N95- 27655

SPACE ENVIRONMENTAL EFFECTS OBSERVED ON THE HUBBLE SPACE TELESCOPE

Joel E. Edelman
LDEF Newsletter
Silver Spring, MD

James B. Mason
NASA Goddard Space Flight Center
Greenbelt, MD

INTRODUCTION

The Hubble Space Telescope (HST) Repair Mission of December, 1993, was first and foremost a mission to improve the performance of the observatory. But for a specialized segment of the aerospace industry, the primary interest is in the return to Earth of numerous pieces of the HST hardware, pieces which have been replaced, repaired, improved, or superseded. The returned hardware is of interest because of the information it potentially carries about the effects of exposure to the space environment for three and a half years.

Like the LDEF retrieval mission four years ago, the HST repair mission is of interest to many engineering disciplines, including all of the disciplines represented by the LDEF Special Investigation Groups (SIGs). There is particular interest in the evaluation of specific materials and systems in the returned components. Some coated surfaces have been processed with materials which are newer and still in use by, or under consideration for, other spacecraft in a variety of stages of development. Several of the systems are being returned because a specific failure or anomaly has been observed and thus there is, at the outset, a specific investigative trail that needs to be followed. These systems are much more complex than those flown on LDEF and, in two instances, comprised state-of-the-art science instruments. Further, the parts used in these systems generally were characterized more rigorously prior to flight than were those in the LDEF systems, and thus post flight testing may yield more significant results.

THE RETURNED HARDWARE

The hardware returned by the repair mission includes two complete instruments and an array of additional components which supported observatory operations. The instruments include the first Wide Field Planetary Camera (WFPC-I), a JPL instrument which was replaced by an updated version of the same instrument containing its own corrective optics, and the High Speed Photometer (HSP), a University of Wisconsin instrument which was replaced with the Corrective Optics Space Telescope Replacement (COSTAR), the Ball Aerospace/Goddard Space Flight Center corrective optics for the remaining instruments on board the HST.

Both instruments were operational at the time of their replacement, although the WFPC-I had suffered from an unusual contamination effect on its extremely cold sensor window, an effect loosely referred to as "measles". This effect is speculated to be condensation around nucleation sites and may also be the initial phases of the kind of process that resulted in the unusual crystal-type growth features observed on LDEF and other space exposure missions. At KSC, significant degradation (blistering and peeling) of the M-1 (UV flood) mirror MgF_2/aluminum coating was observed along part of its outer edge; the remainder of the surface, however, was visually clean, with no evident mottling, cloudiness, or particulates. This mirror was external to the WFPC-I and exposed to a deep space view. The pickoff mirror, which was located in the HST interior, was observed to be in excellent condition. Aside from several dust particles there was no visible evidence of degradation or contamination.

More than two dozen high velocity impact craters visible to the naked eye have been counted on the WFPC-I's exposed radiator surface; impact feature characteristics, similar to those documented on LDEF, were seen in this initial cursory look and include symmetrical and oblique craters, and apparent paint loss in the spall area from the impact shock wave. Contamination effects reminiscent of LDEF were also observed, including a brown line of undetermined origin on the radiator near its bolted edge, and areas of brown stain surrounding rivets; the latter is tentatively attributed to the rivet lubrication, and was present to a much lesser degree prior to launch.

One of the five detectors in the HSP had suffered a throughput drop of nearly two thirds partway through the HST mission; later in the mission there was an equally anomalous recovery. Several possible causes have been speculated but none is a leading candidate at this time.

The degraded solar arrays were replaced on orbit and one of the original two arrays returned as part of this mission; the second array was jettisoned. The original array was returned directly to the European Space Agency (ESA) from the Kennedy Space Center (KSC) and will be subjected to a program of functional testing and characterization as well as an extensive study of micrometeoroid and debris impact craters. Some delamination of the solar array bus bars was observed during the repair mission, and it was also observed that two of the hinge pins had begun to walk out of their hinges.

Other hardware returned included the three rate sensing units (RSUs), or pairs of gyros, two of which had suffered apparent failures during the HST's first three years. Two electronic control units (ECUs), which are also believed to have failed, were returned. Finally, the P-15 and P-16 fuse plugs were replaced with upgraded versions and the original plugs returned for examination.

Minimal evaluation of the returned hardware was performed at KSC at the conclusion of the Repair Mission. Following photography and the taking of contamination samples ,the solar arrays were packed and shipped to ESA, and the remaining hardware was barged to GSFC, using modified containers from previous missions, the Gamma Ray Observatory (GRO) container and the LDEF Assembly Transportation System (LATS). Both containers were continuously purged.

EVALUATION PLANS

Because of the similarities between the LDEF and HST hardware investigations, a serious effort is being undertaken to assure the carryover of as many as possible of the lessons learned from the LDEF experience. On January 27, 1994, several LDEF investigators supported a planning meeting and telecon at GSFC for the evaluation of the returned HST hardware.

The Systems SIG became active in the earliest stages of the HST planning process because of the special significance of the HST hardware for systems and because of the complexity of the testing options.

The Systems SIG recommendations have followed the pattern of the LDEF Test Plan developed by the Systems SIG prior to the LDEF retrieval. The overriding philosophy remains focused on testing from the top down; that is, testing each system at the highest practical level prior to disassembling and testing individual subsystems and components. Specific areas of concern that are highlighted by the Systems SIG included electronics, lubricants, seals, mechanisms, heat pipes, solar cells, adhesives, and optical components including windows, mirrors, filters, and sensors. The Systems SIG has also emphasized the need for all results, including the raw data and any hardware for which no future use is planned, to be archived properly and adequately for future research.

Following are abstracts from the most recent drafts of the investigation plans for the evaluation at GSFC of the returned HST hardware.

Wide Field Planetary Camera (WFPC-I) Evaluation

External Inspection

The WFPC-I will be examined visually and a detailed photographic record made. Operations such as fit checks, integration, and deintegration will be recorded on videotape.

Optical

Assessment of the M1 mirror, the pickoff mirror, and the aperture window are planned for GSFC. The areas of interest are the optical characteristics, such as the reflectance, of optical components and changes caused by the on orbit environment. No end-to-end optical system tests are planned at GSFC. Because extremely cold temperatures under vacuum are required for operation of the CCD, such a test would be inordinately expensive.

Contamination

The contamination assessment will consist primarily of evaluating contaminant deposition on WFPC-I components and external surfaces, both inside and outside of the aft shroud. Activities will include a rinse of the vent baffle plate and flight handle, scraping a sample from the vent pipe, and tape lifts and swabs at various locations. Further assessments of optical elements and the detectors mounted inside the instrument enclosure will be performed at JPL.

Of particular interest is the optical window at the entrance aperture. Because this window acted as a seal between the HST and the WFPC, the inner and outer surfaces will provide accurate, independent characterizations of the instrument and telescope contamination environments, respectively.

Mechanical

The mechanical assessments at GSFC will include measurement of critical areas of the WFPC-I including the location of the pickoff mirror with respect to the "A" latch, features near the pickoff mirror and the instrument (+V3), the radiator light baffle, and the light pipe. The combination of WFPC-I metrology with that of WFPC-II will provide a complete and detailed description of the allowable radial Science Instruments physical envelope. The assessment will also include a detailed evaluation of both the side latches, blind mate connector, and guiderails. A lubricant sample will also be taken from the WFPC-I for analysis. Further assessments of mechanisms and interior mechanical components will be made at JPL.

Electrical

The electrical and electronic assessments at GSFC will consist of system testing using the Vehicle Electrical System Test (VEST). This will include Current-Voltage Test (IVT), Electrical Integration Continuity and Isolation Test (EICIT), aliveness, and functional tests. Both A and B side circuitry will be tested. Comparison of these test results with prelaunch data on WFPC-I will provide an assessment of environmental effects. Further evaluations of specific electrical components such as pc boards and solder joints will be performed after disassembly at JPL.

Thermal

The thermal assessment will include alpha and epsilon measurements of both radiators, evaluation of the thermal properties of external surfaces and MLI, Thermal Emittance Coatings (TEC) degradation, and heat pipe performance to determine the effects of long duration exposure to the low earth orbit environment. Bolt torques for the heat pipe saddles will be checked to assess the effects of thermal cycling. Heat pipe performance and TEC degradation will be evaluated after disassembly of the instrument at JPL.

Impact Craters

An assessment of micrometeoroid and debris impacts on the outside surfaces of the two radiators will be performed. Details of this plan are pending review of recommendations from the LDEF Meteoroid and Debris SIG.

Disposition

The WFPC-I will be returned to JPL for further evaluation. The Materials and M&D SIGs are expected to request sample specimens of the radiator surface for SEM evaluation, subsequent to JPL testing.

High Speed Photometer (HSP) Evaluation

External Inspection

Prior to unpacking, preliminary contamination samples will be obtained from the top of HSP. This will include rinses, tape lifts, and removal of the witness mirror from inside its protective enclosure. Additionally, a visual inspection will be performed and unique contamination features will be sampled.

During the unpacking process, photographic and video documentation will be performed. The latches will be inspected and samples of the Braycote lubricant will be taken. More contamination samples of the box exterior surfaces will also be taken, particularily in the area near the aperture.

Metrology

A survey of the HSP exterior surface will be performed including at least the following: latches, guide block, aft strip, guide block mounting bracket, and all six exterior surfaces. This survey will be performed according to an approved procedure and will use the Automated Image Metrology System (AIMS). The procedure will simply be a modification of the existing COSTAR metrology procedure.

Quarter panel measurements will be made to relate the HSP volume to the quarter panel. The B-latch gap will also be measured. Also, measurements of the aperture location will be made to verify its position.

Internal Inspection
One HSP side panel will be removed and internal wipes, tape samples, and rinses will be performed. Also, a witness mirror will be installed inside of HSP to monitor ground contributions to contamination. If appropriate, one or more flight mirrors will be removed for further analysis. The side panel will then be reinstalled onto HSP.

Electrical Testing
HSP will undergo Electrical Integration Continuity and Isolation Test (EICIT), Current-Voltage Test (IVT), aliveness, short form functional, and long form functional tests using the same Electrical GSE used before HSP was flown. This will allow comparison of the before and after performance of HSP.

Throughput Test
This would be performed in order to try to understand the factor in 3 loss in throughput that the HSP experienced during part of its time in orbit. Although some alternatives have been identified, the method for performing this test is still undetermined.

Depending on whether further electrical tests are planned with HSP at Goddard or at the University of Wisconsin, the Remote Interface Unit (RIUs) can be removed at this point. The RIUs are scheduled for refurbishment and availability for reflight.

Remove Latches
The latches will be removed for refurbishment before HSP is shipped. The latches will undergo a detailed inspection and ultimately be refurbished for reflight.

Disposition
The HSP will be returned to the University of Wisconsin.

Other Hubble Space Telescope (HST) Hardware Evaluation

Much of the testing of other HST hardware will be performed by the original vendors. Proposed plans are now under review. Work that is planned at GSFC is described briefly below. Evaluation of selected components (contamination, optics, materials, and thermal performance) are being discussed.

RATE SENSING UNIT (RSUs)
These units will be visually inspected, particularly the connector pins. Photographs and contamination samples will be taken. Electrical interface continuity and isolation tests will be performed, and the units will be returned to Allied Signal for functional testing and evaluation. It is planned that these units will be refurbished and reflown.

ELECTRONIC CONTROL UNIT (ECUs)
These units will be visually inspected, particularly the connector pins. Photographs and contamination samples will be taken. Full functional tests are desired but not planned at GSFC.

FUSE PLUGS
These units will be visually inspected and photographed. A DC milliohm and high voltage test is planned, as is resistance and current characterization at GSFC.

MULTIPLE LAYER INSULATION (MLI) SAMPLES

Both physical and chemical evaluations are being planned, in addition to thermal performance. Brittleness of some MLI specimens has been observed as a result of its handling on orbit.

FLIGHT SUPPORT EQUIPMENT

A variety of equipment used on the servicing mission, and exposed to the space environment for the duration of the mission, will be examined. Included are the Flight Support System, the instrument carriers, and the tools used by the astronauts.