Welcome!

• Thank you all for serving on the Cycle 24 HST TAC

• The Hubble Space Telescope has now completed 26 years in operation!
  – We are now seven years past Servicing Mission 4
    • At that time planning was for 5 years of operations
  – In most respects, Hubble is working now at its very best
    • There is some slight instrument performance degradation
    • But we all (GOs and STScI+GSFC) are smarter in how we use the observatory

• Over the next several days, the team in this room has the privilege and responsibility of defining what Hubble does next.....
Hubble is As Powerful As Ever

Deep, precise, stable pan-chromatic imaging
Slitted and slitless spectroscopy, coronagraphy, astrometry

Architecture of the universe

Life stories of galaxies

Mysteries of dark matter and dark energy

Births and deaths of stars

Recipes for building planets
Operate Hubble out to 2020 or beyond so that there is at least one year of 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

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
<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Observatory Health</strong></td>
<td>Excellent (even better than expected after SM4)</td>
<td>• Good reliability of science instruments and major systems through 2020 (NESC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Known modes of degradation</td>
</tr>
<tr>
<td><strong>Orbit Decay</strong></td>
<td>Nominal orbit</td>
<td>• Orbit stable until mid-2030s</td>
</tr>
<tr>
<td><strong>Scheduling Efficiency</strong></td>
<td>~50%, near all-time high</td>
<td>• Efficiency declines to ~40-45% upon transition to reduced-gyro mode</td>
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<tr>
<td></td>
<td>Averaging &gt;84 orbits/week</td>
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<tr>
<td><strong>Scientific Productivity</strong></td>
<td>~800 papers per year;</td>
<td>• Publication rate remains high</td>
</tr>
<tr>
<td></td>
<td>~40 PhDs per year</td>
<td>• New discoveries continue</td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td>&gt;1000 proposals per year;</td>
<td>• No near-term decrease expected</td>
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<td></td>
<td>6:1 oversubscription (time)</td>
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<tr>
<td><strong>Staffing</strong></td>
<td>Lean operations</td>
<td>• Work efficiencies are harder to achieve beyond FY16 without loss of capability</td>
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<tr>
<td><strong>Mission Funding</strong></td>
<td>$98.3M/year total budget</td>
<td>• Flat mission budget presents challenges</td>
</tr>
<tr>
<td><strong>Grant Funding</strong></td>
<td>$28-29M/year in grants to the community</td>
<td>• Grant funding is expected to be stable</td>
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## Hubble is in Excellent Health

### Observatory Systems Status

<table>
<thead>
<tr>
<th>Science Instruments</th>
<th>ACS</th>
<th>Operating well. Improved Astrometry, Darks, CTE corrections, and SBC PSF &amp; Flat. Postflash available.</th>
</tr>
</thead>
<tbody>
<tr>
<td>STIS</td>
<td>Operating well. BAR5 coronagraphy competitive with ground reaching 1E-6 with ADI and KLIP.</td>
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<tr>
<td>NICMOS</td>
<td>Safed, warm (NCS shutdown).</td>
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<tr>
<td>WFC3</td>
<td>Excellent stability, sensitivity, astrometry. Spatial scanning and Tiling (DASH) available. CTE corrections for UVIS channel. Persistence maps available for IR channel.</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Fine Guidance Sensors</th>
<th>Slow degradation being monitored, understood.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical and Power System</td>
<td>Batteries and solar arrays - no serious issues.</td>
</tr>
<tr>
<td>Pointing and Control System</td>
<td>GYRO lifetime estimates indicate 3-gyro operation until ~2023. One-gyro science operation &gt;2036.</td>
</tr>
<tr>
<td>Data Management System</td>
<td>Lockups are rare (1-2x per year) and understood.</td>
</tr>
<tr>
<td>Thermal Control System</td>
<td>Excellent, no serious issues.</td>
</tr>
</tbody>
</table>
HST Cycle 24 TAC

Critical System Reliability

Reliability

Gyro Operation 3-3-3-1-1

G6 Off 2017
G5 Off
G4 On 2018
G3 Off 2019
G2 On 2020
G1 On 2021

Jan-16 Dec-16 Dec-17 Dec-18 Jan-20 Dec-20 Dec-21 Jan-23 Jan-24 Dec-24 Jan-26

RF Mux & HGA 2 Ax Gimbal
SSAT
Solar Array III, Diode Box, SADM
RGA
RWA
PCU
EP/TCE
DMA Block 1 with CU/SDF
FGS & FGE
FGS and FGE

HGA Gimbal and RF Multiplexer
SSAT
SA and SADM
RGA
RWA
PCU
EP/TCE
DMA Block 1 with CU/SDF
FGS and FGE
Critical System Reliability
Science Instruments

Normalized Reliability

Year

Dotted plotlines represent projections as of January 2014.
Life Expectancy Summary

- **Orbit life** – most likely reentry in 2036; worst case 2028
- **Instruments** – COS FUV detector is being consumed due to usage
  - Current pace suggests moving to 4\textsuperscript{th} position in 2017 and 5\textsuperscript{th} position for ~2020-2022
  - May revisit previously used positions with lower signal to noise
- **Critical Subsystems**
  - Random failure is determined from historical performance of components flown on Hubble as well as on other known programs
  - FGS 3 “wear out” is estimated based on linear extrapolation of usage
  - Standard flex lead gyros are based on both random failure and corrosion rate of the flex lead due to temperature – corrosion is the dominant term
  - Enhanced flex leads are estimated, based on chemical properties, to last perhaps 5 times longer than standard flex leads – random failure becomes the dominant term
  - Radiation dosage has been examined, and where total dosage is predicted to exceed the design specification, the expectation is for “graceful degradation”

**Hubble is expected to be productive beyond the current 2022 budget horizon**
Advanced Camera for Surveys

- ACS astrometry is now improved (outgrowth in part of Frontier Fields)
  - Time dependence is well understood and modeled
  - Improved 47 Tuc proper motions and Detector/Filter corrections → 1 mas
- Observers should pay attention to CTE for low background (<20e-) images
- Improved calibrations of SBC PSF wings and Flat Field pattern coming

**WFC G.Dist.: Astrometric Residuals**

- **WFC1**
  - $\sigma > 0.1$ pix
  - $\sigma \approx 0.02$ pix

- **WFC2**
  - Original Solution
  - Including 47Tuc Proper Motions
  - Including 2D Detector/Filter Artifacts

**WFC G.Dist.: Time Dependencies [3]**

- **WFC1**
  - After de-trending pre/post-SM4 linear time coeffs.

- **WFC2**
  - After de-trending pre/post-SM4 linear time coeffs.
• COS moved to Lifetime Position #3
• Duration at each LP a function of number of photons on detector
• Slow throughput declines but otherwise COS operating very well

• LP4 will be at ~ -5"
  – Assuming current usage move will be in July 2017
  – LP3 will last ~ 2.5 years
  – Resolution is expected to be within ~ 10% from resolution at LP3
  – Will execute program over Summer 2016 to evaluate resolution with adjusted focus
STIS Performance is Stable
BAR5 Provides $10^{-6}$ Contrast or Better

- Comparable contrast performance to infrared Gemini/GPI
- Depends upon Azimuthal Differential Imaging (ADI) and post processing (e.g. KLIP)
Wide Field Camera 3

Improved UV flat-fields:
- Reduce RMS from 1.5% to 0.7%

Improved background subtraction:
- G102, G141, F110W & F105W are sensitive to He I 1.083μm sky line when HST is in daylight

IR “DASH” Mode:
- Up to 8 tiles per orbit
- Gyro pointing with post-observation removal of small drifts (~0.25 pixel)

The WFC3/ can observe point sources as bright as V~0 mag using the GRISMs in spatial scanning mode
Frontier Fields Will Be Completed this Summer

- Four clusters (+ four parallel deep fields) complete

- Continuing with final two clusters in Cycle 23
  - Abell S1063 - first epoch complete; second by early summer
  - Abell 370 - first epoch complete; second scheduled for July-September
Long Range Plan Highlights

- **Cycle 23 averaging 86.8 orbits/week** over first 33 weeks of cycle.
  - Better than other post-SM4 cycles (84.0 orbits/week since Cycle 17).
  - Due in part to:
    - Flexible mix of science accepted by TAC.
    - Larger-than-normal “tail” (material originally planned past 10/01/16).
      - Allows flexible visits to be pulled forward to fill weekly schedule gaps.

- **Previous Cycle Completeness:**
  - Cycle 22: should be completed by late 2016.
    - 9 orbits remain in the LRP as of May 10.
    - <52 orbits of ToO were granted extensions; expire Oct 1, 2016.
HST Science Productivity Remains High

Refereed HST Publications

- Unassigned
- Archival
- Part GO/Part Archival
- Guest Observer (GO)

Refereed Papers per Year

Year

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

- HST archive size is ~100 TB (1.2 million observations)
- HST archive retrievals doubled after Servicing Mission 4 in May 2009
- >12,000 registered archive users (85 countries, 50 states)
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

- 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......
• **In reviewing Cycle 24 proposals, Panels and TAC should focus on the best science**
  – Leave scheduling constraints to us to consider in the context of the entire Cycle 24 pool of recommended proposals
Hubble may be 26 years old, but its best years are still ahead....