THE HUBBLE SPACE TELESCOPE SERVICING MISSION

Albert Boggess
Goddard Space Flight Center
Greenbelt, MD 20771, U.S.A.

1. INTRODUCTION

This paper will not review in any detail the performance problems that have been discovered with the Hubble Space Telescope (HST) after it was placed into orbit on April 25, 1990, but rather it will concentrate on the efforts currently under way to conduct a servicing mission late in 1993 in order to restore both the telescope and the spacecraft to their expected capabilities. The detailed planning for this mission will intentionally be left flexible as long as possible to be able to respond to future changes in spacecraft performance. The descriptions below reflect the state of the hardware and planning as of November, 1991. These developments include four major types of spacecraft hardware, plus the carriers, tools and the plans for the servicing mission itself. In addition, some other hardware items are being considered as desirable additions, if schedules and budgets permit. The hardware efforts include the following:

- Modified Wide Field/Planetary Camera (WF/PC II)
- Corrective Optics Space Telescope Axial Replacement (COSTAR)
- Improved Solar Arrays
- Improved Gyroscope Packages
- Desirable Extra: GHRS Power Supply

The first two items are needed to compensate for the spherical aberration of the telescope's primary mirror, while the second two are intended to improve and maintain the HST guidance characteristics.

2. OPTICS INSTRUMENTATION: WF/PC II AND COSTAR

Because of the importance WF/PC plays in the scientific program of HST and also because of its important operational role as a finder for other instruments, work began some years before the HST launch on the construction of a spare WF/PC. When the spherical aberration of the HST primary was discovered, it was noted almost immediately that the primary was imaged inside the WF/PC optical train at a point very near the secondaries of the Cassegrain repeaters. Thus a good optical correction could be achieved by imposing an equal, but opposite aberration on these

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secondaries. Construction of the new instrument is proceeding with the modified optics. The principal concern is the very tight alignment tolerances which are imposed by the requirement to match precisely the pupils of the aberrated telescope primary and the compensated WF/PC II secondary. In order to be sure that alignment can be accomplished on orbit, commandable actuator mechanisms must be installed on the WF/PC II optics. Unfortunately, this is a major increase in effort and cost, and all the optical channels can not be outfitted in this way within the available schedule and resources. Consequently, the number of CCD detectors are being reduced to three WF chips and one PC chip. This change will greatly improve the reality of the instrument's performance goals and schedule and still retain all of its scientific capability, albeit at somewhat reduced efficiency.

While WF/PC II provided a natural way to restore the quality of wide-field imaging, correcting the performance of the other scientific instruments is less straightforward. The course that has been chosen is to install sets of corrective fore-optics in front of the various instrument entrance apertures. The optics and their supporting structures are to be contained in an instrument enclosure named COSTAR which will be inserted in place of the little-used High Speed Photometer. After COSTAR is installed in the HST, it will be commanded to raise a turret containing an optical bench, from which the corrective optics can be deployed in front of the FOC, GHRS and FOS. Long-lead items are now being fabricated, including the optics, which were designed from the beginning to be adjustable on orbit. The technical area of concern is the stability of the optical bench, and it will undergo very careful thermal and structural testing.

3. SPACECRAFT INSTRUMENTATION: SOLAR ARRAYS AND GYROS

The solar arrays are performing very well in terms of power generation. However, thermally-induced oscillations in the arrays degrade the pointing and sometimes cause loss of fine control. There had been a concern that the oscillations might cause fatigue or an overstressed condition leading to catastrophic collapse of the array booms. Careful analyses of the test data have demonstrated that this eventuality is very remote. New arrays are being designed and fabricated by ESA to correct the existing problems, and they will be available in time for the planned maintenance mission.

The HST has a complement of six gyroscopes, any three of which are necessary to control the spacecraft during slews and the initial stages of target acquisition. Two of these gyros have failed, the first in December of 1990 and the second in June, 1991. The failures appear to be due to fabrication procedures used in the mid-1970's when four of the gyros were completed. The remaining two flight units were fabricated in the mid-1980's and they should not exhibit this type of failure. Spare gyroscope units already exist, and the plan is to replace the four older gyros with new ones built to current standards. A software procedure has been developed in case more gyros fail to provide coarse control of spacecraft attitude using the on-board solar sensor and magnetometers. In this way the HST can be kept safe, but observations would cease until the new gyros were installed.

4. DESIRABLE EXTRA: GHRS POWER SUPPLY

The four units described above constitute the baseline payload for the 1993 maintenance mission. However, additional payload capacity and mission time are reserved to accommodate at least one additional replacement unit, whose identity will be left open as long as possible to accommodate future failures or changes in spacecraft performance. One of the candidates currently being considered is a replacement for a power supply in the Goddard High-Resolution Spectrograph (GHRS).

One of the instrument's low-voltage power supplies became unusable for routine operations in August, 1991. This supply is required to operate the far-ultraviolet detector, which is necessary for obtaining echelle spectra ($R \approx 10^5$) at wavelengths less than 1600 Å. A scheme has been proposed for replacing the supply on orbit. It is premature to commit to this replacement until its feasibility has been carefully studied, and these studies are currently under way.

5. THE MAINTENANCE MISSION

A timeline has been developed for installing the equipment described above and it is currently being verified by astronauts practicing with HST mock-ups in water tanks. The timeline shows that the installation of the baseline set of modules should take about fifteen hours, distributed among three six-hour periods of extra-vehicular activity (EVA). In order to have margin in the timeline to accommodate unforseen problems, and also to allow for addition of one or two additional items, the mission is being planned for four six-hour EVA periods. The timeline is planned as follows:

Day 1: Replace Solar Arrays. This task is scheduled first because it is the most complex, and also because it most be completed successfully for the continued safety of the spacecraft. The old arrays will be stowed in the array carrier for return to Earth.

Day 2: Install WF/PC II and COSTAR. In each case the old instrument and must first be removed and stowed temporarily on a holding pad in the payload bay, then the new instrument removed from its carrier and installed in HST, and finally the old instrument stowed in the carrier for return to Earth.

Day 3: Install two gyro packages containing a total of four gyros. The actual installation is straightforward. However, startracker baffles must be moved out of the way to gain access to the equipment shelves containing the gyro boxes, so that entry and closure will take time. Two or three hours should be available for additional tasks.

Day 4: Contingency time for unforseen problems or additional tasks.

This will be a challenging mission. There is much work to be done to get ready and the coordinated efforts of many experts in orbit and on the ground will be needed for its execution. The result will be an HST operating very near to the performance that we all originally expected.