STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

Hubble Space Telescope Status

Cycle 28 TAC Presentation

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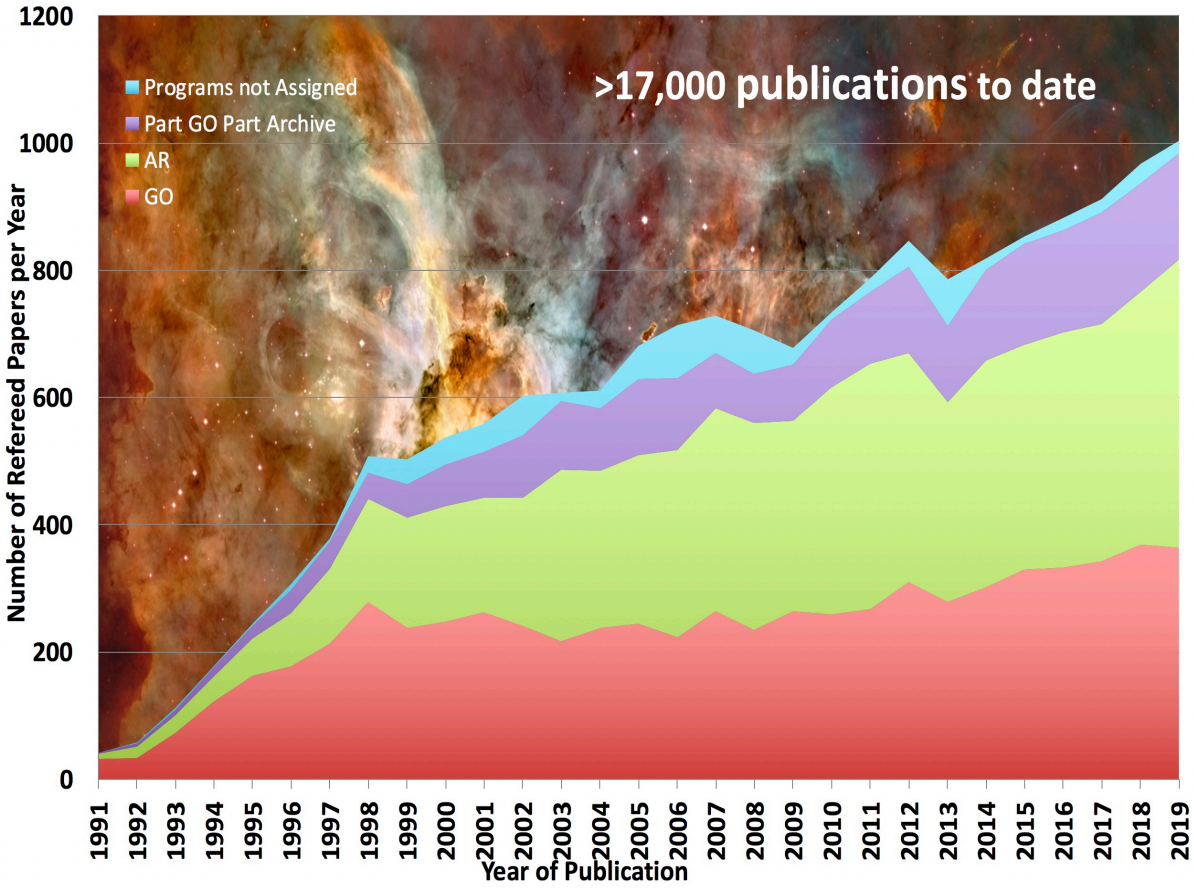
Welcome!

Thank you for serving on the Cycle 28 HST TAC

- The Hubble Space Telescope has now nearly completed 30 years in operation
  - We are now almost 11 years past Servicing Mission 4
    - At that time, planning was for 5 years of science operations
  - In most respects, Hubble is working now at its very best
    - There is some slight instrument performance degradation (mainly in CCD charge transfer efficiency)
    - There is some degradation in the pointing control system resulting in more failed acquisitions
    - But we (GOs and STScI+GSFC) have become smarter in how we use the observatory and continue to work to mitigation these issues
- You, by serving the HST TAC process, have the privilege and responsibility of defining what Hubble does next!

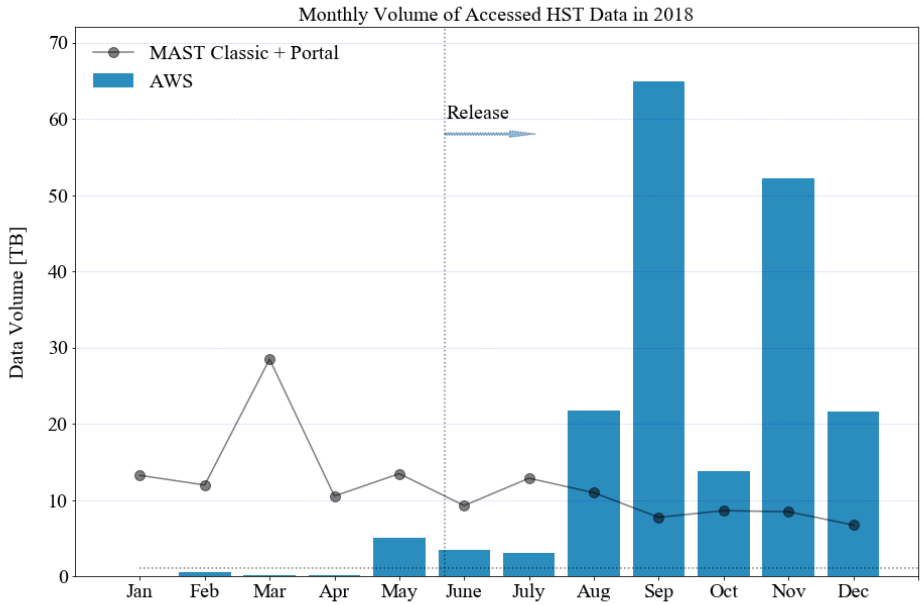
Science Productivity at All Time High



- Hubble GO and AR programs produced over 1000 refereed science papers in 2019
- Now 17,000+ refereed science papers to date
- 600+ PhD theses
  - currently ~1 per week
- 1 in 6 astronomy papers influenced by Hubble

Data from the Programs You Select Will Produce Science for Years to Come

- HST archive size is >160 TB
- 6-15 TB per month retrieved
- >12,000 registered archive users (85 countries, 50 states)
- HST archive online cache delivers data within minutes to users
- Amazon Web Services became available in 2018 for archival research
  - All HST public data with very fast local processing on their servers



2020 → 2025 Vision

Operate Hubble out to 2025 and beyond. Expect overlapping science observations with the James Webb Space Telescope, performed in a manner that maximizes the science return of both observatories by taking full advantage of Hubble's unique capabilities and the astronomical community's scientific curiosity.

How long will Hubble continue to operate?

→ As long as it remains scientifically productive

Expect several years of overlap between HST and JWST

What is needed to keep Hubble scientifically productive? →

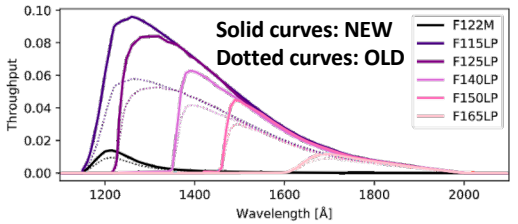
- An operating observatory
- Capable science instruments
- Scientific drivers (demand)
- Adequate staffing and user support
- Appropriate funding
- Common purpose & teamwork

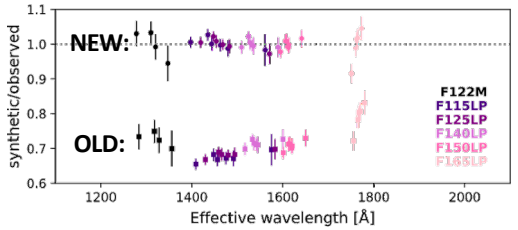
Science Instruments Status

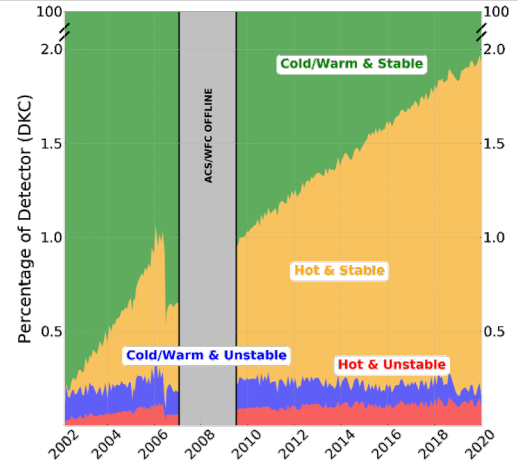
- Engineering estimates give confidence for long term operation beyond 2025
  - >95% COS and WFC3, >85% for ACS and STIS
- Graceful aging of CCD detectors
  - Charge transfer efficiency degradation mitigated by flashing and corrected at the pixel level
  - Vast majority of defective pixels (warm, hot, dead) mitigated through extensive monitoring, reference files, and appropriate algorithms
- Changes in flat fields and sensitivities monitored and addressed in pipeline
- Drifts in focus and alignment corrected by both mechanism motions and calibration updates

Advanced Camera for Surveys

- Continued Good Performance
- Updates to CALACS include sink pixel detection, DQ-array flagging, retention of long-term stable hot pixels in DQ array, high dynamic range WFC super darks, Gaia DR2 refinements to WFC Geometric Distortion solution, updates to WFC bias shift correction
- **SBC revised flux calibration: 30% higher sensitivity (*at upper right*)**
- Updated web tools for ACS Zero-Points and Pixel-Area Maps
- Revised L-flats for WFC, based on 16 years of 47 Tuc monitoring
- **Analysis of entire WFC pixel history: vast majority (≈99.8%) of CCD pixels are stable and no longer flagged (*at lower right*)**



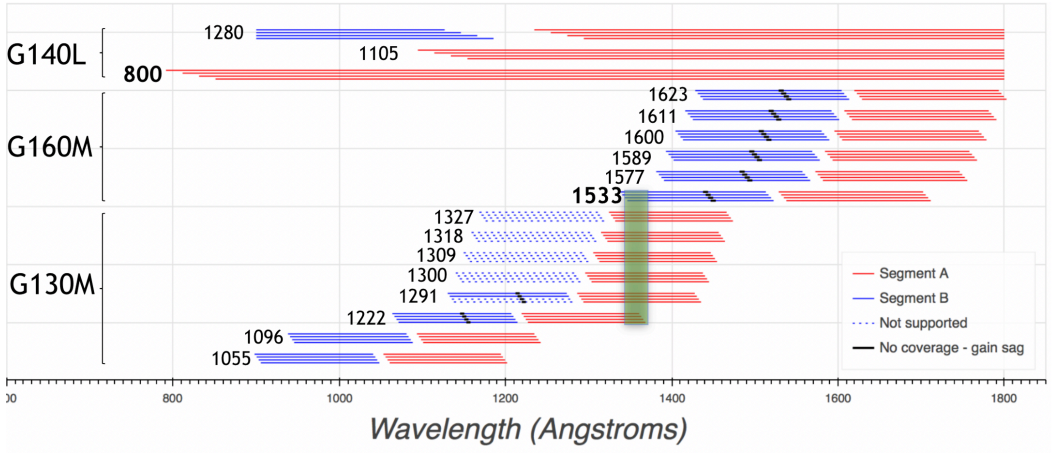


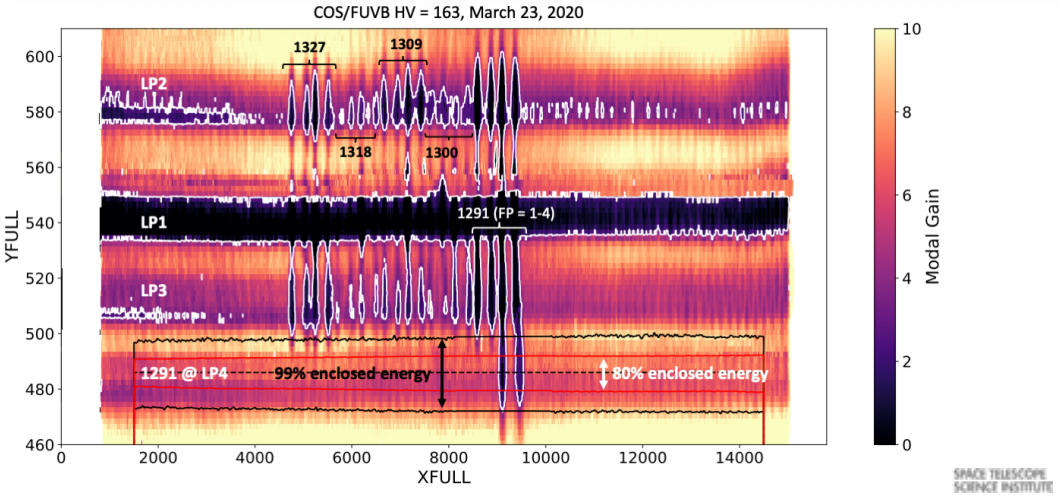


Cosmic Origins Spectrograph

COS is operating nominally

- New FUV observing modes since Cycle 26
  - G160M/1533 enables high SNR, medium resolution spectra over a broad range of wavelengths with just 2 settings: G130M/1222 and G160M/1533.
  - G140L/800 provides broad wavelength coverage (800-1950 Å) on FUV segment A with no gaps and lower astigmatic height
- FUV detector at LP4 since Oct. 2017
  - Changes in strategy extend useful LP4 until ~2023; longer with other strategies under development
  - Future options for extending COS FUV exist





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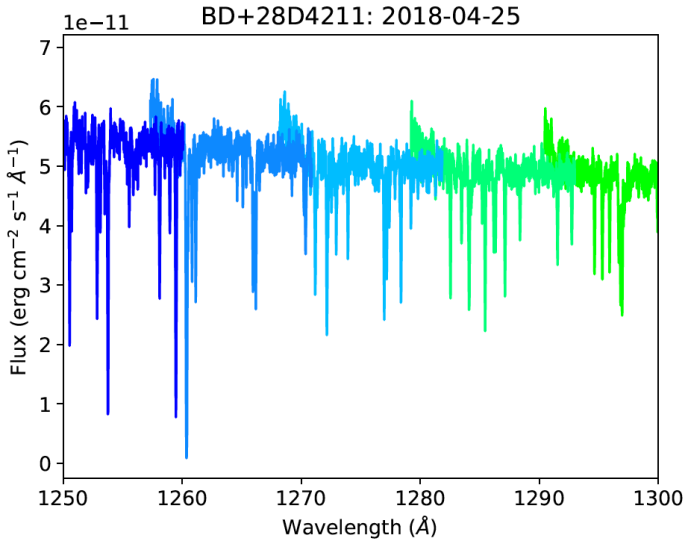
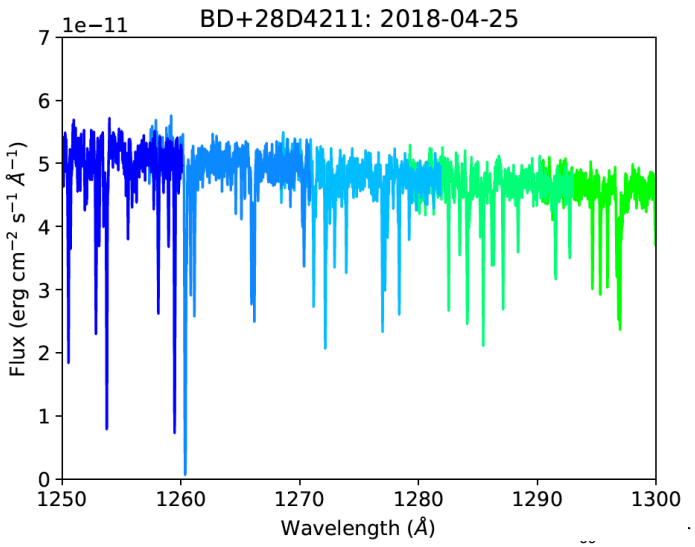
Space Telescope Imaging Spectrograph

- STIS status unchanged, celebrating 23+ years in space
- New empirical models for coronagraphic contrast performance →accurate predictions for coronagraphy programs (*Note*: high spacecraft jitter can impact contrast)
- Updated E140M flux calibrations repair echelle blaze shape changes
- New instrument focus monitor shows STIS focus near historical levels

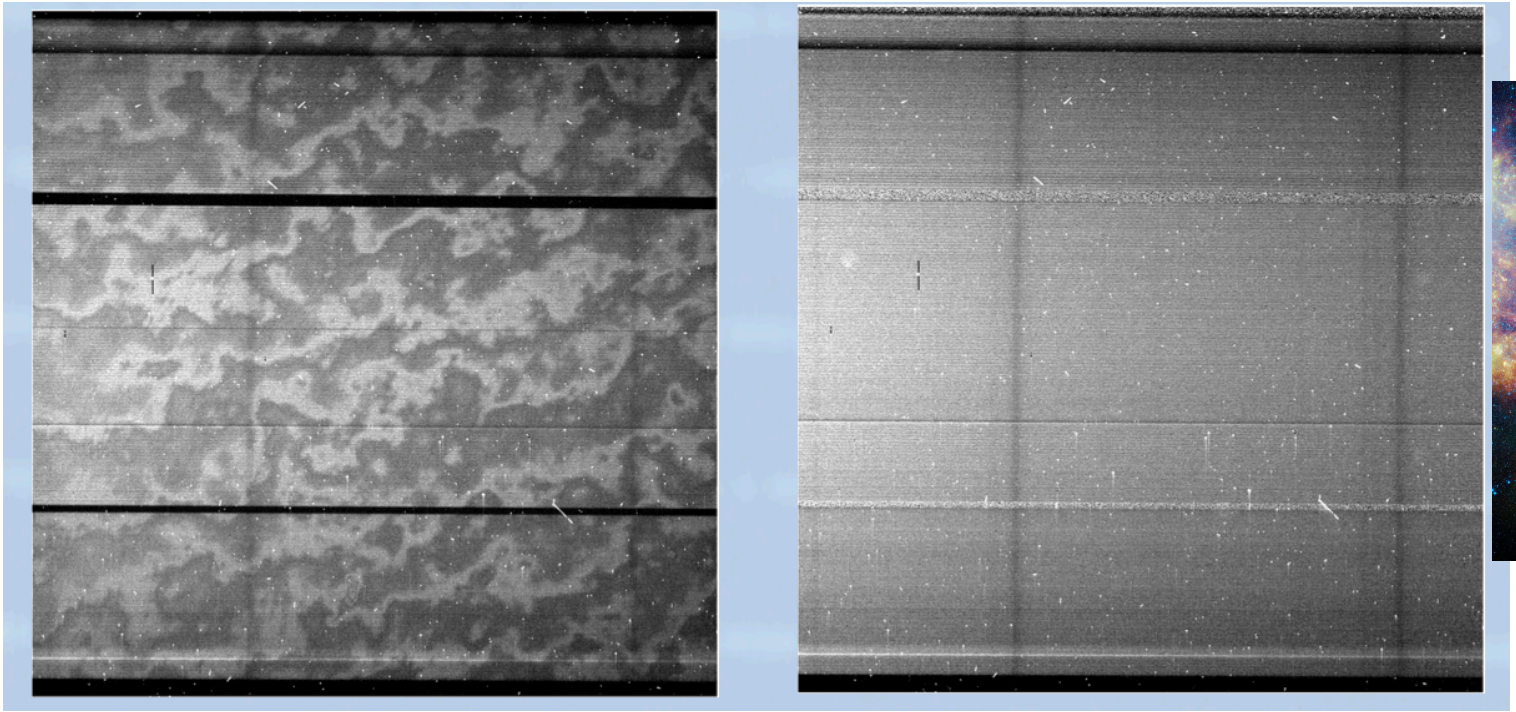


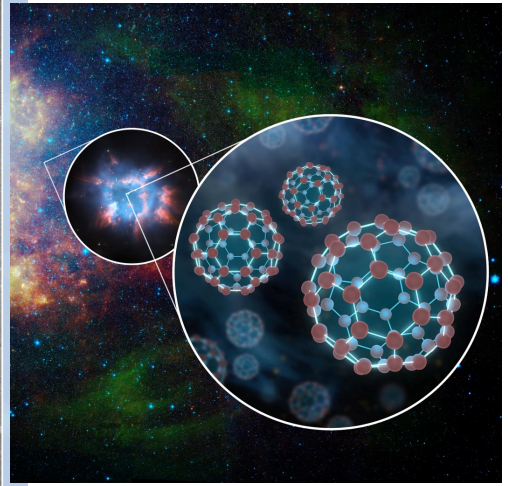


et al. (2019)

Spatial Scanning

STIS Visible spatial scanning spectroscopy allows SNR~600 observations from 7000-10000 Å or timeseries spectroscopy—available but unsupported mode



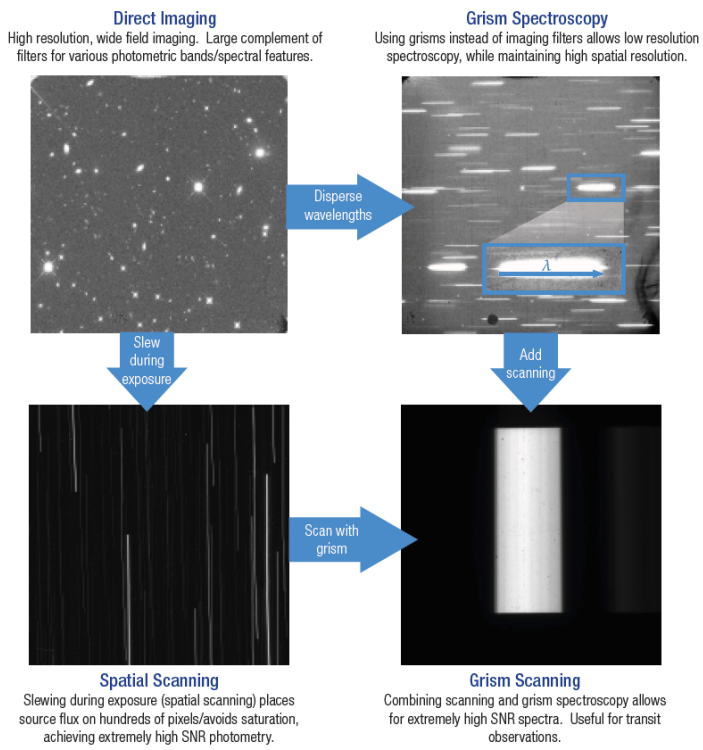


Cordiner et al., 2019

WFC3 status

- WFC3 operating nominally
- As of Mar 31 ~267, 000 WFC3 images in MAST archive

- PSF image database: 4.5 / 23 million entries for IR/UVIS
- Spatial scans: post-calwf3 analysis software available
- Improved astrometric solutions in pipeline. See http://www.stsci.edu/hst/instrumentation/wfc3/news
- IR photometric repeatability 2-3% with 5pix dither; 10 pix dither achieves ~0.5% (ISR 2019-07)
- Guidelines for observers with ultra-rapid ToO programs (SMO/WFC3 ISR 2020-01)
- G102/G141 grism backgrounds: 3-component models available



Spacecraft Status

- High confidence in operations beyond 2025
- Several SIC&DH lockups in past year; faster recoveries now enabled
- Main constraint is remaining time in 3-gyro mode
    - 3 (of 6) Gyros remain functional although one (G3) has higher drift rate
        - Has resulted in higher acquisition failure rates; operational and software mitigation efforts have improved this with additional improvements expected
    - Remaining gyros are enhanced devices (one now at 100K hours; old gyros average 40-50K)
        - Not possible to predict remaining lifetime but expected to be ~5x old gyros
    - 1-Gyro mode available and tested; models predict operations into 2030s
    - TAC should assume 3-gyro mode for Cycle 28
- HST orbit stable beyond 2030
- Power, thermal, communications, etc. retain significant redundancy

HST GYROs since SM4

- SM4 installed 6 new Gyros
  - 3 with enhanced flex leads(*)
- Historical HST Gyro lifetimes were ~5 years
- Gyro #2 had high level of jitter in its final year
- Gyro #3 has stability issues
  - Bias drift impacts (re-)acquisitions
- On-going work to accommodate Gyro #3
  - Some efficiency implications including small increases in overheads and scheduling constraints

Gyro	Status	Lifetime (Years)
1	Failed 4/18	5
2	Failed 10/18	5.4
3*	Operating^	>4
4*	Operating	>11
5	Failed 3/14	5.9
6*	Operating	>6

- Impacts to Science Operations:
  - Higher rate of acquisition failures: 1-2% increased to ~5% since late 2018
    - Results in a higher HOPR rate impacting LRP stability and efficiency
  - Potential for some periods (weeks to months) of higher jitter and reduced scan rates
    - Image jitter would increase to ~5-8 mas vs nominal ~3-4 mas

Long Range Plan: Current Status (April 2020)

Cycle 27 averaging 86 orbits/week over first 28 weeks

- Cycle 17-23: 84 orbits/week
- Cycle 24: 82 orbits/week
- Cycle 25: 85 orbits/week
- Cycle 26: 80 orbits/week
  - 85 orbits/week if exclude 3-week downtime for loss of Gyro 2

Instrument	Orbits
WFC3	1108
COS	604
ACS	420
STIS	324
FGS	0
Total	2456(1)

(1) Some programs have more than one prime SI.

Previous Cycle Completeness

- 2454 orbits remain in the Long Range Plan.
  - Cycle 25: 91 orbits remain. Windows (mostly HOPRs) into Dec 2020.
  - Cycle 26: 278 orbits remain. Windows into summer 2021.
  - Cycle 27: 2085 orbits remain.

C26 snaps	1466
C27 snaps	616
Total snaps	2082

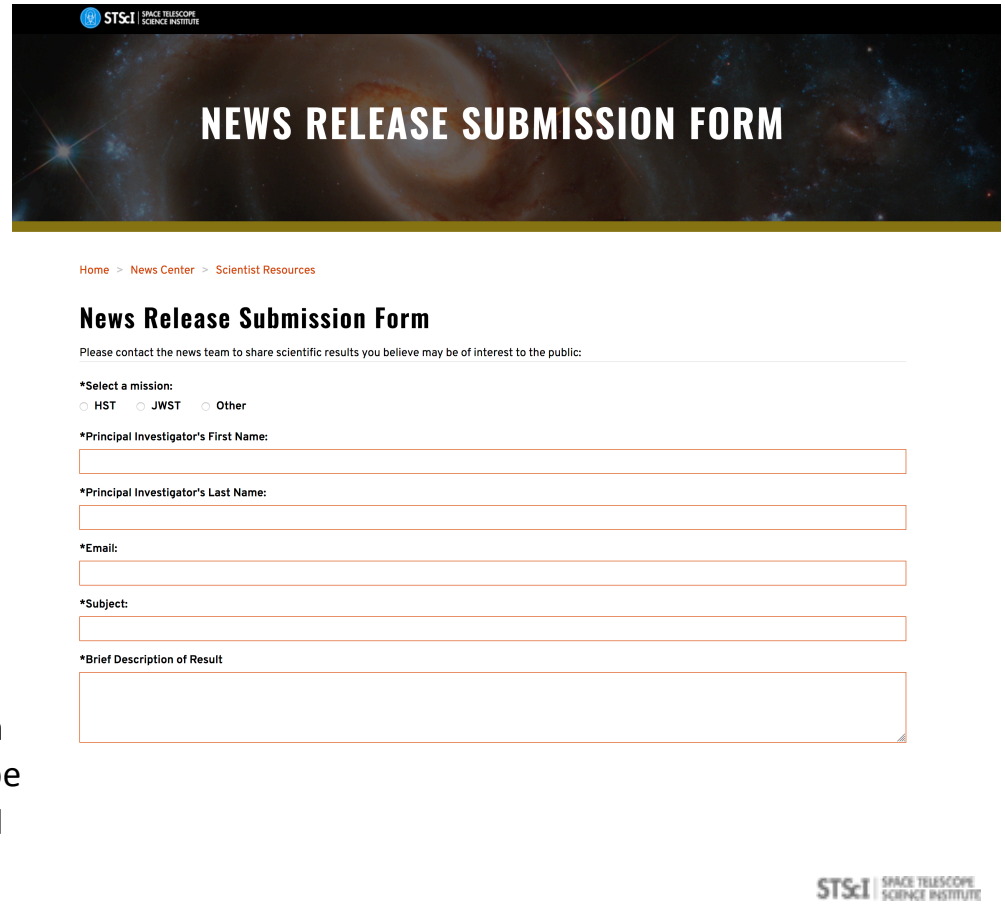
Challenges to Efficiency – Time Constrained Science Programs

- Approximately 20% of science visits in Cycles 24 and 25 had timing constraints of a few orbits or less; this has declined slightly in Cycles 26 and 27 with the completion of two large programs having timing constraints
- Creates conflicts between science programs and may cause programs to have delayed execution dates
- Results in fewer flexible visits later in the plan that can be moved forward to fill schedule gaps and thus a less efficient program overall
- We ask proposers to avoid constraints and special requirements that are not scientifically required
- Starting in Cycle 26 proposers are now required to justify their constraints at the Phase I stage

Please Share Your Science with the Public

- Scientist PR submission form
  - Alerts news chief
  - Automatically logs entry for news team
  - Initiates follow-up from STScI to PI
  - http://www.stsci.edu/news/scientist-resources/scientist
- Archive auto-notice
  - Reminds PI of pending “end of program”
  - Encourages communication to STScI about publications and newsworthy results

Congratulations! Your program, GO-12345, “Amazing HST Observations”, is nearing completion. As your program draws to a close, we would like to ask you to coordinate with Space Telescope Science Institute to improve the dissemination of your results and help us better follow HST usage…



Leave the Scheduling and Technical Issues to Us

- In reviewing Cycle 28 proposals, Panels and TAC should focus on the best science
  - Constraints/Special Requirements must be scientifically justified
  - However, leave scheduling constraints to us to consider in the context of the entire Cycle 28 pool of recommended proposals
  - Also, let us consider the suitability of observing programs if we do not remain in the nominal 3-gyro configuration