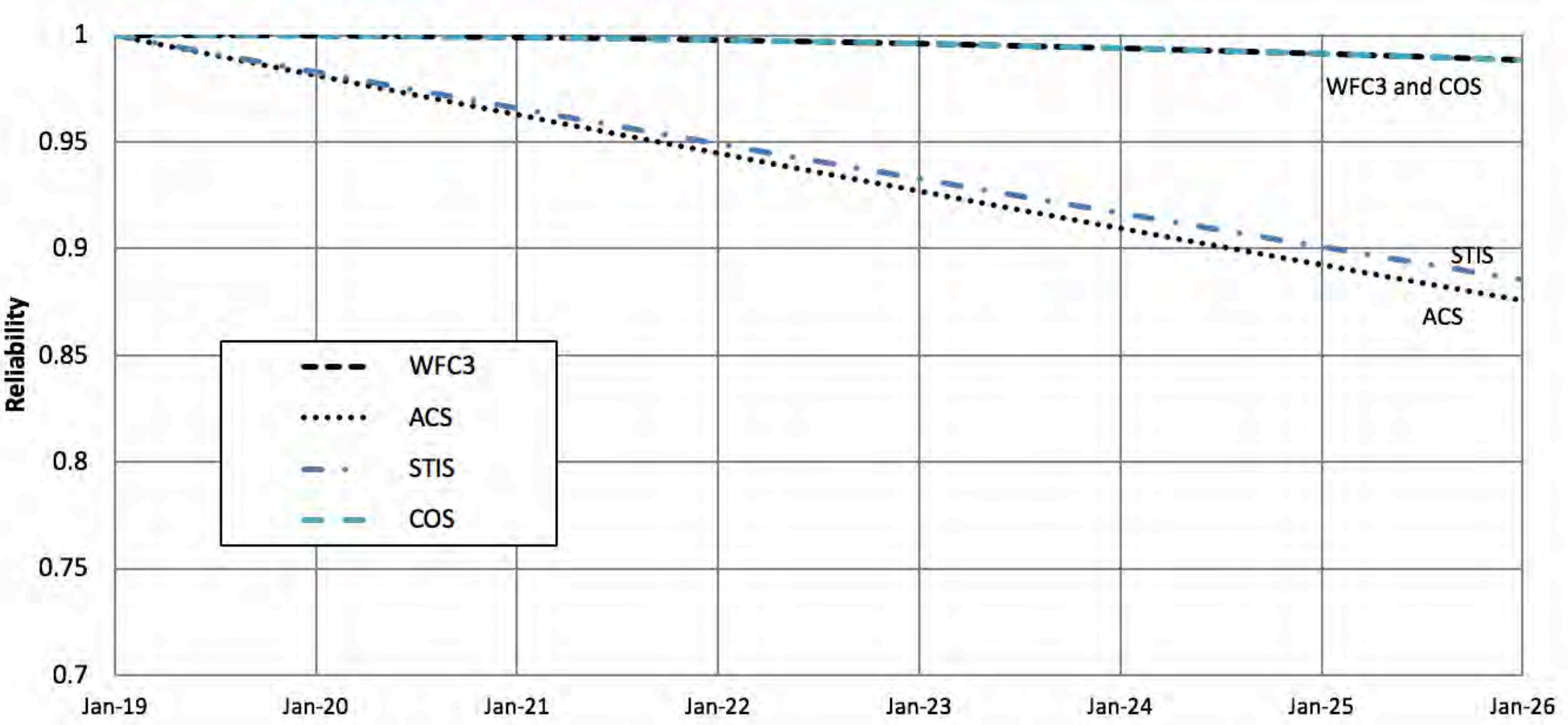
Operations teams respond quickly to address anomalies and perform sustaining engineering

- Payload flight software team, working in concert with the COS instrument team enabled implementation of COS 2025 initiative, significantly extending the life of the instrument and providing the pathway for operations beyond the 4th lifetime position; assessing the location and characterization of a potential 5th COS lifetime position
- Utilized effective technical reach back to provide anomaly response for the January WFC3 suspension, as well as the ACS suspensions associated with the normal anneal cycle
- Developed requirements and operations concept for a rapid recovery from the periodic Science Instrument Control and Data Handling lock up events to reduce return to science from ~24 hours to less than 10 hours; anticipate Operations Readiness Review on May 31
- Looking forward – preparing for transition to One Gyro Science to minimize science down time when the need occurs

Instrument Reliability

Science Instrument reliability remains high beyond the budget horizon

- NASA Engineering and Safety Center provided methodology
- Greater than 95% probability for each of WFC3 and COS operating through 2025
- Greater than 85% probability for each of ACS and STIS operating through 2025



Healthy Spacecraft

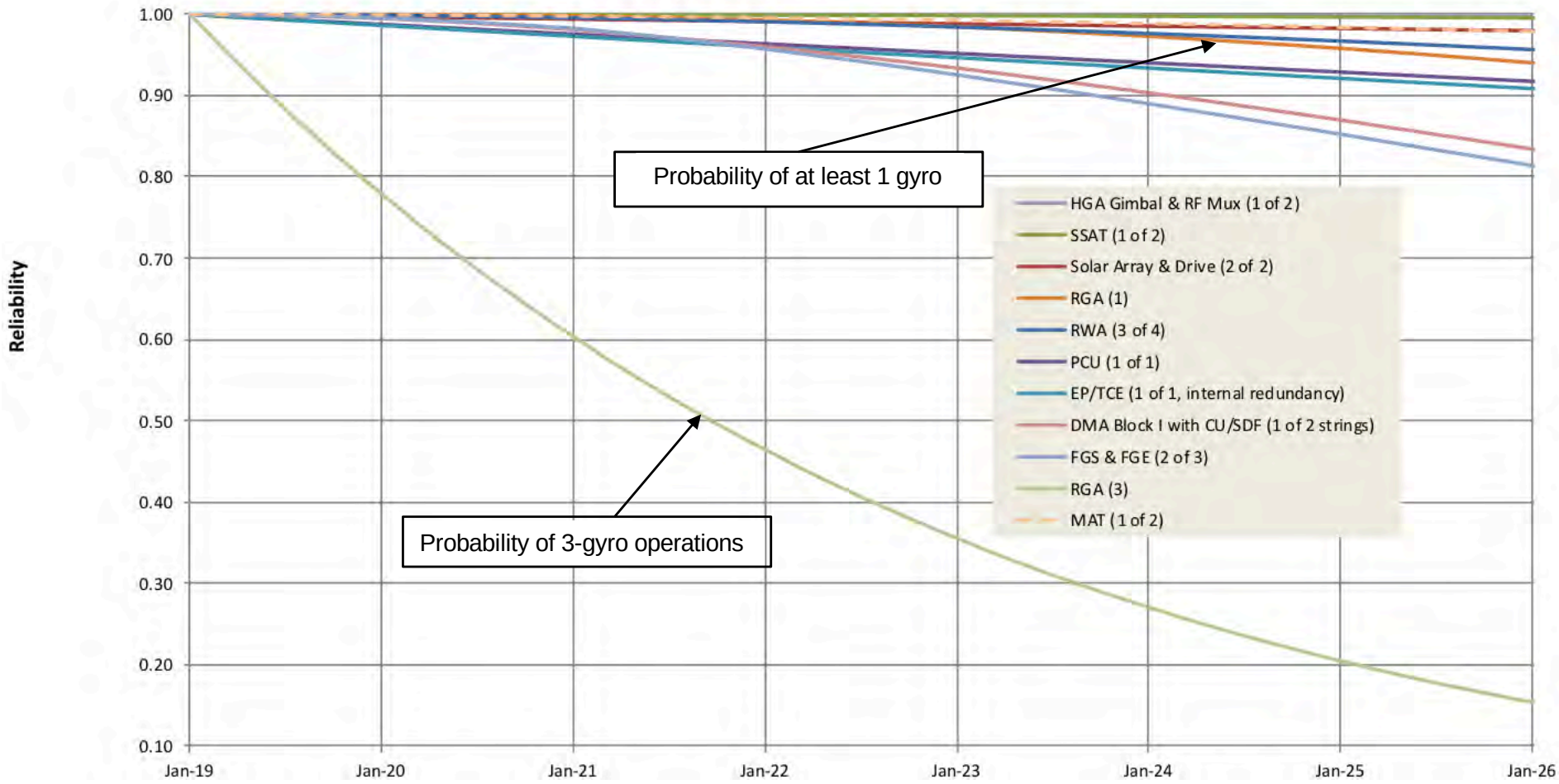
Subsystem		Summary
Electrical Power System	G	• Excellent battery performance; 510 Amp hour benchmark; Solar Array 3 performance remains excellent • Solar Array Drive Electronics (SADE) investigation following 2/15/13 SWSP completed; no further actions
Pointing Control System	G	• Gyro 6 motor current increased from ~120 mA to ~180mA on 3/21/2019; Gyro 4 similar event in 9/2011 • Gyro 3 powered on 10/6/2018 – initial high output rates reduced to normal 10/19/2018; (3-4-6 complement) • Gyro 2 failed on 10/5/2018 • 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 • 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	• 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	• 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	• New Outer Blanket Layers (NOBLs) installed on Bays 5,7, and 8 during SM4 • Thermal performance is nominal

- Hubble has greatest productivity in 3-gyro mode; 1-gyro provides equivalent performance as 2-gyro; when necessary the plan is to transition from 3-gyro to 1-gyro mode
- Gyro-3 rate bias noise is challenging the operations teams

Spacecraft Reliability

Critical subsystem reliability remains high beyond the budget horizon

- Greater than 80% probability of critical systems operating through 2025
- Nearly 95% probability of one gyro being available through 2025; 50% probability of 3-gyro operations through late 2021



Summary of Current Gyro-3 Mitigation Efforts

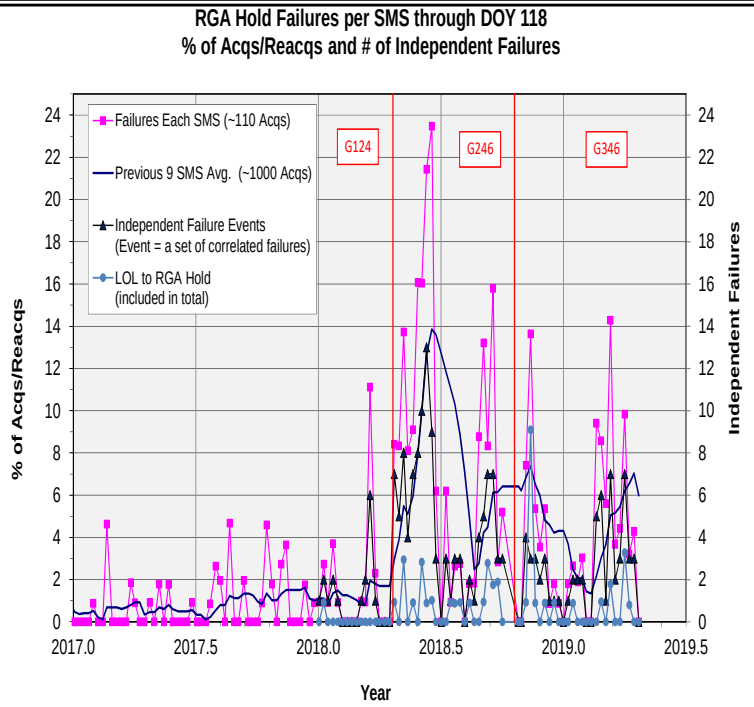
Addressing gyro-3 rate bias

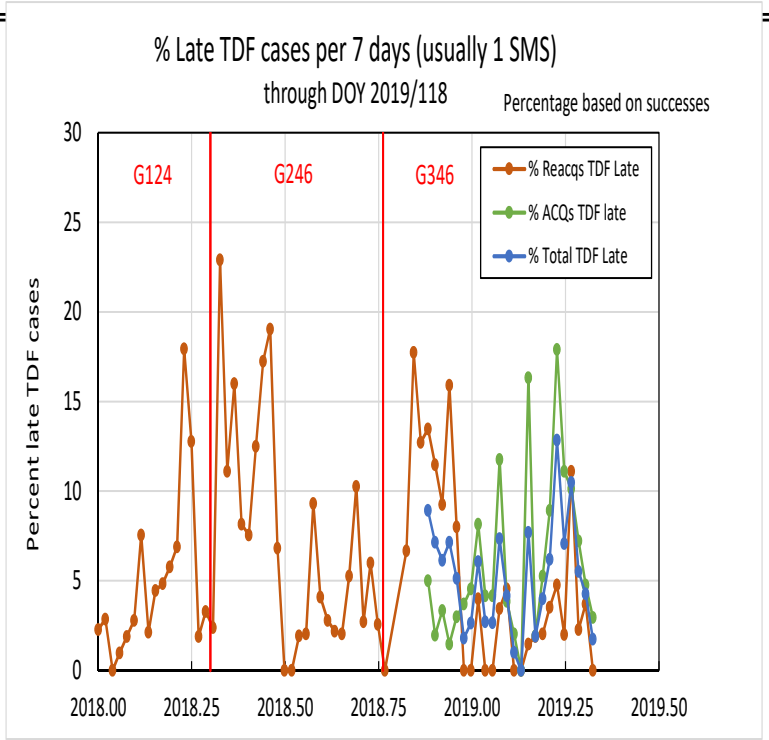
- Planning and scheduling actively reduces the time, when possible, between the onboard attitude update scheduled prior to the observation and the actual target acquisition
- Planning and scheduling added onboard attitude corrections prior to target reacquisitions (observations of the same target that are interrupted by Earth occultation)
- Added 60 seconds to the scheduled acquisition durations when possible without impacting science

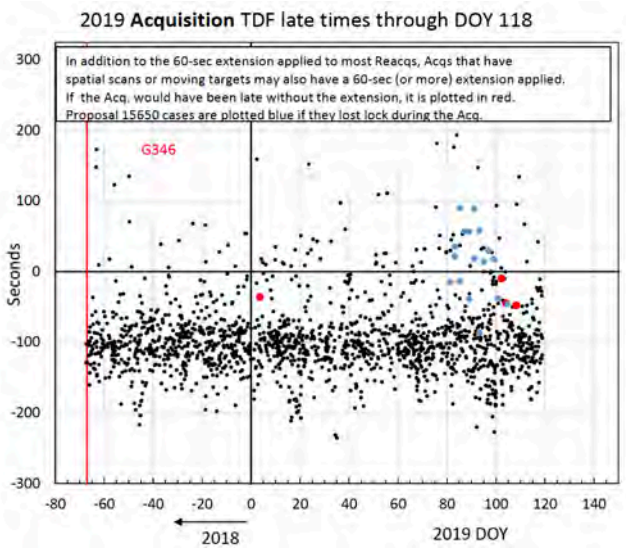
Addressing instances of Loss of Lock during the target acquisition sequence

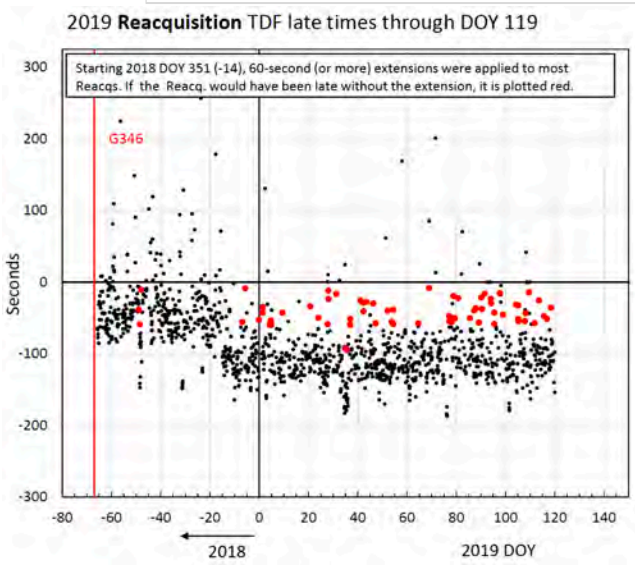
- Spacecraft engineers, working with science operations, recently modified the Fine Error Signal configuration parameter for all 3 Fine Guidance Sensors to match spacecraft dynamics more closely
- Modified the routine target acquisition sequence
  - Implemented Early Detection Loss of Lock (LOL) Autonomous Command Routine-7 to expedite the LOL recovery sequence if the system detects the presence of a ‘likely’ erroneous large roll bias to improve likelihood of acquiring the target within the allocated time and prevent a Take Data Flag late event
  - Utilizing Diagnostic Data Recorder to gather data to characterize Fine Guidance Sensor performance during LOL events
  - Beginning April 29 when possible, will plan guide star acquisitions such that vehicle offset maneuvers will not be executed

Target Acquisition Performance Trending



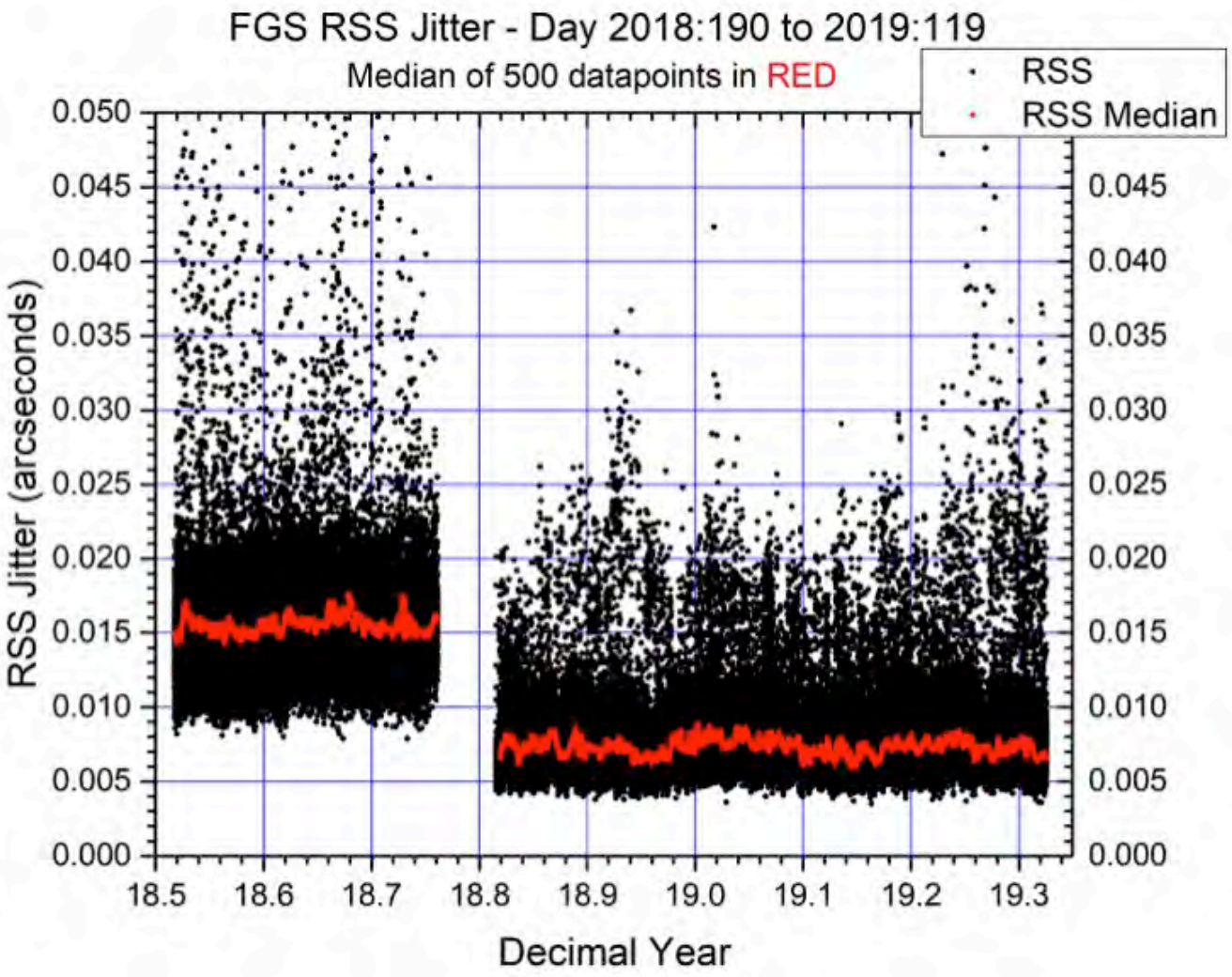






Pointing Jitter Trend

- Jitter in current 3-4-6 gyro configuration is 7-8 mas RSS
- Jitter in the 2-4-6 configuration was as high as 15 mas due to G2 noise



Additional Near Term Gyro-3 Mitigations

- Modify planning and scheduling software to place onboard attitude determinations closer to the acquisition for all observations to minimize the attitude error introduced by n uncompensated gyro bias – expected to be operational mid-summer

- Provide a 10 Hz Attitude Observer controller in addition to current 1 Hz mode
  - Designed to improve “high” gyro noise compensation and reduce jitter
  - May also improve Loss of Lock performance
  - Included in flight software release 4.4 expected to be installed in July

- Historical Observer bin duration adjustment from 1 minute to 15 seconds to improve the gyro bias compensation due to the Attitude Observer Anomaly (AOA) over the orbit period, particularly driven by sharp changes at the Enter Orbit Day terminator
  - Modifying software installed in 2012 in response to Gyro 3 AOA in 2011
  - Expected to improve target acquisition performance due to gyro bias errors
  - A future flight software enhancement

One Gyro Science (OGS) Readiness

- Hubble is one gyro failure away from needing to use One Gyro Science mode
- Preparation steps have been completed to minimize the time required to make the transition into OGS and minimize our science down time
  - An OGS Operations Acceptance Test for the recovery from Kalman Filter Sun Point Safemode into OGS operations using an OGS Health and Safety timeline was completed successfully on December 11
  - An operations team training session was conducted on February 5
  - An end-to-end exercise of science operations in OGS mode was conducted on February 14
  - A Flight Readiness Review Assessment (FRRA) was held on March 12
  - The FRRA plan remains on the shelf and will be maintained as necessary for any changes in the observatory configuration that may occur going forward

Budget Status

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

$M	FY19	FY20	FY21	FY22	FY23	FY24	FY25
Senior Review	$98.3	$88.3	$93.3	$98.3	$98.3	$98.3	
PBR		$83.3	$93.3	$98.3	$98.3	$98.3	$98.3
PPBE-21	$98.3	$88.3	$93.3	$98.3	$98.3	$98.3	$98.3

  - Expected to manage $15M in FY20-21 NOA reduction by utilizing the existing uncosted carryover associated with awarded grants; have adjusted the grants funding profile going forward

- **General Observer / Archival Research Outlook**
  - Cycle 24-26 were awarded the value recommended by the Financial Review Committee
  - Working to provide recommended Cycle Values through the budget horizon

Discussion

- **Questions?**