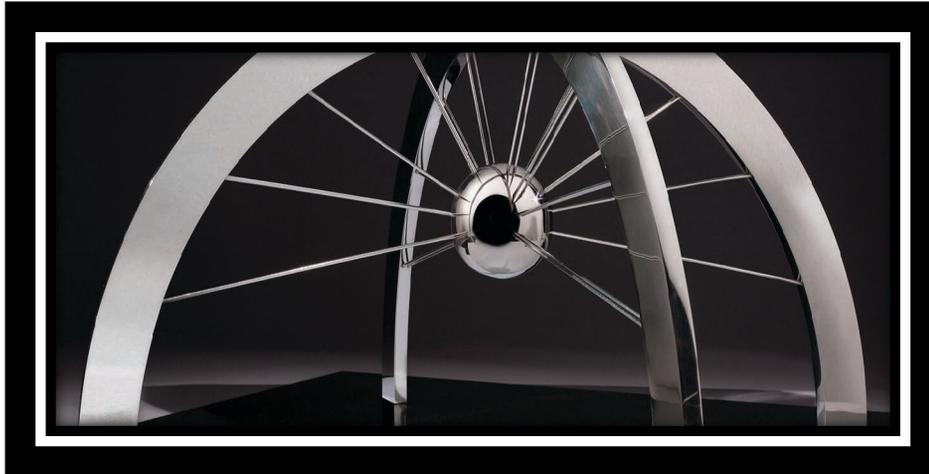




# HST/GSFC Project Report



February 21, 2020

## [Hubble Team Wins the 2020 Michael Collins Trophy](#)

*The Operations People Behind The Space Telescope's 30 Years of Breakthrough Science  
Are Honored By the National Air & Space Museum*

Through its 30 years of discoveries and awesome celestial images, the Hubble Space Telescope has redefined the universe for new generations of astronomers and the public alike. This would not have been possible without the perseverance and expertise of a team of Hubble operations experts at NASA's Goddard Space Flight Center, Lockheed Martin Space, and the Space Telescope Science Institute. The National Air and Space Museum in Washington, D.C. has awarded their 2020 Collins Trophy for Current Achievement to the Hubble operations team. "Through the efforts of the Hubble team the observatory has continued to produce research unachievable with any other instrument. System engineers in Hubble's control center and science operations facility have continued to find creative ways to operate the 30-year-old spacecraft to make this revolutionary science possible ensuring its capabilities will continue for years to come," the museum reported. The Collins Trophy recognizes achievements involving the management or execution of a scientific or technological project, a distinguished career of service in air and space technology, or a significant contribution in chronicling the history of air and space technology. **STSci-2020-17**

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**Space Telescope  
Users Committee  
Meeting  
April 14, 2020**

# Agenda

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- **Science highlights**
- **Project News/COVID-19 Impacts**
- **30<sup>th</sup> Anniversary news**
- **Observatory Status**
- **Budget Status**

## Hubble Finds Best Evidence Yet for Elusive Intermediate-size Black Hole

NASA, ESA, and D. Lin (University of New Hampshire)

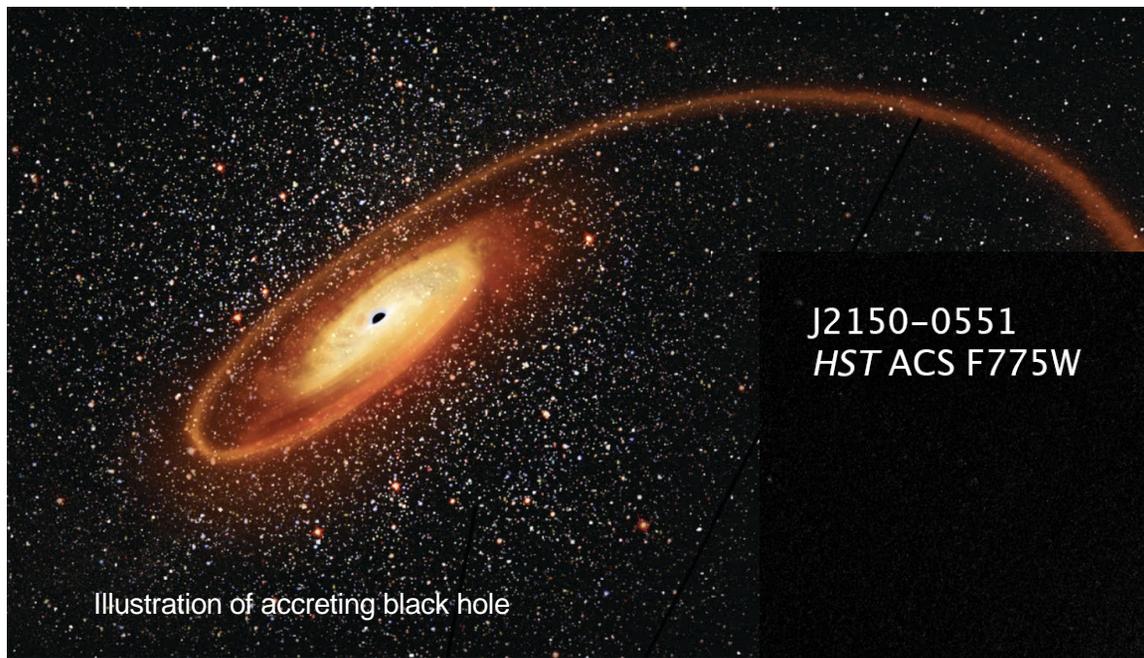
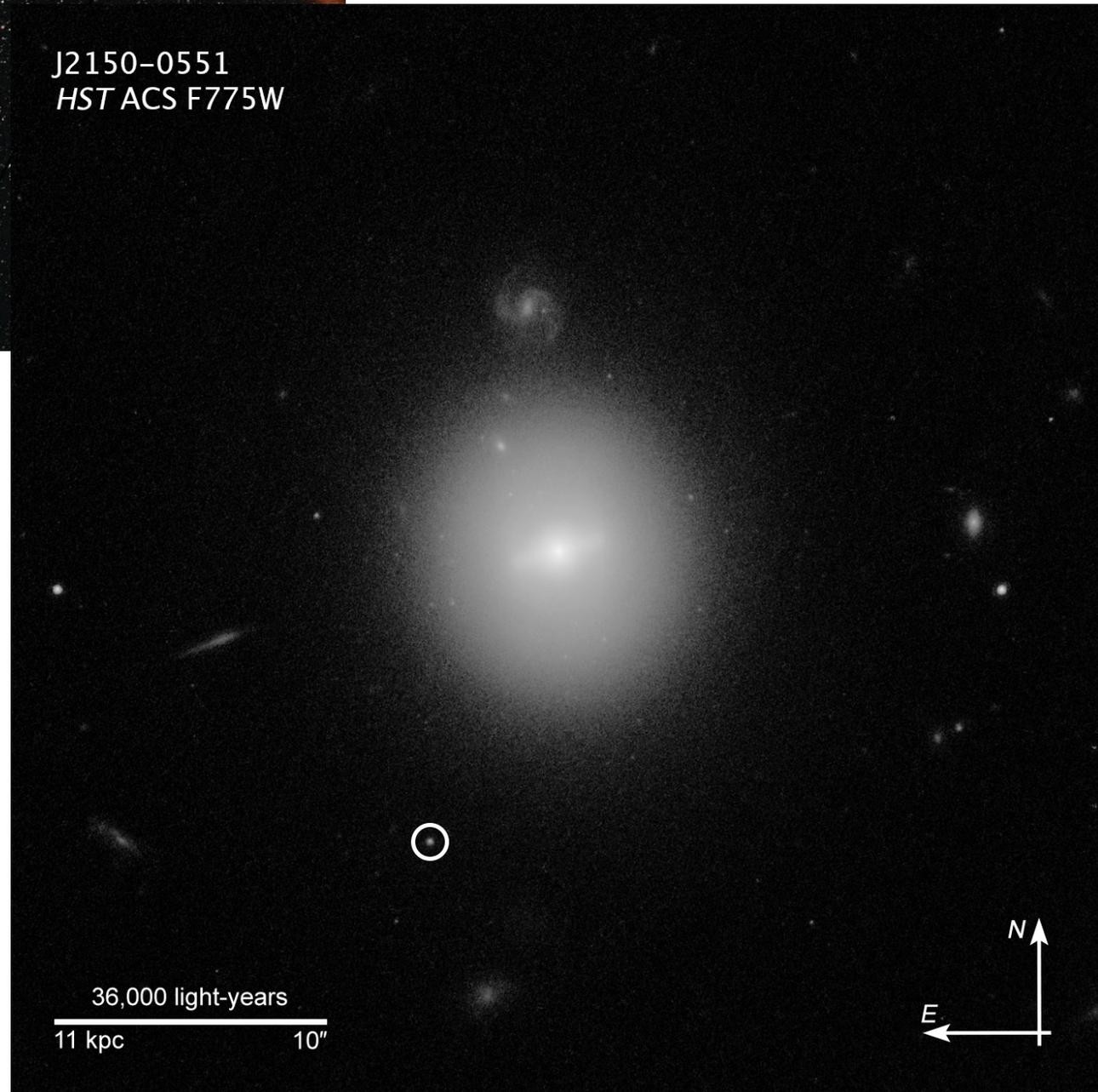


Illustration of accreting black hole

- Hubble followed up on flare detections from Chandra and XMM-Newton; unclear whether source was galactic or extragalactic
- Source was found by Hubble to be in a dense star cluster on the outskirts of another galaxy
- Flaring implies black hole with mass of **50,000 solar masses** accreting a neighboring star
- Intermediate mass black holes have been difficult to identify
- Star cluster may be the stripped-down core of a dwarf galaxy disrupted by larger galaxy host

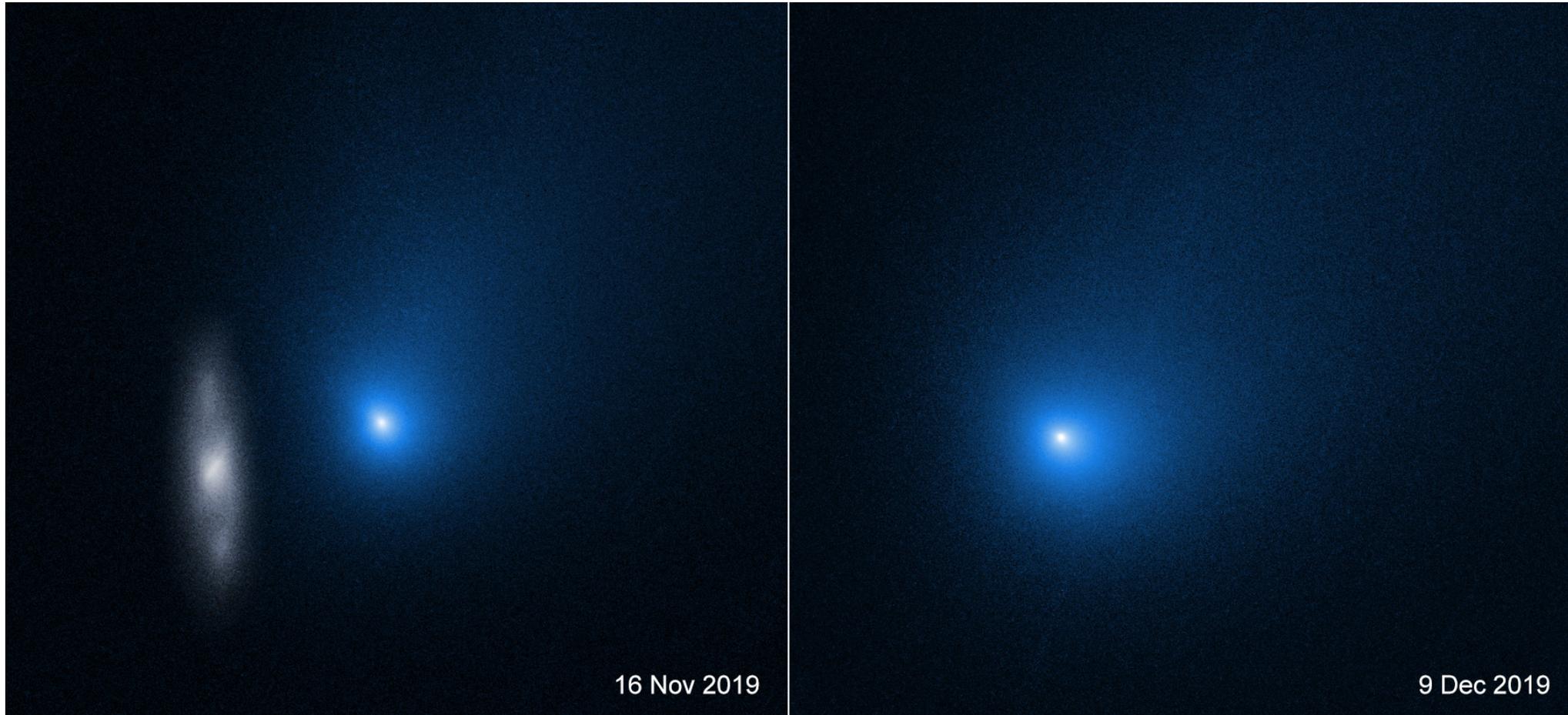


J2150-0551  
HST ACS F775W

36,000 light-years  
11 kpc 10"

# Hubble is observing Interstellar Comet 2I/Borisov !

NASA, ESA, and D. Jewitt (UCLA)



Left: Comet Borisov (and background galaxy).

Right: Comet Borisov near perihelion, 185 million miles from Earth.

- 2<sup>nd</sup> known Interstellar Object to pass through Solar System (1<sup>st</sup> known is 'Oumuamua)
- Fast moving: 100,000 miles per hour
- Radius small – about .5 km
- **Observations are continuing:** to deduce comet's composition and changes in morphology as it moves away from perihelion and will eventually exit the solar system

# Project News/COVID-19 Impacts

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- **Hubble team was recognized by the National Air and Space Museum to receive the 2020 Collins Trophy for Current Achievement**
  - Ceremony, originally planned for March, has been postponed to September
- **Hubble team was selected as one of nine finalists for the 2019 Collier Trophy that recognizes the greatest achievement in aeronautics and astronautics**
  - Finalists panel presentations, planned for April 2, have been postponed
- **Science operations at STScI have been performed remotely since mid-March**
- **Mission operations at GSFC have been performed remotely to the maximum extent possible since mid-March**
  - Routine operations onsite support is limited to 2-3 people on a single Friday shift
  - Special commanding that can be planned for Fridays, will be
  - Ultra Rapid Target of Opportunity, triggered on April 1, was supported onsite on April 2 to enable observations to occur within ~34 hours of trigger
  - Anomaly response scenarios have been reviewed to minimize onsite presence

# Hubble 30<sup>th</sup> Anniversary

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- **In-person 30<sup>th</sup> Anniversary events have been postponed**
- **NASA.gov/hubble and @NASAHubble social media support continues:**
  - What Did Hubble See on Your Birthday – 75 million pageviews and growing
  - Birthday Messages – videos from celebrities and social media influencers
  - Hubble Stargazing – view the night sky and compare to Hubble’s view
  - 30 Images, 30 Years – one year’s image released each day leading up to April 24th
- **Video production continues:**
  - One-hour historical documentary for NASA TV
  - Three-part documentary (10 minutes each) on Hubble operations
  - Six social media videos covering history and science achievements
- **Podcast production continues:**
  - Three-part Hubble series that is part of NASA’s Curious Universe podcast program
- **Image release planned:**
  - Live television interviews with news and morning shows across the nation
    - Includes Jim Bridenstine, Charles Zurbuchen, Paul Hertz....
  - Social media video on anniversary image with possible Q&A session
- **Provided materials and interviews for TV, magazines, & YouTube channels**

# Observatory Status

3/31/2020

Subsystem		Summary
Science Instruments (SI)	G	<ul style="list-style-type: none"> <li>ACS monthly anneal process to no longer cycle the Main Electronics Box (and the EPROM chip with temperature dependence) has been used monthly since the October 17 anneal</li> <li>WFC3 performance is excellent; Channel Select Mechanism movements minimized without science impact; 7 dust particles on the optic in 2018, one in 2019; no impact to science</li> <li>COS               <ul style="list-style-type: none"> <li>4<sup>th</sup> lifetime position began 10/2017 using COS 2025 initiatives; investigating 5<sup>th</sup> position</li> <li>FUV detector sensitivity loss continues as expected; Sensitivity ARB closure 4/2011</li> </ul> </li> <li>ACS and STIS repaired instruments (SM4) performing nominally</li> <li>NICMOS in standby following decision to not restart following Cycle 19 proposal evaluations</li> </ul>
Electrical Power System	G	<ul style="list-style-type: none"> <li>Excellent battery performance; 510 Amp hour benchmark; Solar Array 3 performance remains excellent</li> <li>Solar Array Drive Electronics (SADE) investigation following 2/15/13 SWSP completed; no further actions</li> </ul>
Pointing Control System	G	<ul style="list-style-type: none"> <li>Operating in 3-gyro mode using 3-4-6 gyro complement; gyro 4 exceeded 100,000 hours on July 30, 2019</li> <li>Gyro 6 motor current increased from ~120 mA to ~180mA on 3/21/2019; Gyro 4 had similar event in 9/2011</li> <li>Gyro 3 powered on 10/6/2018 – initial high output rates reduced to normal 10/19/2018; gyro bias increasing toward low mode saturation point</li> <li>Gyro 2 failed on 10/5/2018</li> <li>Gyro 1 failed on 4/21/2018; Gyro 6 powered on 4/21/2018</li> <li>Gyro 5 failed on 3/7/2014; Gyros 1&amp;2 powered on; Gyro 6 powered off 3/13/2014</li> <li>Attitude Observer Anomaly (AOA) (ARB report 10/2011) mitigation completed 11/2012</li> <li>Due to AOA, Gyro 3 removed from control loop/powered off 2011; Gyro 6 powered on</li> <li>FGS-3 bearings degraded (~10% duty cycle to preserve life); FGS-2R2 Clear Filter operations began 1/2015</li> </ul>
Data Management System	G	<ul style="list-style-type: none"> <li>SI Control and Data Handling (C&amp;DH) has had 15 lockup recoveries since 6/15/09; most recent was 12/15/19</li> <li>Solid State Recorders (SSRs) 1&amp;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</li> </ul>
Communications	G	<ul style="list-style-type: none"> <li>Multiple Access Transponder 2 (MAT2) coherent mode failed (12/24/2011); Two-way tracking unavailable</li> <li>Joint Space Operations Center (JSpOC) now the source for the operational ephemeris via Conjunction Avoidance Risk Assessment (CARA) team and the Flight Dynamics Facility</li> </ul>
Thermal Protection System	G	<ul style="list-style-type: none"> <li>New Outer Blanket Layers (NOBLs) installed on Bays 5,7, and 8 during SM4</li> <li>Thermal performance is nominal</li> </ul>

# Mission Operations – Gyro Run Time Performance

3/31/2020

## Current Gyro Runtimes

Post SM4 RGA	Status	Flex Lead	Total Hours 2020/091 (3/31/2020)
G1	Failed April 2018	Standard	43,359
G2	Failed October 2018	Standard	47,550
G3	On	Enhanced	35,383
G4	On	Enhanced	105,881
G5	Failed March 2014	Standard	51,497
G6	On	Enhanced	52,995

## 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

Maximum runtime hours (current G4 – Enhanced Flex Lead)	105,881
Second highest hours (G1 from SM3A)	60,444
Mean runtime hours for the 3 operating Enhanced Flex Lead gyros	64,753
Mean runtime hours for 19 Standard Flex Lead gyros	42,332
Mean runtime hours for all 22 HST gyros	45,390
Mean runtime hours for the 8 HST Standard Flex Lead failure gyros	44,405

# Normal 3 Gyro Mission Operations

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- **Gyro Low Mode**

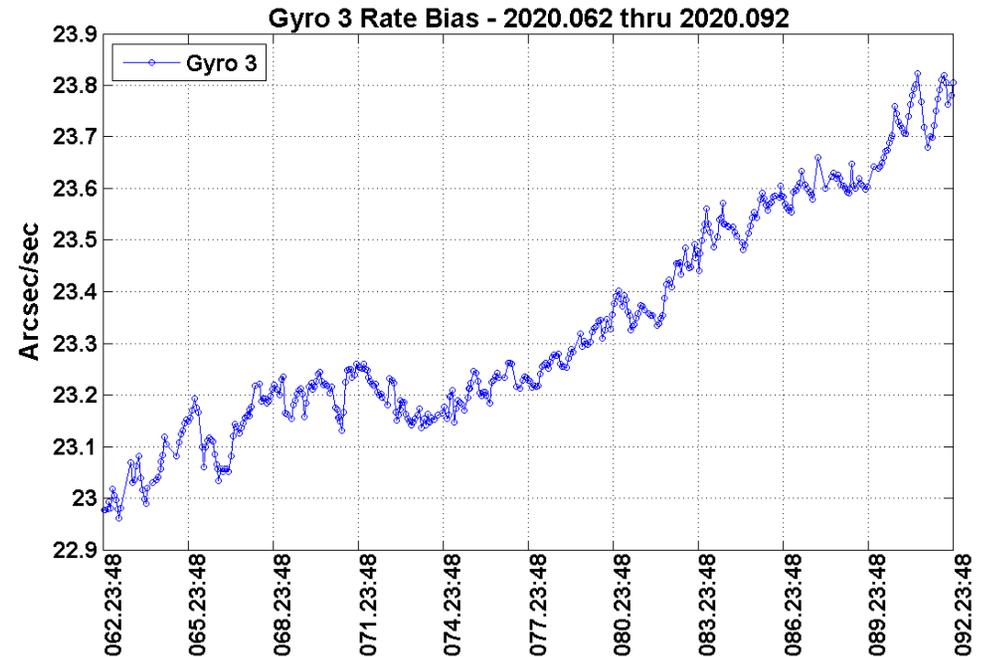
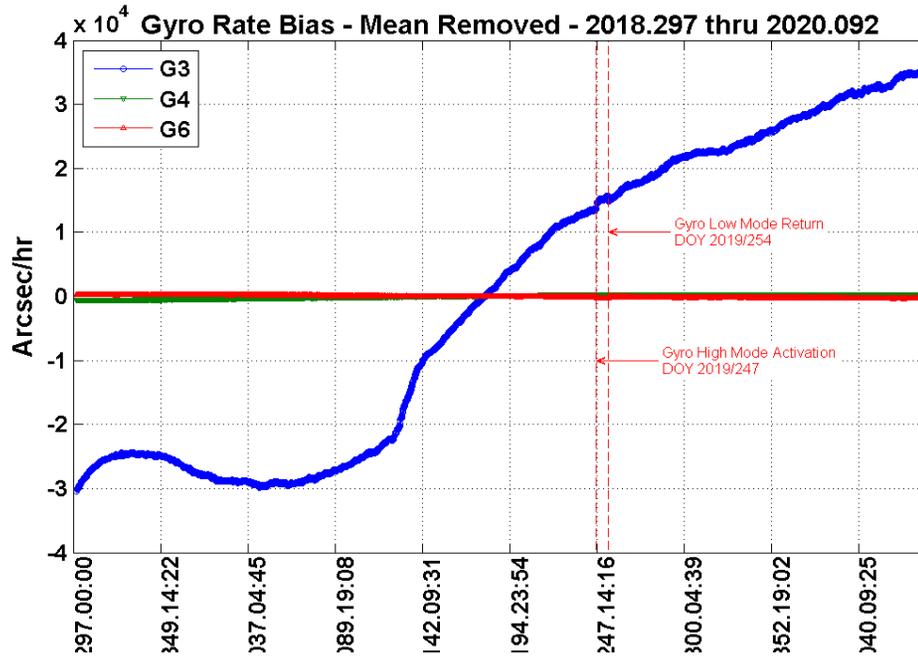
- Used while observatory is inertially pointing, during target acquisitions, and for low rate science observing slews < 8 arcseconds/sec guiding (as/s)
- Gyro bias gets updated during inertial Fine Guidance Sensor guiding periods
- Shifts in the gyro bias between this update and the next acquisition can impact target acquisition performance; operations continues to make adjustments to mitigate this issue
- Low Mode dynamic range is +/- 35.7 as/s
- Resolution = 0.005 as/s per count

- **Gyro High Mode**

- Used during large vehicle slews
  - Flight software computes a “shaped” maneuver to reach new attitude
  - Gyros are switched to high mode onboard when the commanded rate in the shaped maneuver reaches a threshold value and back to low mode as the new attitude is approached at a separate threshold value
    - Nominal value was 11 as/s up to high mode and 9 as/s down to low mode
    - Values updated on March 17 to 8 as/s up and 6 as/s down due to bias growth
- High Mode dynamic range is +/- 2258 as/s
- Resolution = 0.314 as/s per count

# Gyro-3 Bias Trend

3/31/20



- Gyro 3 bias (drift-rate) was  $\sim 5$  arcsec/sec after recovery in October 2018
- After initial sinusoid, the drift-rate has been increasing and there is a risk of saturating the low mode in the next few months

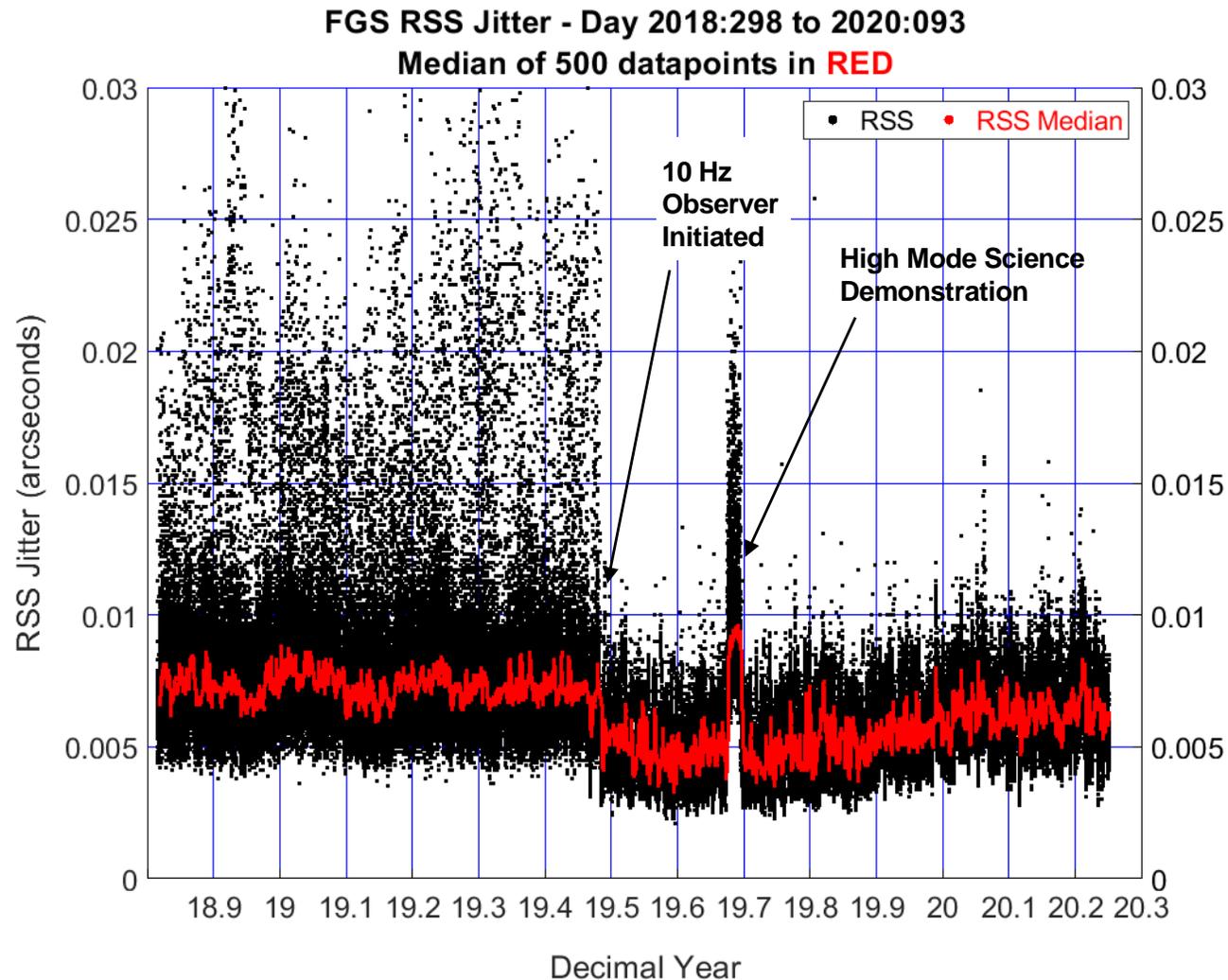
# Gyro-3 Low Mode Saturation Mitigation Efforts

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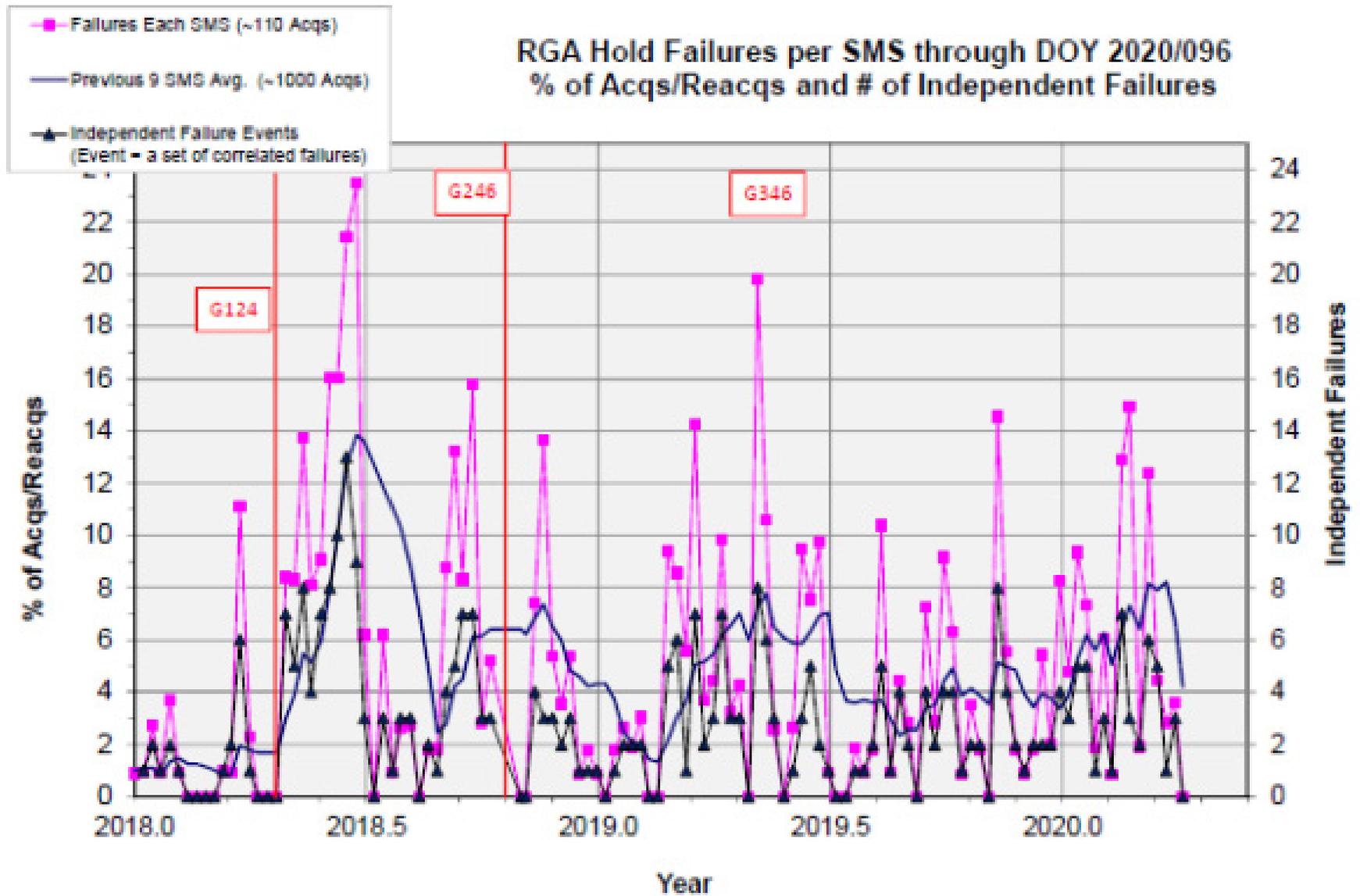
- Procedures are in place to transition to One Gyro Science (OGS) if necessary
- Procedures, similar to those used in October 2018, are available to attempt to de-saturate the gyro if this appears to be necessary; considered low, but non-zero risk to execute
- A 10 Hz (in addition to the legacy 1 Hz) observer controller was developed and is now be used in operations and reduces jitter in both low mode and high mode
- Developed a High Mode Science capability
  - Gyros are maintained in High Mode at all times – for large slews, science slews, and fine inertial pointing control
  - Demonstrated on orbit September 4 – 11, 2019
    - Jitter level increase as expected, but the 10 Hz observer kept average to ~10 mas
    - Reaction wheel zero speed crossings caused some increased jitter; wheel speeds were offset March 27-April 3, 2020 and confirmed expectations that zero wheel speed crossings can be drastically reduced; expect to use wheel speed offsets if high mode is required
  - Increased loss of locks were observed due to gyro 3 quantization when rates pass through dead bands centered on multiples of 60 counts ( $\pm 18.8$  as/s); next band around  $\pm 37.6$  as/s
- A hybrid control mode is being developed that will use the 3-gyro controller to perform maneuvers between science observations, and switch to Fine Guidance Sensors and 1 gyro controller (3G F1G) to perform observations
  - Mitigates quantization issue observed in high mode
  - About 80% testing completed
  - Expected to be available for operations by July 23, 2020; expect to be able to shorten the schedule if necessary

# Jitter Performance

- Jitter in the 2-4-6 configuration in 2018 was as high as 15 mas due to G2 noise
- Jitter in the current 3-4-6 gyro configuration using 1 Hz controller was 7-8 mas RSS
- 10 Hz controller reduced the average jitter (~5 mas in Low Mode; ~10 mas in High Mode)



# Target Acquisition Performance Trending



# HST Operations Top Risks

3/31/20

		Rank Risk ID	LxC Trend	Title	App	Status
		1 HST-24	4x3 ⇔	Significant degradation or loss of a gyro will impact science productivity in the next 3 years	M	<ul style="list-style-type: none"> <li>Probabilistic random failure analysis shows less than 50% probability of 3 operational gyros within 33 months; gyro 3 degradation, short of failure, may impact science performance</li> <li>One Gyro Science (OGS) readiness will be maintained to minimize science downtime if transition from 3-gyro control is required</li> <li>10 Hz observer (implemented) mitigates gyro noise during 3-gyro science observations; On board attitude determinations with corrections are planned prior to acquisitions/reacquisitions when possible to mitigate impact from bias shifts between acquisitions</li> <li>High Mode Science mitigates impact of gyro 3 low mode saturation</li> <li>3G FIG Hybrid Mode in development to mitigate High Mode Science quantization issue at post-saturation levels and mitigate future gyro noise growth</li> </ul>
		2 HST-22	4x2 ⇔	Gyro 3 rate bias may exceed low mode (science) saturation point and impact science productivity	M	<ul style="list-style-type: none"> <li>Rate bias was <u>23.8 deg/hr on 4/1/2020</u>; the threshold for the low to high mode transition was modified to accommodate 27.7 deg/hr</li> <li>De-saturation procedures are ready for use; low, but non-zero risk</li> <li>3-gyro High Mode Science demonstrated 9/4-9/11/2019; alternative to OGS; quantization effect did impact target acquisition performance</li> <li>10 Hz observer implemented; reaction wheel speed offset <u>was tested March 27-April 3, 2020</u> to mitigate jitter in High Mode</li> <li>3G FIG Hybrid Mode in development; will mitigate increased jitter in High Mode Science and the quantization effect; available for operations by <u>July 23, 2020</u></li> </ul>
		3 HST-13	1x4 ⇔	WFC3 Channel Select Mechanism failure due to motor shaft bellows and pins interface degradation	W	<ul style="list-style-type: none"> <li>Number of dust particulates increased since launch; 3 in 2013; 2 in 2015; 2 in 2016; 9 in 2017; 7 in 2018</li> <li>Implemented change in mechanism commanding to eliminate unnecessary moves; campaign approach deemed to be a significant impact and will not be pursued at this time</li> <li>January 2018 review, following 2017 increases, by 2013/2014 Tiger Team did not recommend any new actions to be taken</li> <li>Continue to monitor trends (no new particles in 2019)</li> </ul>

Criticality	Approach
HIGH	M-Mitigate
MED	W-Watch
LOW	A-Accept
	R-Research

L x C Trend	
↓	Decreasing (Improving)
↑	Increasing (Worsening)
⇔	Unchanged
NEW	New since last month

# Budget Status

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

\$M	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26
2019 Senior Review	\$98.3	\$88.3	\$93.3	\$98.3	\$98.3	\$98.3	\$98.3	
PPBE-22		\$90.8	\$88.3	\$98.3	\$98.3	\$98.3	\$98.3	\$98.3

- HQ expects the FY20-21 \$2.5M NOA reduction from the 2019 Senior Review to be managed by utilizing the existing uncosted carryover associated with awarded grants
- The FY20-21 NOA, coupled with larger NASA Hubble Fellowship Program classes and no inflation adjustments in this budget window, will effectively reduce operations staffing and science program support

- General Observer / Archival Research Outlook**

- Cycle 24-26 were awarded the value recommended by the Financial Review Committee; Cycle 24 was ~\$31.6M and Cycle 25-26 averaged was \$33.9M
- Cycle 27 Cycle Value was ~\$30M despite ~20% fewer orbits awarded
- Current budget, without inflation adjustments, will be challenged to maintain \$30M cycle values as we progress through the horizon
- Inflation will further erode purchase power and effective cycle value