Briefing to STUC

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MISSION GOAL: When the astronauts leave Hubble for the last time, it will be at the apex of its capabilities - better than it has ever been before.

WFC3 + ACS + NICMOS = Most powerful imaging ever

COS + STIS = Full set of tools for astrophysics

The architecture of the universe

The mysteries of dark matter and dark energy

The life story of galaxies

The birth and death of stars

Recipes for building planets
Hubble Space Telescope Program

HST Servicing Mission 4
Planned Mission Manifest and Priorities

Manifest in Priority Order

1. RSUs (Gyros)
2. WFC3
3. COS
4. Battery Modules
5. FGS2RR
6. STIS Repair
7. ACS Repair
8. NOBL 8
9. NOBL 5
10. NOBL 7

Note: SCM and Reboost are parallel activities that do not contend with other EVA tasks and, therefore, do not affect priorities.
## HST Science Instrument Failure History

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Side</th>
<th>Installed</th>
<th>Activated</th>
<th>Failed</th>
<th>Operating Time (months)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHRS</td>
<td>1</td>
<td>Apr-90</td>
<td>Apr-90</td>
<td>Sep-91</td>
<td>17</td>
<td>Side 1 was used to run detector 1, and Side 2 was used to run detector 2. Both sides were routinely used in operations until failures occurred. There was a failure of the carrousel drive electronics on Side 1 in June 1991. This was eventually worked around by using Side 2 to drive the carrousel for both Side 1 and Side 2. There was a more serious failure in the Side 1 power distribution in September 1991 that rendered Side 1 unusable. Side 1 was repaired in SM1 with an external kit that provided alternate paths and a second chance to use it. It then operated until January 1997, when there was a failure on Side 2. This Side 2 failure, combined with the earlier carrousel failure on Side 1, made the carrousel, and hence the instrument, totally unusable. Side 2 operated from launch through the Side 2 failure in January 1997.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Dec-93</td>
<td>Mar-94</td>
<td>Jan-97</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Apr-90</td>
<td>Apr-90</td>
<td>Jan-97</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>NICMOS</td>
<td>1</td>
<td>Feb-97</td>
<td>Feb-97</td>
<td>Jan-99</td>
<td>24</td>
<td>Failure of the dewar common element made the instrument unusable after 24 months, making both sides useless. Counted as two failures, one for each side. The instrument was then revived via NCS in SM3B and continues to accumulate operational months on Side 1 without another failure.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Mar-02</td>
<td>Mar-02</td>
<td>Jan-08</td>
<td>70</td>
<td></td>
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<tr>
<td>STIS</td>
<td>1</td>
<td>Feb-97</td>
<td>Feb-97</td>
<td>May-01</td>
<td>51</td>
<td>Ran on Side 1 until failed, then switched to Side 2. No failures in common components.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Feb-97</td>
<td>May-01</td>
<td>Aug-04</td>
<td>39</td>
<td></td>
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<tr>
<td>ACS</td>
<td>1</td>
<td>Mar-02</td>
<td>Mar-02</td>
<td>Jun-06</td>
<td>51</td>
<td>Ran on Side 1 until failed, then switched to Side 2. No failures in common components.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Mar-02</td>
<td>Jul-06</td>
<td>Jan-07</td>
<td>6</td>
<td></td>
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</tbody>
</table>

These instrument sides operated for a total of 373 months with 9 failures, for an average lifetime of 41.4 months. If NICMOS dewar is counted as a single failure, rather than a double failure, then the average lifetime is 46.6 months, a difference of only 12%.
Fine Guidance Sensor Reliability Model

- Two factors to consider for FGSs:
  - Random failures
  - On-going steady degradations that will eventually cause FGS-2R and FGS-3 to fail

- Mean Time To Failure (MTTF) is difficult to determine for FGS system
  - Each FGS is a part of a single string system comprising a radial bay module and a separate electronics box installed on the doors of OTA ES bays D, F, and G
  - We have operated three in parallel for 18 years without any random failures
    - SN 2001 (FGS-1R) - 10.9 years
    - SN 2002 (FGS-2R) - 14.9 years
    - SN 2003 (FGS-3) - 17.7 years
    - SN 2004 (FGS-2RR) - 9.7 years
    - Each FGE is an original 18 year old unit
  - Pre-launch MIL-STD-217 calculated MTTF for each FGE+FGS system was 4.8 years
  - Bayesian adjusted MTTF for a single system, updated for 3 units operating 18.4 years with no failures is 17.6 years
  - Constant failure rate premise ignores unknown susceptibility to onset of end-of-life electronic failures that may make the future risk of random failures higher than past experience indicates.
Hubble Life-Limiting Items
(50% Probability)

- Instruments – Nominal SM4
  - Imaging 6.8 years (one operating channel)
  - Spectroscopy 6.8 years
  - Working Instrument 9.4 years

- Instruments – Off-Nominal SM4 (one instrument excluded)
  - Working Instrument ≥ 7.4 years

- Gyros – Nominal SM4
  - 3 Gyros 5.7 years
  - 2 Gyros 7 years
  - 1 Gyro >10 years

- Gyros – Off-Nominal SM4 (only two RSU’s installed)
  - 3 Gyros 4.6 years
  - 2 Gyros 5.8 years
  - 1 Gyro >10 years
Hubble Life-Limiting Items – continued
(50% Probability)

- Fine Guidance Sensors – Nominal SM4
  - 2/3 FGS Guiding 7 years
  - 2 FGS Guiding 9 years

- Fine Guidance Sensors – Off-Nominal SM4 (No Changeout of FGS2R)
  - 2/3 FGS Guiding 3 years
  - 2 FGS Guiding 10 years

- Worst Case Scenario – Off-Nominal SM4 (No Changeout of FGS2R) and FGS1R Fails Within 3 Years After SM4
  - 2 FGS Guiding 3 years
  - 1 FGS Guiding 4-5 years (considered feasible but requires development of alternate method of roll control – e.g. FHST’s or camera sub-array)
Hubble Life-Limiting Items

Conclusions

● We have a reasonable basis for estimating lifetimes of instruments and gyros

● FGS/FGE lifetimes are more problematical since none has ever failed after 54 total years of operation

● The present study indicates that instrument lifetime is the likely determining factor of observatory longevity

● Even without FGS2R change out, the observatory should be able to continue operations on at least one FGS for longer than the instruments will last
  - Exception would be “worst case” of FGS1R randomly failing in advance of FGS2R or FGS3 wear out (<3 years after SM4)

● In a mission contingency we do not recommend sacrificing both STIS and ACS repairs in order to ensure FGS change out

● Two “world views” of contingency planning
  - Enable maximum science capability and accept additional risk to spacecraft longevity
  - Enable extended spacecraft lifetime even at the sacrifice of some science capability

● In the mission priorities a reasonable compromise between the two “world views” would be to place either of the instrument repairs above FGS in relative priority
Backup
Hubble Space Telescope Program

Current HST SM4 EVA Timeline

**EVA Timeline as of January 3, 2008**
(From official time estimates from JSC)

- **EVA 1** (FD4)
  - Setup: 0:00
  - WFC3: 1:00
  - Bay 3 Battery Module: 2:00
  - Daily Close-out: 3:00

- **EVA 2** (FD5)
  - Sun Protect Attitude: 1:00
  - RSUs: 2:00
  - Bay 2 Battery Module: 3:00
  - Daily Close-out: 4:00

- **EVA 3** (FD6)
  - Sun Protect Attitude: 2:00
  - COS: 3:00
  - ACS Repair Part I: 4:00
  - Daily Close-out: 5:00

- **EVA 4** (FD7)
  - Sun Protect Attitude: 3:00
  - STIS Repair: 4:00
  - NOBL 8: 5:00
  - Daily Close-out: 6:00

- **EVA 5** (FD8)
  - Sun Protect Attitude: 4:00
  - FGS: 5:00
  - ACS Repair Part II: 6:00
  - Final Close-out: 7:00

**Priority Task Times**
1. RSUs (3) 3:30
2. WFC3 2:45
3. COS 2:30
4. Bay 3 Battery Mod. 1:50
   - Bay 2 Battery Mod. 1:40
5. FGS 2 2:40
6. STIS Repair 3:25
7. ACS - part I 2:00
   - part II 1:45
8. NOBL 8 0:45
9. NOBL 5
10. NOBL 7
11. SCM 0:15
12. Reboost

**Note:**
- Total ACS task time is 3 hours. If placed on one day with COS, EVA duration is 7.25.
- By splitting into two days, setup and cleanup need to be performed twice. At the end of ACS Part I, two cards have been removed.

**Note:**
Indicates a sun protect attitude is required from start of opening aft shroud door to closing of aft shroud door. The length of the arrow is not to scale of task time between door opening and closing.
## Contingency Plans For Shortened Mission

<table>
<thead>
<tr>
<th>EVA'S REMAINING</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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</thead>
<tbody>
<tr>
<td>5</td>
<td>NOMINAL PLAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>EVA 1 - WFC 3, BAY 3 BATT (6:30), EVA 2 - RSU, BAY 2 BATT, (6:40), EVA 3 - COS, FGS 2 (7:20), EVA 4 - STIS, FINAL CLOSEOUT (6:20)</td>
<td>NOMINAL PLAN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>N/A - FOCUSED INSPECTION NOT UNTIL AFTER EVA 1</td>
<td>EVA 2 - RSU (5:00), EVA 3 - COS, ACS- ALL (7:20), EVA 4 - STIS, NOBL 8 (6:30), EVA 5 - FGS 2, BAY 2 BATT (6:15)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>EVA 1 - WFC 3, BAY 3 BATT (6:30), EVA 2 - RSU (2), FGS 2 (7:10), EVA 3 - COS, BAY 2 BATT, FINAL CLOSEOUT (6:50)</td>
<td>EVA 2 - RSU, BAY 2 BATT (6:40), EVA 3 - COS, FGS 2 (7:20), EVA 4 - STIS, FINAL CLOSEOUT (6:20)</td>
<td>NOMINAL PLAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>EVA 1 - WFC 3, BAY 3 BATT, NOBL 8 (7:10), EVA 2 - 2 RSU (2), BAY 2 BATT, FINAL CLOSEOUT (6:40)</td>
<td>EVA 2 - RSU (2), FGS 2 (7:10), EVA 3 - COS, BAY 2 BATT, FINAL CLOSEOUT (6:50)</td>
<td>EVA 3 - COS, FGS 2 (7:20), EVA 4 - STIS, FINAL CLOSEOUT (6:20)</td>
<td>NOMINAL PLAN</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>EVA 1 - WFC 3, RSU (#1), FINAL CLOSEOUT (7:05)</td>
<td>EVA 2 - RSU (2), BAY 2 BATT, FINAL CLOSEOUT (6:40)</td>
<td>EVA 3 - COS, NOBL (3), FINAL CLOSEOUT (6:40)</td>
<td>EVA 4 - FGS 2, ACS PT. 2, FINAL CLOSEOUT (6:40)</td>
<td>NOMINAL PLAN</td>
</tr>
</tbody>
</table>
Completed ACS Repair