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.

2014 Senior Review: *The large oversubscription in scientific demand for observing time on Hubble indicates that there remains far more important and exciting science to be done than the observatory can accommodate. If appropriately funded, the Hubble observatory will in all likelihood continue at its present level of achievement and productivity for years to come.*

2014 Senior Review: *The collective brainpower of the worldwide scientific community that openly competes to utilize Hubble is responsible for extraordinary scientific gains that would not have been envisioned even a decade ago. We find no evidence that this trend of frontier-bending scientific achievement is likely to falter anytime soon.*
Hubble has a finite lifetime

Operations through FY21 (Cycle 28)

7 cycles (including Cycle 22) x \( \sim 4000 \) science orbits per cycle

\[ \Rightarrow 28,000 \text{ orbits remaining} \]

What should we do with those precious orbits?
Shaping the 2020 Vision

A person who has not made his great contribution to science before the age of 30 will never do so. - A. Einstein

<table>
<thead>
<tr>
<th>Year</th>
<th>Astro PhDs*</th>
<th>HST PhDs</th>
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<tbody>
<tr>
<td>2012-13</td>
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<td>2005-06</td>
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</table>

Average = 25%

Monitoring the outer planets

- Solar System Advisory panel raised the issue of long-term monitoring of atmospheric activity in the outer planets
  - Absent *in situ* planetary probes (e.g., Cassini), HST is crucial in providing high-resolution observations of atmospheric features
    - Probe atmospheric circulation and weather systems; seasonal changes; energy balance – particularly in Uranus & Neptune
    - Serve as local templates for exoplanet properties
  - Year-by-year proposals tend to be regarded as incremental by the TAC
    - Significant gaps in coverage over Hubble’s lifetime
    - These impact our understanding of long-term seasonal variations

| Table 1: Years w/ Planet Coverage by Hubble UV/Visible camera |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Planet  | '94 | '95 | '96 | '97 | '98 | '99 | '00 | '01 | '02 | '03 | '04 | '05 | '06 | '07 | '08 | '09 | '10 | '11 | '12 | '13 | '14 |
| Jupiter  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  | Y  |
| Saturn   | R  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  |
| Neptune  | R  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  | B  | G  |

Color code: white = no data, blue = imaging only, green = wind pairs, red = high res. global maps

STUC - Oct 2014
Monitoring strategies

- White paper submitted by Amy Simon-Miller, Glenn Orton, & Michael Wong on behalf of the outer planet community
- Summarizes the science goals of atmospheric studies
- Outlines several scenarios for routine monitoring of atmospheric features on Jupiter, Uranus, Neptune & Saturn (post-Cassini)
  - Paired snapshots / Global maps / Paired global maps
- Global maps of the outer planets provide full longitudinal coverage and determine the spatial variation of distinct cloud features
- Pairs of global maps provide global measurements of the wind field

Figure 4. Seven contiguous orbits allow for full longitude coverage on Jupiter.
HST Vision Programs

- Long-term monitoring programs – Outer Planet Atmosphere Legacy (OPAL) program
  - 29 DD orbits/year (41 with Saturn, post-Cassini)
  - Approved by Director through the end of HST’s lifetime
  - Perhaps this concept should be applied more broadly to other astrophysical objects/phenomena (e.g., SN1987A?)

- Institute-led initiatives
  - Frontier Fields – conclude in Cycle 23

- Community-led initiatives
  - Another Multi-Cycle Treasury Call?

- Joint JWST / HST programs?