Hubble Space Telescope
High Speed Photometer
Orbital Verification Test Report

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1. Purpose of HSP OV Final Report

The purpose of this report is to provide a summary of the results of the HSP Orbital Verification (OV) tests and to report conclusions and lessons learned from the initial operations of the HSP. The HSP OV plan covered the activities through fine (phase III) alignment. This report covers all activities (OV, SV, and SAO) from launch to the completion of phase III alignment. Those activities in this period that are not OV tests are described to the extent that they relate to OV activities.

2. Executive Summary

All HSP systems were verified and performed as designed. Difficulties encountered during OV were not the fault of the hardware, software, or design, but were the result of incomplete understanding of the orbital environment (the brightness of the bright earth, for example), test design errors (the PMT high voltage turn-on test, for example), incomplete information about other HST systems (the alignment of the FGS, for example), the effects of spherical aberration (the inability of the original HSP fine alignment test to obtain the required information, for example), or ground system problems (inability to capture and verify HSP memory, for example). At the end of OV the HSP is fully capable of supporting the planned SV, SAO, and OLT programs. Most SV activities as well as several OV tests had to be redesigned to accommodate the effects of spherical aberration.

3. HSP Performance

HSP performance throughout OV has been nominal. There have been no failures of any hardware or software and the HSP continues to operate in the original pre-launch configuration; there have been no redundant unit reconfigurations. There have been two soft single event upsets affecting engineering telemetry later cleared by a system controller "reboot". There have been two cases of bright object protection limits being exceeded and the HSP safing as a result. Thermal performance, power consumption, and general operation have been as expected.

3.1 Thermal

The major requirements for the HSP thermal control system were to maintain detectors as cool and stable as possible, to keep the electronics temperatures within design limits, and to meet the HST interface temperature requirements that were generally imposed on HSP external surfaces near other HST structures. Selected areas of the HSP were required to be maintained between -20 and + 20 degrees Celsius. These interfaces were required to be maintained while the HSP is operating and while in the "hold" mode. Hold mode power was limited to 58 watts orbital average which, given the cold orbit effective sink temperatures, required careful balancing of the thermal design. While the design had to meet the worst case combination of interface requirements, it was recognized that the actual environment in orbit might prove to be much more benign than the interface documents implied because of the conservatism inherent in the interface definition. Therefore, the HSP thermal design provided for the possibility of taking advantage of operational experience.

The general approach was a passive thermal design radiating heat from the electronics and detectors to external radiators. Because the detectors were to be maintained as cool as possible, they are thermally isolated from the higher power dissipation electronics. The detectors and electronics are thermally coupled to their own radiator surfaces, which are isolated from each other. The forward and aft bulkhead interface surfaces required to be kept within ICD limits are equipped with heaters. One problem faced early in the design was that of controlling power supplied to the heaters while the input bus voltage varies between interface limits of 24 to 32 volts. The HSP heater control application processor in the NSSC-1 monitors the input bus voltage and controls the power applied to the heaters. The heaters can be set for a specified power level and can be controlled to any of 20 power levels in sequence providing for a 20 point "warm up" curve. The heaters also can be controlled in a thermostat mode in response to a specified telemetry temperature monitor. The specific monitor, turn on temperature, and turn off temperature can all be changed on command. The capability also exists to inhibit heater switching during specified times. All parameters in the heater control processor can be loaded from the ground.

The flexibility built into the design of the HSP thermal control system has already been used several times. The original pre-launch HSP hold mode used the heater control application processor to apply a constant orbital average power to the forward and aft bulkhead to maintain the interface temperature above -20 degrees Celsius with all other electronics off. In that case, when the HSP made hold to operate mode transitions, the electronics were subjected to large temperature changes. A year or so before launch, a "new hold" mode was defined that kept the common electronics on to maintain HSP temperatures but left all heaters off. Thermal model predictions suggested that in worse case cold orbit conditions, some limited areas of the HSP aft bulkhead might reach -25 degrees Celsius. The change was never formally adopted in the interface control documents because agreement could not be obtained from all parties, but was nevertheless adopted by the Space Telescope Science Institute into the standard operating procedures. It was felt that the increased reliability from the lessened thermal transitions outweighed the potential problems due to out of limit interface temperatures. Several months after launch, the HSP "new hold" mode was put into operation and has proven to be very successful. Temperature changes between hold and operate are now small and because the aft shroud thermal environment is warmer than worst case predictions, interface temperatures only rarely drop below -20 degrees Celsius and then only during unusual circumstances, such as vehicle safing events. The only hitch was that for several weeks in the fall of 1990 just after the "new hold" mode was put into effect, both the old and new hold modes were actually running. The heaters were on and being controlled to the old hold values while the system controller was also on. There was no danger or urgency to correct the error on an emergency basis so the correction was simply incorporated into the SMS pipeline and took effect about two months later. The new hold has proven to be a stable and effective mode with no known disadvantages. Power consumption in the new hold mode is 46.3 watts. The old hold mode power consumption is 58.0 watts.

Spacecraft power may become more critical as solar arrays degrade or for other reasons. HSP detector temperature may later prove to be critical for some kinds of observations. The HSP thermal control system, unlike systems based on conventional thermostatically controlled heaters, can adapt to new conditions as they occur. For example, if information developed later in the mission suggests the need to control detector or bulkhead temperatures, the heater control processor can be operated in the "software thermostat" mode to control the area of interest to the desired temperature, subject to available power. A test of that capability was requested several times but not approved. Since this thermal control method has many advantages over conventional techniques, many of which have already been exploited to the advantage of the HST mission, it seems short sighted not to demonstrate the remaining capabilities, even briefly. Orbital verification of the HSP thermal control system has been satisfactory to the extent that it has been done, but it has not exercised more than a limited portion of its capabilities.

3.2 Power

HSP power consumption has been as predicted throughout the OV/SV period to date. The present "new hold" mode consumes less power (46.3 W) than the fixed power "old hold" mode (58.0 W). Because there are no hardware thermostats, HSP power consumption is predictable and is not a function of aft shroud temperature.

3.3 Electrical and Mechanical

Contrary to prelaunch expectations, analysis of the aperture mapping tests (1380, 3093, and 1526) suggests that there is no discernible "banana" effect, i.e., a distortion of the optical bench caused by thermally-induced forces. Motions of the apertures are not temperature dependent as far as can be determined, indicating that the structure is more stable than expected. Also, the stable thermal environment contributes to HSP mechanical stability.

There have been no electrical problems. The HSP continues to operate on the primary (prelaunch) set of redundant electronics, including the RIUs. There have been no electrical reconfigurations.

There is, however, a known EMI problem which may or may not require additional work. The reply bus driver is in the RIU. The level of conducted emissions was far in excess of specified limits during pre-launch RIU electromagnetic interference (EMI) testing. The out-of-limit condition was resolved by the project office by increasing the allowed limit rather than by pursuing a technical solution. There has been some indication that reply bus noise can be found in certain detector data. Later SV tests are expected to determine if the reply bus noise is a significant problem or not. The reply bus can be turned off if needed during critical observations. A test of this scheme was written (SV 2749) and submitted but still awaits implementation; so the required commanding has not been incorporated into SOGS.

The RIU reply bus emissions appear to be readily correctable by incorporating an internal shield in the reply bus transformer. Such a correction should be investigated before this RIU is used in another spacecraft.

3.4 Depressurization

The HSP has no pressure gauge. There was no evidence of any significant partial pressure in the HSP when the high voltage was turned on. The dark count was nominal and there was no sign of noise caused by arcing or corona.

3.5 Flight Software

Flight software has operated as expected with no anomalies and no revisions. Especially noteworthy was that the flight software calculated correctly the magnitude and direction of the small angle maneuver required for target acquisition. No corrections or modifications were required. As indicated above, the heater control application processor has been only partially exercised.

3.6 Detectors

All five detectors have operated satisfactorily. There have been three detector operational problems that have been resolved and were not the fault of the detectors themselves.

The PMT signal during the high voltage turn-on test increased in a manner suggesting an approaching bright object. This was originally though to be the bright earth, but later was shown to be a characteristic of turning on the high voltage well below the nominal operating voltage of the corotron, a gas discharge regulator used to drop the high voltage power supply voltage down to the level required by the PMT. When the PMT was turned on with a higher voltage on the corotron (1900 volts, rather than 1500 volts), closer to but still somewhat below the nominal corotron operating voltage, performance was normal. There has been no recurrence of any anomalous output since the PMT was confined to the higher turn-on voltage. See Appendix B for additional details of the investigation of this problem.

The first attempt to perform the PMT dark count test ended with a bright object safing when the bright earth came into view of the PMT. Later analysis shows that the PMT is safe to operate with the bright earth as a target. The bright earth protection limits have been relaxed to allow such operation.

Similarly, the first attempt to perform aperture mapping on the VIS detector ended in a bright object safing when the read beam intersected the finding aperture during a mapping with the bright earth (which occasionally is about 50 times brighter than had been expected) in view. It was later determined that some filters on both the VIS and POL tubes should not be used with the bright earth since they may cause too large a current to be drawn from those detectors. Calibrations are now performed on selected filters with the Orion nebula instead of the bright earth.

In all three cases mentioned above, the problems were the result of incorrect operating procedures. The safing mechanisms worked. Changes were made in the operating procedures and there have been no additional problems with the detectors.

OV testing has also shown that the order of the filter strips on the POL detector were reversed from that shown on the drawings. The same drawings define the orientations of the polarizing strips, which have not been verified yet in the OV or SV program, but will be in later SV tests.

3.7 Alignments

Alignment of the HSP apertures to the HST focal plane, FGS-to-SI alignment, was a major difficulty until the FGS alignment matrices were determined to the required accuracy. Initial attempts to perform the phase II alignment (1503) produced data from the two UV detectors that were not consistent. The phase III alignments at first failed (in January and February 1990) completely because the target could not be placed in the desired aperture. In fact, the FGS to SI alignment was not known well enough to place a target reliably in the HSP's ten arc second diameter finding apertures. It was therefore decided to stop further alignment testing in October 1990 until FGS/SI alignment problems were better understood and resolved. Testing was resumed in March 1991 when improved FGS/SI alignment matrices along with the results of a redesigned HSP fine alignment test produced high quality data. The redesigned HSP fine alignment test did not assume that the target could be placed in the aperture with high accuracy and therefore was much more robust and forgiving than the original test. The aperture positions of the image dissector tubes (except the POL tube) are now known to within 0.02 arc seconds, which is better accuracy than was anticipated before launch.

The degraded image also contributed to the difficulty of determining accurate alignment. The model used to specify aperture position now uses 13 parameters. Had the HST star images been as predicted, a model with 6 parameters would have sufficed. The two factors, poor FGS to SI alignments and degraded images, both contributed to the delay in determining alignments.

3.8 Magnetic Shielding and effects

The HSP detectors have double magnetic shielding. HSP instrument level acceptance tests verified the detectors would be insensitive to the effects of the earth's magnetic field or HST ICD level fields. There have been no specific OV tests performed to verify magnetic field sensitivity but no evidence has been found to date of any measurable sensitivity.

3.9 Sensitivity to SAA

Tests have been proposed to measure HSP sensitivity to the SAA but none have been approved or scheduled. Most HSP data have been collected outside the SAA.

3.10 Contamination

There is no evidence to date in the OV test data of any contamination effects. The SV program is designed to quantify throughput and will be more likely to detect the presence of contamination, if any.

3.11 Throughput

The SV program, rather than the OV program, is intended to more precisely quantify HSP throughput. However, the targets observed to date in the OV test program verify that the HSP throughput is generally as expected except for a few (two or three) filters, F551W for example, where the data are not consistent with pre-launch predictions.

3.12 Sensitivity to bright objects

The HSP instrument safings during VIS tube aperture mapping and PMT dark count tests were caused by the bright earth triggering the HSP bright object protection application processor. The standard operating procedures and the 10.2 reconfiguration software were modified to allow operation of the HSP without unintended safing events because of bright earth limb occultations. The PMT bright object limits are relaxed during warm-up and data-taking and the VIS/POL tube's sensitive filters are not used with the bright earth.

3.13 Primary Mirror Spherical Aberration

An HST image would have had 70% of its encircled energy within a 0.2 arc second diameter if the telescope mirror specifications had been met. This would have meant over 90% encircled energy within a 1.0 arc second aperture. The degraded image caused by spherical aberration has only about 50 to 70% energy in a 1.0 arc second aperture and about 20% in a 0.4 arc second aperture. The design goal of 0.3 to 3.0% throughput in the 1.0 arc second apertures has been reduced by a factor of two to three. The reduction is about a factor of four or five in the 0.4 arc second apertures. Because of the loss of signal the 0.4 arc second apertures are no longer acceptable for photometry. Test plans have been modified to increase required observation times in the one arc second apertures and remove the 0.4 arc second apertures from the planned program.

Had the telescope's performance been within specification it would have been possible to do accurate photometry in crowded fields. The broad point spread function makes this impossible for separations less than 2.5 arc seconds.

3.14 Jitter

Because the image is larger, more of the energy is spread out to the edges of the 1.0 arc second apertures making photometric performance much more sensitive to centering and jitter. The design goal for long term (weeks to months) photometric stability was 0.1%. It is expected that centering errors will introduce 1 to 2% errors in long term photometric stability. The short term (seconds to weeks) photometric stability design goal was 0.001 to 0.01%. Assuming nominal jitter performance, errors of 0.01 to 0.1% at 0.1 to 0.6 Hz may be introduced.

4. Program Development, Execution, and Results

4.1 Program Development

The HSP OV program was an extension of the ground test program beginning at the sub-box level and extending though VAP, A&V at LMSC, and the various GSTs at LMSC and KSC. The orbital verification program was designed to activate and verify the HSP in a methodical, step-by-step manner, minimizing risk but also conserving operations timeline. The OV program was based on the overall HST OV program in that the test pre-requisites were intended to be consistent with the state of verification of the other ST elements upon which the operation of HSP depends. All essential functions were included but no redundant units were activated or verified. Tests were deliberately made as similar as possible to previously run ground tests to take advantage of experience in both test design and the ground database.

Some tests were changed during OV in response to experience, the degraded HST image, and to correct problems in test design. The prelaunch planning tended to be success oriented and overly optimistic about HST capabilities upon which the test objectives depended. Experience has shown the wisdom of planning tests in small, incremental steps with provisions incorporated to get the desired results even if the assumed HST performance is less than nominal. A major example is the HSP fine alignment test. The test (1504) design assumed that the FGS to SI alignment would be known to a fraction of an arc second when the test was performed but in fact, a target could not be reliably placed within the HSP 10 arc second finding aperture. Because the HSP detectors had such large finding apertures, thought to be adequate to allow for any conceivable HST pointing errors or uncertainties, no spiral scan routine was provided in HSP's target acquisition flight software. The impact on the HSP OV program of the FGS alignment problems were, therefore, significant.

4.2 OV Events in Chronological Order

Launch (liftoff) of HST occurred on April 24, 1990 at 12:32:52 UT

The major events in the OV period are listed below:

Test number	Test Name	SMS	Date
Launch			4/24/90

HSP-iA	Off to Safe (first power to HSP - HSP in safemode)	n/a	4/24/90
2201 - Part 1	Safe to Hold - part 1 (heater control AP started)	n/a	4/24/90
2201 - Part 2	Safe to Hold - part 2 (log dump executed)	901241K3	5/4/90
1499	Command Response	901252K1	5/5/90
2113	Memory Dump	901252K1	5/6/90
1500	Detector Data Test (trailing logs lost by SDF cutoff)	901271M1R	5/8/90
1502 - Part 1	HV Turn On - Part 1	901352M2	5/15/90
1502 - Part 2	HV Turn On - Part 2 (PMT data anomalous)	901413M5	5/22/90
1502 - Part 3	HV Turn On - Part 3	901452M8	5/25/90
1379 - Part 1	Dark Count (UV1 & VIS)	901562P4	6/5/90
1379 - Part 2	Dark Count (UV2 & POL)	901613A3	6/11/90
1502PMT-1	PMT Special Test - part 1	901773B3	6/27/90
1502PMT-2	PMT Special Test - part 2	901823A3	7/2/90
1502PMT-3	PMT Special Test - part 3	901844A9	7/4/90
1380	Aperture Map (HSP bright object safing by VIS)	901974A3	7/17/90
1502A - PMT	PMT HV Turn On	902165B5	8/6/90
1379 - PMT	PMT Dark Count (HSP bright object safing by POL)	902314A4	8/19/90
1380 - UV1	Aperture Map UV1	902384A6	8/26/90
1380 - UV2	Aperture Map UV2	902494A6	9/7/90
1503 - UV1	Phase II Alignment UV1	902537AB	9/13/90
1503 - UV2	Phase II Alignment UV2	902607D2	9/22/90
1382 - UV1/2	PAD Threshold Test UV1 & UV2	902817B8	10/2/90
1504 - UV1	Phase III Alignment (target not placed in 1.0 " aperture)	902957A9	10/22/90
1526 - UV1/2	Aperture Map - SV (UV1 & UV2)	903027AC	10/29/90
3069	10.2 Test (VIS, POL, & PMT)	903104A4	11/8/90
1503 - UV1/2 II	Phase II Alignment (UV1 & UV2, repeats)	910217BD	1/21/91
3140	Phase III Alignment - partial (failure: target not acquired)	910427D6	2/11/91
3093	Aperture Map - VIS and POL	910707C6	3/11/91
3152	Phase IV Align - UV2 (first revised alignment)	910707C6	3/11/91
3152	Phase IV Align - UV1	910707C6	3/15/91
3072	*Target Acquisition UV1	910917BC	4/1/91
3073	*Target Acquisition UV2	910917BC	4/1/91
2948	*FGS/HSP Fine Alignment UV2 (old scheme)	910987C9	4/10/91
2949	*FGS/HSP Fine Alignment UV1 (old scheme)	910987C9	4/10/91
3152	Fine Alignment VIS & POL	911057D5	4/21/91
3007-UV2	**Jitter (SAO) (data timing problem)	911197B8	5/9/91
3074	*Mode II Target Acq - VIS	911276A2R	5/9/91
3071	*Mode II Target Acq - VIS	911276A2R	5/9/91
3233	*Fine Alignment - UV	911337C8	5/18/91
3233 - POL	Fine Alignment - POL	911547D3	6/3/91
1385	*Photometric Performance	911547D3	6/5/91
3233 - VIS	Fine Alignment - VIS	911547D3	6/8/91

* SV Test
** SAO Test

4.3 Test Specific Performance

Orbital verification began with the initial application of power to the HSP, proceeded through verification of the various functions of the HSP, and ended with phase III alignment.

Launch Configuration

The HSP launch configuration is: all power off and all redundant units configured to the A side.

HSP-iA - Off to Safe - OVIS seq 10

The initial application of power and transition HSP to the safe mode occurs soon after deployment and is performed by real time commanding from the ground. All relays are commanded to the launch configuration, power bus relays are closed, HSP primary power is turned on, and one forward and one aft heater is turned on. This leaves the HSP preregulator and two heaters on and everything else off.

The first HSP operation in orbit was the transition from the prelaunch configuration with all power off to the thermal safe mode. The HSP safe mode requires the primary power relay on, and two bulkhead heater circuits on, one on the forward and one on the aft bulkhead. The commands were sent by PSTOL procedures from the MOR at GSFC. Engineering telemetry verified the commands were received and the HSP was in the correct configuration. Temperatures during the period remained within expected limits.

2201 - Part 1 - Safe to Hold - Part 1

The HSP was reconfigured from thermal safemode to hold mode. In hold mode, the HSP bulkhead heaters are controlled by the NSSC-1 heater control application processor. The heaters can be controlled in several ways: a selected state can be maintained, a specific temperature range can be selected (the "software thermostat" mode), or a power level can be chosen for each heater. In the constant power mode, a series of power levels can be arranged in sequence to provide a desired "warm up" transition. In OV, only the constant power mode was exercised. The heater control application processor performed as designed and the resulting HSP temperatures were as expected. The initial heater control configuration involved cycling all three bulkhead heaters. This was later changed to a single heater to reduce relay cycles.

Still later in OV, use of the heater control application processor was discontinued when the "new hold" mode was put into use. In the "new hold" mode, the heaters are not used but the HSP system controller is turned on to provide thermal input to maintain interface temperatures. The "new hold" mode has several advantages: the thermal transients between hold and operate modes are greatly reduced, thereby increasing the HSP optical path stability. Power consumption is less than in the hold mode. Because thermal cycling is reduced, greater reliability is expected because thermally induced stresses are less.

2201 - Part 2 - Safe to Hold - Part II - 901241K3

The second part of the safe to hold transition was the dump of the HSP Standard Header Packet and Unique Log (SHP & UDL). The dumps were successfully executed by PSTOL procedures sent from the MOR and the data were transmitted to the ground. The procedures worked as designed even with an unplanned hold in mid-procedure ordered by the Mission Operations Manager to restore order in the MOR. But, because the ground system design did not provide for this type of data (logs dumped by themselves with no associated science data), the data were inaccessible and never reviewed. No fix was ever made for this problem because logs without a "normal" data collection is not a normal operation and is not ever expected to be repeated.

1499 - Command Response - 901252K1

In the HSP command response test, all commands are exercised except those involved in HSP reconfiguration with redundant subsystems. The test is divided into six sections separated by two hours to avoid confusion in interpretation of results. The six sections are: One each for each of the five detector's serial commands, and one for serial commands not specific to any particular detector. The engineering telemetry was examined to verify that the commands were received and properly executed. The test was completed and all responses were nominal. All commands were verified to be functioning properly.

2113 - Memory Dump - 901252K1

In this test the HSP system controller RAM was dumped four times. The HSP would have liked to have the resulting data delivered in a manner similar to normal science data, but, the ground system is not presently capable of delivering HSP memory dump data. The ground system was designed to compare the memory dump with a ground master image and report the number of miscompares. The number of reported miscompares was about twelve thousand because the ground master image did not consider the memory locations that are subject to change. To evaluate the memory dump properly the data must be available for review. In the current system, the data go to a trouble file from which they are extremely difficult to retrieve. A paper listing of the data was eventually provided for our analysis. This enabled us to determine that the memory dump contained the expected values, but review of voluminous paper listings is extremely error prone.

Recently (June 1991) there was a telecon with HSP and ST ScI personnel to agree on a reasonable procedure for dumping the HSP memory, including the bus director memory (which was not dumped by the 2113 procedure), and making it available in standard FITS file format, similar to normal science data. The new procedure would be useful in analyzing future instances of single event upsets and other possible anomalies. Without it, reviewing HSP memory is difficult and extremely error prone.

1500 - Detector Data Test - 901271M1R

This test exercises the data collection capability of each detector electronics using simulated science data having a constant value depending on the integration time selected. Verification consists of checking the resulting science data to make sure the data values are as predicted and that all the data were received. This test uses the spacecraft clock as a simulated data input to store a predictable number of counts, determined by the integration time chosen, into the science data words. The data are sent to the ground system and if the values are all as expected, the data path from the HSP to the ground is verified. The test was executed and the science data were as expected. The standard practice for HSP data collections is to dump both the Standard Header Packet (SHP) and the Unique Data Log (UDL) before and after the data collection. However, some SHP and UDL data were missing from the data received on the ground. It was later determined that the missing SHP and UDL were the result of an error in the time calculated in the SMS for the science data path to the tape recorder to be enabled. The time calculation algorithm was subsequently corrected and, since then, no SHP and UDL data have been lost.

1502 - Part 1 - HV Turn On - part 1 - 901352M2

This test is designed to turn on high voltage to each detector in a careful, step-by-step manner to minimize the chance of damaging the detectors because of arcing or corona discharge. The pressure in the HSP is intended to be less than 10^{-5} torr before high voltage is turned on. This test was therefore scheduled to begin no earlier than day 22 of the mission and would hav been postponed if ST aft shroud pressure data indicated the pressure was significantly higher than desired. The test consists of a 192 second data collection during which the high voltage power supply is commanded on. The test is performed in segments separated by at least 24 hours as follows:

1. Turn on detector 1 HV to the lowest program value.
2. Detector 1 HV at $0.5x10^5$ gain setting, detectors 2-5 at lowest program value.
3. Detector 1 HV at 10^6 gain setting, detectors 2-5 at $0.5x10^5$.
4. Detector 1 HV at $2x10^6$ gain setting, detectors 2-5 at 10^6.
5. Detectors 2-5 at $2x10^6$ gain setting.

The data from each segment, consisting of the 192 seconds of science data from each detector (192 words because the integration (sample) time is one second) is examined for evidence of noise due to corona or arcing. If the data indicates there is no problem, a command is sent from the ground to change the state of a flag on board and the next segment is performed as scheduled. If the command is not sent, the HSP is automatically put in the safemode.

The design of the HSP prevents damage from most operations, but turning on high voltage is one of the few where damage is possible. If the voltage level is set too high or if there is incomplete venting of the instrument, arcing or corona is possible. The first turn-on of the high voltage power supplies was therefore planned to be done in a careful step-by-step manner allowing time to retreat before damage could be done if problems were encountered. The first part of the high voltage turn on involved only one detector, detector one, the POL tube. The high voltage power supply was turned on for 38 seconds at its lowest setting, approximately 1500 volts, during a science data collection. The data collection was started before the high voltage was turned on and continued after it was turned off so that the transients could be seen in the data. There was no evidence of any problems in the first part of the test.

1502 - Part 2 - HV Turn-on - 901413M5

The intent of the second part of the high voltage turn-on test was to repeat the first part for the high voltage power supply exercised in the first part, but at a higher level (the lowest of the three nominal gain settings for the detector) and to perform the first part of the test on the remaining four high voltage power supplies. There were no problems discovered in the operation of the high voltage power supplies, but the test design was faulty because the high voltage level cannot be changed during a data collection. Therefore, the test did execute to completion as planned. The test was later modified to be performed at nominal high voltage gain but in steps of increased analog output sensitivity.

A second problem occurred in this part of the high voltage turn-on test. The PMT output appeared to represent a signal of increasing brightness that was first thought to be the approaching bright earth limb.

1502 - Part 3 - HV Turn-on - 901452M8

The results from the third part of this test were identical with the first two parts except that some stray light was detected. The anomalous PMT response was the same as in part two. A series of special tests were planned to further explore the PMT response.

1379 - Part 1 - Dark Count - 901562P4

This test was intended to provide the first baseline dark count data from all five detectors. The tests consist of collecting data for five minutes at each of three cathode locations with high voltage on and one cathode location with high voltage off (to verify electronic noise level) on all four image dissector tubes. Five minutes of PMT data are collected with high voltage on and five minutes with high voltage off.

Verification consists of analyzing the data to determine the level and frequency characteristics of the noise. The integration time used for this test is 0.1 second, which will facilitate detection of RIU reply bus noise interference if it exists.

In this first part, detector two and three (UV-1 and VIS) were tested. The test executed as planned and data were satisfactory.

The VIS tube dark counts were:

Location	Counts/sec
Dark 1	0.238
Dark 2	0.295
Dark 3	0.198

The UV-1 dark counts were:

Dark 1	0.090
Dark 2	0.100

Dark 3	0.137

Electronic noise ("dark count" with high voltage off) in both detectors were zero.

1379 - Part 2 - Dark Count - 901613A3

Detectors one and four (POL and UV-2) were tested in part two of the dark count test. The results were as expected and dark counts were satisfactory.

The UV-2 results were:

Location	Counts/sec
Dark 1	0.264
Dark 2	0.218
Dark 3	0.231

The POL results were:

Dark 1	0.224
Dark 2	0.174
Dark 3	0.167

Electronic noise in both detectors were zero.

1502PMT-1 - PMT Special Test - Part 1 - 901773B3

This special test was designed to replicate the PMT high voltage turn on test but with shorter integration time and with the "all" format to collect analog data (at a gain of 1000nA full scale) as well as pulse counting data. These changes were intended to make the test more likely to be sensitive to subtle noise characteristics not detectable with longer integration times and using only pulse counting data. The results were similar to the original high voltage turn-on test and no new insights were gained except that the characteristic output was clearly repeatable and apparently not due to partial pressure in the aft shroud.

1502PMT-2 - PMT Special Test - Part 2 - 901823A3

This second part of the PMT special test was a repeat of the first except that a higher analog gain, 100nA full scale, was used in an attempt to gain insights into the characteristics of the anomalous signal. The results were nearly identical with those in Part 1.

1502PMT-3 - PMT Special Test - Part 3 - 901844A9

The third part of this test was a repeat of part two but at still higher analog gain, 10nA full scale. Again, the results were similar to the earlier data At this point it was concluded that the characteristic behavior was repeatable and possibly caused by the fact that the PMT and corotron and were operating far below their nominal operating voltage. A subsequent test at higher operating voltage confirmed operation is normal at higher voltages.

1380 - Aperture Map - 901974A3

This test was designed to map all apertures of all four image dissector tubes (about 200 total) using the bright earth as a "flat" field. The filter strips are scanned using the HSP Map mode with a 12 x 80 raster using 0.4 arc second steps. Selected apertures are then mapped using a 20 x 20 scan using 0.1 arc second steps. The test began with the VIS detector but when the clear (no filter) finding aperture came into view of the VIS (detector three) read beam, the bright object application processor sensed a value in excess of the limits and triggered an HSP safing. The application processor operated as planned and turned off all HSP high voltage. The bright object application processor limits were set too low to accommodate the actual bright earth that is occasionally much brighter than we had anticipated. The aperture mapping tests were redesigned to use the Orion Nebula as the "flat field" for the particular filters on the VIS and POL detectors that allow excessive throughput with the bright earth. The bright earth was used for the remaining filters.

The safing occurred after most of the VIS filters had been mapped. The test succeeded in getting useful information about VIS aperture positions from the 12 x 80 filter strip scans. The 20 x 20 scans of individual apertures were less successful, however, because the apertures had moved significantly in deflection space from their pre-launch values, as anticipated. The aperture mapping test was revised to increase the size of the individual aperture scans to 30 x 32 and the filter strip scans to 16 x 60.

1502A - PMT - PMT HV Turn On - 902165B5

This is the revised PMT turn-on test incorporating the turn-on at 1900 volts. The test ran satisfactorily but the science data went to the trouble file because the 1900 volts used in this test is not one of the standard operating voltages incorporated into the data base. The data were extracted manually and were satisfactory. No corrective action was taken because data are not normally taken at 1900 volts.

1379 - PMT - PMT Dark Count - 902314A4

A problem was encountered in the dark count test of the PMT. The PMT high voltage is turned on before the observation to allow time for the detector noise to settle down after the turn-on transient. During the time before the dark count observation was to begin, the bright earth occulted the dark target. The bright object protection application processor sensed an analog output higher than the limit and safed the HSP high voltage. The operation of the bright object application processor was as intended. The limit was exceeded because the bright earth was occasionally much brighter than expected. The eventual corrective action for this problem was to allow the PMT to view the bright earth with the bright object limit disabled during occultations.

1380 - UV1 - Aperture Map - 902384A6

The original design of this test included all four image dissectors. The first attempt to run 1380 in the 90197 SMS (discussed above) ended with a safing in the VIS detector portion of the test, which was the first of the four detectors scheduled. It was obvious after that experience that tests should be scheduled in smaller units to create fire walls such that a failure in one part of a test would not waste excessive spacecraft time. Subsequent tests were redesigned and rescheduled one detector at a time. The first instance of this new approach, the UV1 portion of 1380, was executed as planned. The data were satisfactory. The only anomaly during this test was a T error caused when the commanded value of a parameter does not agree with the value in the telemetry value table. In this case a deflection value was commanded, for example, to 4098 and the telemetry table was reporting 4098 modulo 4096 or 002. The T error indicated the deflection had "wrapped" and had been commanded to a value modulo 4096 from value in the test procedure. This did not cause any difficulties in either operations or data reduction because the modulo 4096 value is valid and useful data were extracted.

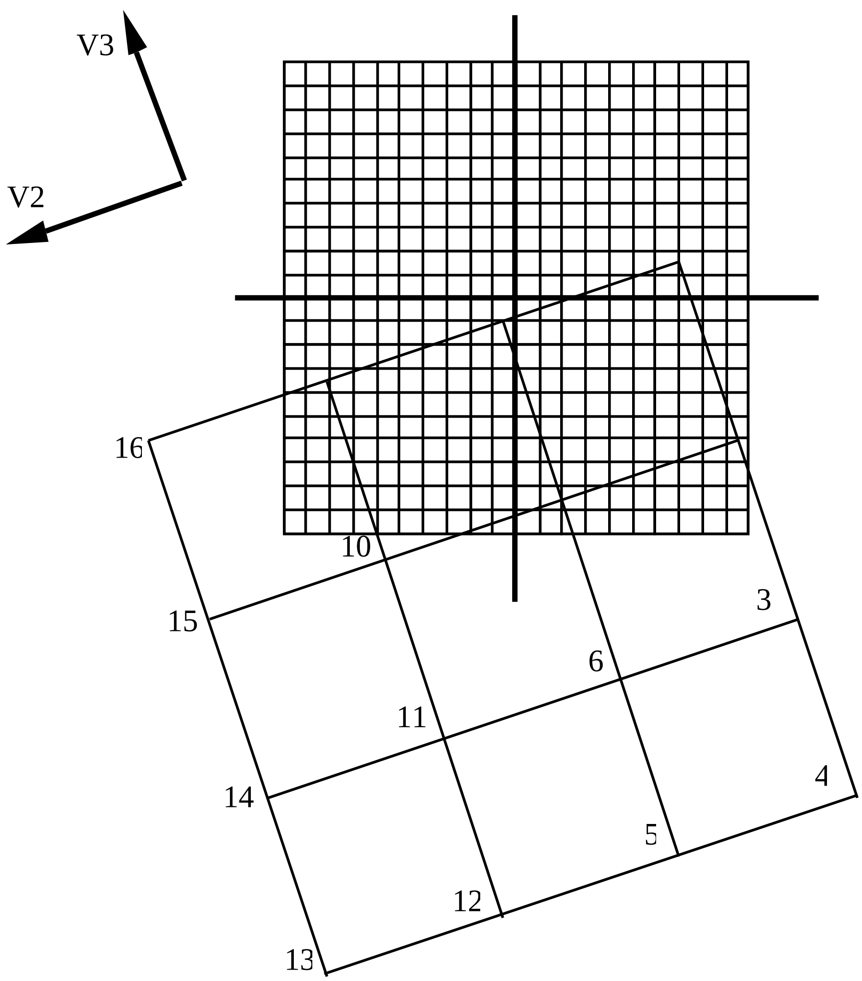
1380 - UV2 - Aperture Map - 902494A6

The results from this test were similar to the UV-1 portion of the test. Satisfactory initial aperture maps were obtained. From these data it was evident that the expected "banana" effect was not as large as expected and the "new hold" mode was providing a stable thermal environment.

1503 - UV1 - Phase II Alignment - 902537AB

This test was the first HSP observation of an actual star, the first old photons detected by the HSP. The test was designed to locate the ten arc second diameter finding aperture to within 0.5 arc seconds in HST V2/V3 coordinates. The general idea of the test was to point the HST to the target star placing it in the 10 arc second finding aperture, then offset to the corner of a 4 x 4 HST step and dwell scan pattern (each step being 2.0 arc seconds) and perform a 20 x 20 HSP map mode scan (using the standard default 0.5 arc second step size) at each of the 16 points of the HST dwell scan. The HSP 20 x 20 map covers the entire finding aperture. The resulting data are a set of "images" of the finding aperture at each of the 16 HST dwell points in a 4 x 4 square pattern. The idea was to locate the target even if the initial blind pointing had errors of several arc seconds. Analysis of the data would provide the location of the finding aperture in V2/V3 coordinates. The test was executed as planned but the resulting V2/V3 locations were inconsistent with the UV2 positions determined in the subsequent test of UV2 in the 90260 SMS. The errors in the FGS-to-SI alignment matrices at the time were the cause of all the difficulties. Later improved matrices were used to reanalyze the data and resulted in consistent and precise positions.

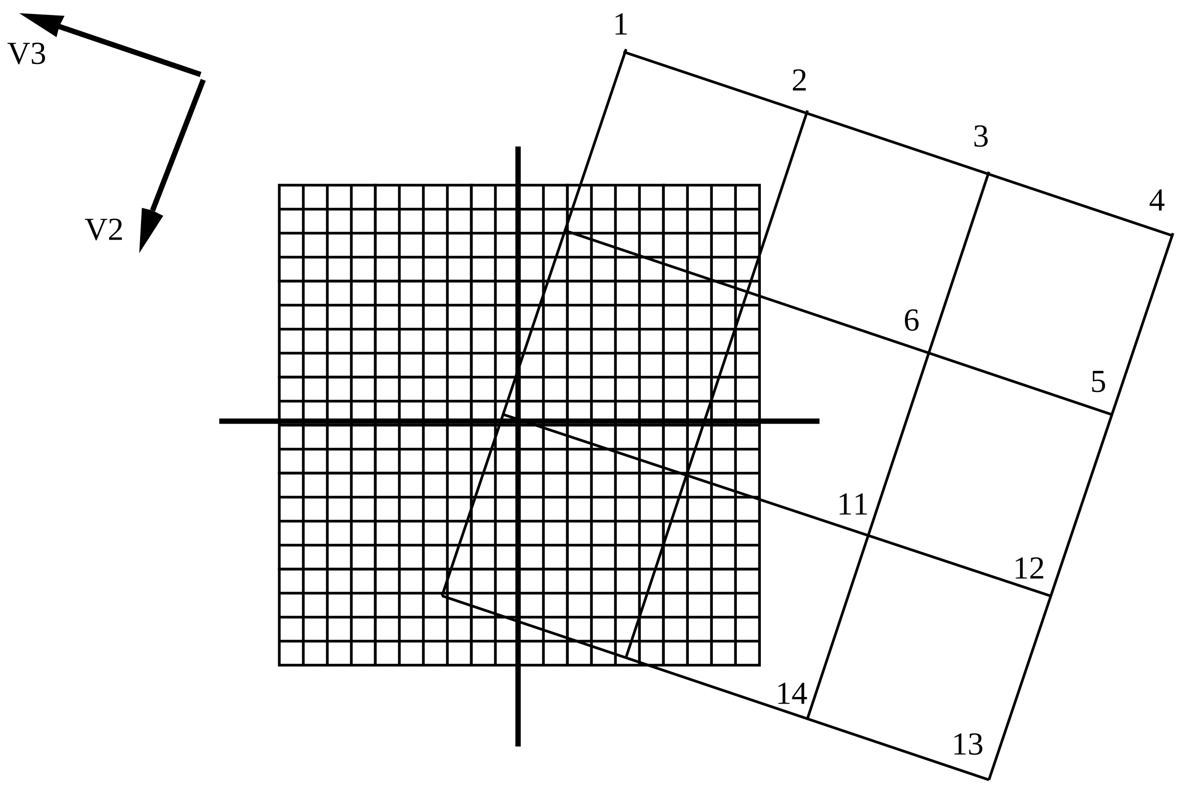
IDT 2 (UV1) 1503 Results



The chart above shows the position of the target star in the HSP 20x20 map of the finding aperture for each of the 16 positions of the HST step and dwell scan. The target was seen only in steps 1, 2, 7, 8, and 9.

1503 - UV2 - Phase II Alignment - 902607D2

The test method for this portion of the test is the same as for detector UV1 described above. The results for UV2 did not agree with the UV1 results in that there was no rigid body shift of both detectors that could account for the V2/V3 positions derived from the data. Further, the differences between the positions derived from the 1503 data and the prelaunch positions are too large to be accounted for by measurement error. The problems were due to errors in the FGS-to-SI alignment matrices, later improved. Using the improved matrices, the HSP positions were consistent and credible.

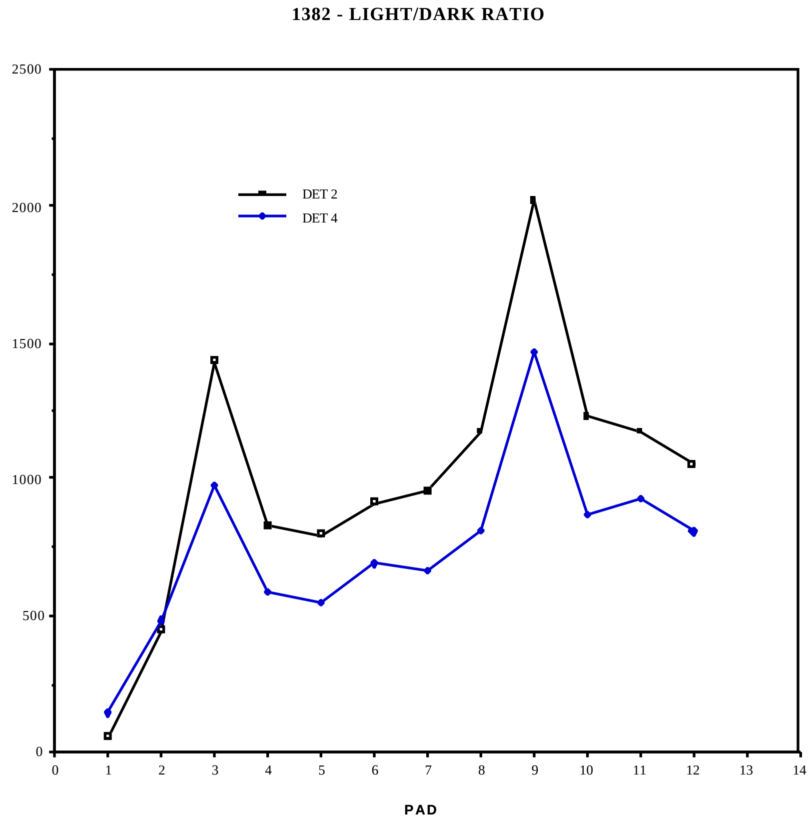


IDT 4 (UV2) 1503 Results

The above chart shows the position of the target star in the 20 x 20 map of the HSP finding aperture for each of the 16 points in the HST step and dwell scan. The target was seen only in steps 7, 8, 9, 10, 15, and 16.

1382 - UV1/2 - PAD Threshold Test - 902817B8

The purpose of this test was to determine the optimum PAD threshold by observing the bright earth at various threshold levels and plotting the curve of response as a function of threshold level. The unpredictably large variations in the brightness of the earth proved to be greater than differences between threshold levels and the resulting data (see chart below) were of little value beyond confirming that the prelaunch PAD default values were satisfactory.



1504 - UV1 - Phase III Alignment - 902957A9

This test was designed to map precisely the edges of the finding aperture and of selected one arc second apertures. This was accomplished by first acquiring the target in the finding aperture, offsetting the target to near the edge and performing a spacecraft linear step and dwell scan while collecting single color photometric data. The design of the test predated the discovery of spherical aberration and it was executed before good FGS-to-SI alignments were available. The acquisition was successful but the spherical aberration made the length of the step and dwell too small to indicate the edge of the aperture reliably. The FGS alignment was sufficiently imprecise at this stage to place the target in the one arc second aperture. The test did not, therefore, accomplish the intended objectives. The HSP fine alignment test was redesigned to use a spacecraft continuous scan to sweep the target across selected apertures in a raster pattern designed to be sufficiently large to cover the uncertainties in the FGS-to-SI alignment.

1526 - UV1/2 - Aperture Map - SV - 903027AC

This test is the SV version of 1380, aperture map, for the UV detectors. It ran as planned and the data were used to improve our knowledge of aperture locations in HSP detector deflection space.

3069 - 10.2 Test - 903104A4

This test was run to verify the changes in 10.2 reconfiguration software required to correct the bright earth safing problems encountered in 1380 by the VIS detector and in 1379 by the PMT. The detectors were operated in the same manner as the proposed revisions to the 10.2 reconfiguration software. There were no problems and everything worked as planned. Several interesting and useful results of the test were obtained that were not entirely planned. The VIS, POL, and PMT detectors were operated throughout the orbit, both during the dark target time and earth occultation. This gave not only useful dark count data, but information about the settling time required to return to nominal dark counts after bright earth exposure. That time was shorter than expected and is about five minutes for the PMT. Since the data were taken in the "all" format, both analog and pulse counting data, it was possible to plot pulse counting response as a function of analog output over a wide range of brightness. The variations in brightness of the earth here produced a data set that would otherwise be impractical to obtain with stars. The results shown in the chart on the following page confirmed the detector dead time and linearity characteristics.

1503 - UV1/2 II - FGS/HSP Coarse Alignment - 910217BD

This test repeated an earlier test. It was scheduled before it was clear that FGS-to-SI alignment matrix errors were the cause of the inconsistencies in earlier data. But, once the alignments were determined, this data set and the prior data verified repeatability of the alignment.

3140 - Phase III Alignment - (partial)- 910427D6

This test was a reduced version of the previously run 1504 test that was scheduled before the new HSP fine alignment test was created and approved. This test was not successful because at the time of execution the FGS-to-SI alignments were not known to the required precision. HSP system controller T errors were observed in the engineering data. These were later identified as the result of a single event upset in HSP RAM. The HSP system controller was "rebooted" and the problem disappeared.

3093 - Aperture Map - Det 1 & 3 - 910707C6

The VIS detector aperture mapping test was revised to use the Orion Nebula for selected filters and the bright earth for others. It was run as soon as the revised 10.2 reconfiguration software was available. The test executed as planned, except for some missed bright earth observations because of a problem between SOGS and PASS in calculating when the bright earth limb was in view. The data were used to refine aperture positions as a function of detector deflections.

3152 - Phase IV Align - Det 4 - 910707C6

This is the first use of the revised HSP fine alignment test using a raster scan of the target across selected small apertures. The data proved to be remarkably good and led to more precise determination of aperture positions than was originally anticipated. The data also are useful for determining the point spread function of a target in the HSP apertures. This was also the first test run after the T error (single event upset) reboot and since there were no T errors or other anomalies it confirmed that there were no permanent consequences of the single event upset.

3152 - Phase IV Align - Det 2 - 910707C6

This test of UV1 executed smoothly as did the portion for UV2. The data were high quality and similar to the 3152-UV2 data.

3072 - Target Acquisition UV1 - 910917BC

In this SV test the first HSP mode II (on-board) target acquisition was done. The target was acquired and all algorithms performed as intended on the first try. Several iterations were designed into the test that showed that the accuracy and repeatability of the acquisition improved if it were done twice. The standard Mode II procedures were subsequently modified to perform two acquisitions to more precisely center the target star in the finding aperture, which is critical with the spherical aberration degraded image.

3073 - Target Acquisition UV2 - 910917BC

The results of the UV-2 portion of the test were similar to those obtained for UV-1.

2948 - FGS/HSP Fine Alignment UV2 - 910987C9

This test is the originally planned SV version of the HSP fine alignment test and was put into the schedule before the alignment test was revised. It executed properly and provided good data, considering the limitations imposed by the spherical aberration, but the data were not as useful as that provided by the revised test.

2949 - FGS/HSP Fine Alignment UV1 - 910987C9

This test is the UV-1 portion of the originally planned SV version of the HSP fine alignment test and was put into the schedule before the alignment test was revised. It executed properly and provided good data, considering the limitations imposed by the spherical aberration, but the data were not as useful as that provided by the revised test.

3152 - Fine Alignment VIS & POL - 911057D5

Here the first attempt to perform the new modified HSP fine alignment test on the VIS and POL detectors was made. The VIS detector data were satisfactory and met objectives. The POL data appeared at first to be the victim of a "missed observation" because the count rate was much lower than expected. Later analysis showed the test executed properly but the filters on the POL detector were apparently reversed from the order shown in the drawings. The data also showed that the desired accuracy for determination of the POL tube apertures in both deflection and V2/V3 coordinates could not be obtained because the POL tube has a 16 apertures (rather than the 50 of the other image dissector tubes) with which to fit the 13 parameters of the aperture position model. A new test was devised (3377) to obtain the required data.

3007-UV2 - Jitter (SAO) - 911197B8

This test was intended to check HST jitter by observing a target for an hour with 2.0 millisecond integration times. The test failed for two reasons: the target was not seen in the finding aperture and was therefore not acquired; the HSP did not complete science data transfer to the SDF. The reason the target was missed was incorrect coordinates. The target has relatively large proper motion that was not properly considered. The science data transfer problem was one that was identified in 1984 but was forgotten when the test was designed. The HSP cannot use multi-line frames with the lower data rates (32 kbs and 4 kbs) because of the timing constraints between lines. The reasons for this were explained in Richard White's 1984 paper (Timing Considerations for HSP Data Collection, 21 March 1984) as follows:

> "Because the SDF was designed for image data, it expects the SIs to send all lines of a given frame in rapid succession. If a line is not ready within 10 msec of when it is requested, the SDF assumes that something is wrong with the SI and puts it off-line, terminating the observation...
>
> The minimum length for a line when it is written onto the tape is 1 segment, which requires about 30 msec at 32kb. This means that the HSP must require more than 30 msec to collect a line in order that the tape recorder be able to keep up with it. On the other hand, the HSP to SDF transfer always goes at 1Mb, and takes at the most 15 msec. Thus the difference between the HSP data collection time and the HSP to SDF transfer time must be greater than 15 m sec and must therefore exceed the 10 msec limit. The same arguments apply (with stronger limits) for the 4kb link. Consequently, all observations using the slow links will have only 1 line per frame."

This problem would have been exposed earlier by the planned but scrubbed OV test 1501, Data Integrity. (The test was scrubbed because it was a test of the science data path, not of the HSP itself. Arguments that system level interactions should be tested were not accepted. In any case, we were remiss in forgetting this aspect of HSP data collection.) A simple fix has been found that would allow long data collections at the 32 and 4 kbs rates. Since there are no timing constraints between frames, the present HSP upper limit on number of frames could be relieved by resetting the frame count during the data collection.

3074 - Mode II Target Acq - VIS - 911276A2R

The results of this test were similar to 3072 and 3073, mode II target acquisition tests of UV1 and UV2. It was successful and confirmed the need to perform two acquisitions to get the best centering of the target star.

3071 - Mode II Target Acq - POL - 911276A2R

This test was similar to 3072, 3073, and 3074. The results were, as in the other tests, successful, and confirmed the need for two iterations of the mode II acquisition to get the required centering of the target star.

3233 - Fine Alignment - UV - 911337C8

Test 3233 was similar to 3152 except mode II target acquisition was used and the size of the HST raster scan was reduced. The scan was executed twice, in orthogonal patterns, to provide higher quality results. The test was successful and excellent data were obtained.

3233 - POL - Fine Alignment - POL - 911547D3

The results of the fine alignment on the POL tube were satisfactory, but because of the greater uncertainty in the determination of the aperture positions on the POL tube (there are only 16 apertures on the POL tube rather than the 50 on the other image dissector tubes with which to fit a 13 parameter model) the resulting model fit did not produce positions with as small uncertainty as the other image dissector tubes. A new SV test (3377) was devised to produce the required data.

1385 - Photometric Performance - 911547D3

This SV test was designed to verify the photometric linearity and accuracy of the HSP. The data were satisfactory except for missed targets.

3233 - VIS - Fine Alignment - VIS - 911547D3

The results for the VIS detector were similar to the UV detectors. The data was satisfactory and produced good aperture positions.

4.4 Database Updates

The OV database updates involved two different files: the SICF file containing the positions of the HSP apertures in detector H/V deflection coordinates and the SIAF file containing the positions of the HSP apertures in HST V2/V3 coordinates. The early stages of OV were designed to refine the SICF (deflection coordinates) data using the bright earth as a flat field. Later tests were intended to determine the SIAF (V2/V3 position) parameters using stars once the deflection parameters were well established.

The first test designed to provide SICF input was 1380, HSP aperture mapping. The test provided useful data but also showed that the bright earth was too bright for several filters on the VIS and POL detectors. It was also clear from the initial data from 1380 that the test parameters could be optimized to provide much higher quality data. The size and number of points in the aperture maps were changed to provide more resolution. In 1380, 20x20 maps of individual apertures having 0.5 arc second spacing were used. The revised tests used 30x32 maps with 0.1 arc second spacing. The 80x12 maps of filters were changed to 60x16 to better fit the dimensions of the filters. The "flat field" target for selected filters of the VIS and POL detectors were changed from the bright earth to the Orion Nebula. The following filters on the VIS and POL detectors and all UV filters use the bright earth: POL: F216M, F237M, & F277M; VIS: F184W, F240W, & F262V. All other filters use the Orion Nebula. Integration times were also adjusted based on the 1380 results to provide improved signal to noise ratio. Data quality was also affected by scattering in the detectors and variations in the brightness of the bright earth during the time of the observation.

The next round of aperture mapping tests, 3093, incorporated the changes described above and produced much better data. The new data were applied to the model and produced some interesting results. It was known that the electron optics in the IDTs had pin cushion distortion but the model results also showed that there were different plate scales for H and V. The standard deviation of the fit for the VIS detector is about 3-4 deflection steps in both H and V.

Early attempts to produce data for the SIAF file were frustrated by the poor FGS-to-SI alignment. In fact, it was so bad that a target could not be reliably placed in a 10 arc second finding aperture. Tests were put on hold for several months until the FGS to SI alignment matrices were sufficiently accurate to continue. In the interval, the test was redesigned to capture the desired information even if the HST pointing had larger than expected errors. The revised scheme involved a five arc second square HST scan of the area around the intended target to insure it was detected. The revised tests were successful and the FGS to SI alignments improved so that the resulting data has uncertainties in aperture positions of 0.01 arc second in V2 and 0.02 in V3.

Once the SICF and SIAF files were updated, the mode II target acquisition tests were performed. The most significant result was that two iterations reduce the pointing error substantially in some cases. We therefore adopted two iterations as standard practice. A summary of the database updates made in the OV period follows:

Test	SMS	Database	File	date of update
1503	90-253, 90-260	PDB	SIAF	10-16-1990
	91-021,	1-31-1991		
1504	90-295	PDB	SIAF	1-31-1991
1526	90-302	PDB	SICF	1-29-1991
3152	91-070	PDB	SIAF	3-25-1991
	91-105	4-30-1991		
3093	91-070	PDB	SICF	3-29-1991
3233	91-133,91-154	PDB	SIAF	Not Planned

3071	91-127	None	----	---------
3072	91-091	None	----	---------
3073	91-091	None	----	---------
3074	91-127	None	----	---------
1385	91-154	None	----	---------
		CDBS	CVCCP5R	Not Planned
		CDBS	CVCCP4R	Not Planned
2769	91-168,91-175	CDBS	CVCCP4R	Not Planned
3006	91-182	None	----	---------
3362	91-189	PDB	SIAF	Not Planned
3363		PDB	SIAF	Not Planned
3377		PDB	SIAF/SICF	+3 Weeks
3119	Wk38	PDB	SICF	Not Planned
3120		PDB	SICF	+2 Weeks
3135		PDB	SICF	Not Planned
3007		None	----	---------
1386		CDBS	POLEF??	+3 Weeks
1383		None	----	---------
1389		None	----	---------

4.5 OV Anomalies

The major unresolved problem from the OV period, although not strictly the result of an OV test, was the data hang in 3007. The fix is straightforward and involves resetting the frame count during the data collection to remove the 255 frame per observation limit.

There were many HSTARs written but most were not indicative of major problems. The major anomalies that occurred during the OV period that had significant schedule impact are:

1. HSTAR 574 - PMT High Voltage Turn-on

The PMT high voltage turn-on anomaly was corrected by limiting operation of the PMT high voltage power supply to higher voltages closer to the nominal operating range of the PMT's corotron. Appendix B contains a more detailed discussion of the PMT high voltage turn on anomaly and subsequent investigation.

2. HSTARS 836 and 1072 - Bright Object Safing

The operational procedures were modified to avoid bright earth limb safing.

3. HSTAR 1537 - Missed Target

The FGS/SI alignment was not sufficiently accurate to support the planned test design when HSP fine alignments were first attempted. Subsequent improvements in both the alignment matrices and the design of the test resulted in satisfactory data. But, there was substantial schedule impact to the HSP OV program because the FGS alignment took much longer than planned.

The following list of HSP related HSTARs represents our understanding but should be used with caution because HSTARs concerning the HSP are often opened without our knowledge, HSTARs that are opened by HSP team representatives sometimes are lost, HSTAR closures submitted by the HSP team are often lost, and often HSP related HSTARs are closed by others without our knowledge.

HSP HSTAR dispositions as of 11-07-91:

HSTAR #	Description	Disposition	Due	ORG
010	HSP Structure Temp VTPMTPB	CLOSED	04-29-90	

205	HSP 2113 Mem. Dump Miscompares	STGS DR 1097	07-19-90	HSP
207	HSP High Volt Out of Limit	CLOSED	06-19-90	HSP
232	DCF Missing Data Packet for HSP 1500	CLOSED	06-07-90	LMSC
242	HSP 2113 Mem. Dump Miscompares	STGS DR 1097	07-19-90	PORTS
298	HSP High Volt Mon Out of Limit	CLOSED	06-19-90	MOC
369	HSP UDL and SHPs Missing	CLOSED	06-07-90	LMSC
401	STR P/B of HSP Data Missing SHPS and UDLS	CLOSED	08-07-90	LMSC
529	HSP Data Missing from STR Dump	CLOSED	06-12-90	LMSC
530	HSP Data Missing from STR Dump	CLOSED	06-12-90	LMSC
574	Unexpected PMT Behavior in 1502	CLOSED	10-05-90	HSP
578	HSP Data from STR Missing SHP/UDL	CLOSED	06-14-90	STPG
579	HSP Data Missing from STR Dump	CLOSED	07-24-90	STPG
581	HSP Data Missing from STR Dump	CLOSED	07-24-90	MOC
672	Missing Calibration Files 1500	CLOSED	07-19-90	HSP
836	HSP Safed by BOP in 1380 Det 3	CLOSED	09-20-90	HSP
958	HSP Safing Recovery STBF Error	CLOSED	08-28-90	STSCI
998	AN Crossing Times Missing	CLOSED	08-17-90	STSCI
999	OSS Not Able to Print Tab Listing	CLOSED	08-17-90	OSS
1072	HSP Safed by BOP During 1379 PMT	CLOSED	09-20-90	HSP
1112	VTPAFB1/VTPAFB2 Low Lim Violation	CLOSED	09-20-90	MOC
1115	VTPNP2C Low Lim Violation	CLOSED	09-20-90	MOC
1120	ESS Time Tag Error	CLOSED		ESS
1145	HSP 1380 T Errors	CLOSED	09-26-90	HSP
1186	Third Dump of HSP STR Data Missing	CLOSED	09-14-90	
1267	OSS Data doesn't Match PODPS Data for HSP 1503 Det 4	CLOSED	01-17-91	STSCI
1358	HSP Clock Overflow Error	CLOSED	10-22-90	HSP
1476	HSP Data Contains Inversion	CLOSED	11-07-90	LMSC
1514	HSP Data Contains Multiple Inversions	CLOSED	11-21-90	LMSC
1537	Missed Target HSP	CLOSED	11-21-90	STPG

1555	Data Inversion In HSP Data	CLOSED	01-08-91	CD500
1662	HSP 1526 Failed Observations	OPEN	02-04-91	STSCI
1957	HSP TLM Error	OPEN	02-20-91	MOC
1959	HSP 3140 Pointing Error Exceeds 2"	CLOSED	02-20-91	PCS
1967	VTERROR out of limits	CLOSED	02-20-91	HSP
2094	Incorrect Stmts in PSTOLS HSPSBYHD & HSPHDSBY	CLOSED	03-19-91	MOC
2169	Missing Bright Earth in HSP 3152	OPEN	03-27-91	STScI
2208	HSP FITS Header Discrepancies	OPEN	04-09-91	STScI
2235	PDB Update Identified Post Final Mode	CLOSED	04-10-91	HSP
2274	Missing HSP Observations in 2948/2949	OPEN	05-03-91	STScI
2307	HSP SCP Collection Star Not Seen in Aperture	CLOSED	04-30-91	STPG
2317	Missing Obs in HSP 3152 POL	CLOSED	05-02-91	STPG
2329	Missing Obs in HSP 3007	CLOSED	05-07-91	STPG
2334	HSP Bus Dir Memory Not Dumped	OPEN	05-08-91	STScI
2343	HSP Error Flag	OPEN	05-09-91	MOC
2371	HSP Memdump Compare Needs Modification	OPEN	05-17-91	MOC
2408	BE of HSP Microprocessor Dump	REJ.	05-28-91	MOC
2420	HSP Obs Not Written to FITS FMT Tape	OPEN	05-30-91	STScI
2471	No Target for HSP Program 1385	OPEN	06-12-91	STScI
2485	Targets Not Seen In HSP 1385	OPEN	06-14-91	STScI
2635	Missing Bright Earth HSP 3362	CLOSED	08-16-91	PCS
2659	Bad HSP 2769 VIS Data Due to S/C Jitter	CLOSED	08-19-91	PCS
2660	Inconclusive HSP 2769 Data Using AGK+81DZ66	CLOSED	08-19-91	STScI
2661	Missing Bright Earth in HSP 3119	CLOSED	08-19-91	STScI
2681	HSP FITS HEADER KEYWORD PTSROFLG CALLED-	OPEN	08-22-91	STSCI
2697	HSP DATA LOSS DUE TO STR	OPEN	09-03-91	STSCI

	TAPE TRACK CHANGE			
2733	HSP 1389 DATA DEGRADATION	OPEN	09-13-91	PCS
2796	UNEXPLAINED PERIODIC EFFECT IN HSP 1389 SCI-	OPEN	10-01-91	SESD
2868	HSP DATA LOG AFTER OUTPUT CEASE	OPEN	10-25-91	STSCI
2869	OSS DISCARDED DATA FROM HSP OBSERVATION	OPEN	10-25-91	STSCI

OPEN HSP HSTARs as of 11-07-91:

HSTAR#	Title	Status	Asgnee	Due
1662	HSP 1526 failed observations	Open	STScI	02-4-91
2208	HSP FITS Header Discrepancies	Open	STScI	04-09-91
2274	Missing HSP Observations in 2948/2949	Open	STScI	05-03-91
2334	HSP Bus Dir Memory Not Dumped	Open	STScI	05-08-91
2343	HSP Error Flag	Open	MOC	05-09-91
2371	HSP Memdump Compare Needs Modification	Open	MOC	05-17-91
2420	HSP Obs Not Written to FITS FMT Tape	Open	STScI	05-30-91
2471	No Target for HSP Program 1385	Open	STScI	06-12-91
2485	Targets Not Seen In HSP 1385	Open	STScI	06-14-91
2681	HSP FITS HEADER KEYWORD PTSROFLG CALLED-	Open	STSCI	08-22-91
2697	HSP DATA LOSS DUE TO STR TAPE TRACK CHANGE	Open	STSCI	09-03-91
2733	HSP 1389 DATA DEGRADATION	Open	PCS	09-13-91
2796	UNEXPLAINED PERIODIC EFFECT IN HSP 1389 SCI-	Open	SESD	10-01-91
2868	HSP DATA LOG AFTER OUTPUT CEASE	Open	STSCI	10-25-91
2869	OSS DISCARDED DATA FROM HSP OBSERVATION	Open	STSCI	10-25-91

4.6 End of OV Status and Liens

All basic HSP functions have been verified and all are working properly as of the end of the OV period. The fine alignment, especially the POL tube alignment, will continue into the SV period.

No reasonable mechanism is available for dumping the HSP memory and getting the resulting science data in electronic form. The bus directory memory pages require special procedures to dump. The single event upset events (two so far) have demonstrated the continuing need to have a straightforward means to dump and check the HSP memory including the bus director memory. As of the end of OV, an effort is underway to create standard procedures to perform this operation and to provide FITS files of the resulting data.

The commanding change to provide for resetting the frame count during a data collection is needed to restore full HSP capability.

5. Modifications and Recommendations

The major modifications to operations procedures arising from HSP OV results are:

1. The minimum HVPS turn-on voltage for the PMT was increased from 1500 to 1900 volts.

2. The management of bright earth occultations was modified for the VIS, POL, and PMT to avoid bright object safing

3. The mode II target acquisitions include two iterations. (this is actually the result of an SV test)

5.1 Trend Monitoring Recommendations

There are no trend monitoring procedures for the HSP engineering data. However, any significant or sudden unexplained change in temperatures, voltages, or other parameters should be investigated. Any limit exceeded also should be investigated. Detector parameters are monitored as part of the on-going HSP calibration plan.

5.2 Instrument Operational Recommendations

There are several issues unresolved as of this writing. The following actions should be taken before the close of the SV/GTO period:

1. The capability to reset the frame counter should be implemented to allow the HSP to function with the 32 kb link to the tape recorder.

2. The RIU polling on/off capability should be prepared and tested. There is evidence that the RIU reply bus noise is detected by the HSP. The polling on/off capability could be used to perform observations that would otherwise be compromised.

3. The remaining capabilities of the HSP thermal control system should be exercised.

4. The capability to dump HSP memory, including the bus director memory, and to provide fits files of the resulting dump data should be implemented as soon as possible. If there are future single event upsets, or other anomalies, it will be important to have this capability to enable timely analysis of the problem.

5.3 Conclusions & Lessons Learned

The OV program has demonstrated that the ground system lacks the flexibility and capability to respond reasonably to normal verification activities. The inability to routinely process generic science data is one example. One should be able to process science data with other than anticipated detector gain settings.

The pre-launch test design and schedule were too success oriented. Tests had to be broken into smaller units to prevent large losses of spacecraft time in the event of problems. Tests were scheduled on the assumption that needed spacecraft support capabilities would exist by the time the test was executed. Often these assumptions were incorrect and led to additional test failures, loss of spacecraft time, and additional delays in implementing improved tests.

The OV program has shown that efficient operations depend on being able to adjust operations procedures to meet the conditions actually encountered that may be different than anticipated before launch.

Appendix A - HSP OV, SV, & GTO proposal numbers and names

"pgm" classes:

OV	Orbital Verification
SV	Science Verification
SVD	Science Verification (Delta plan)
GTO	Guaranteed Time Observation
SAO	Science Assessment Observation
/X	Cancelled

prop	pgm	name
1079	GTO	Opportunity occultations by small bodies (see 3319)
1080	GTO	The size and composition of planetary ring particles(see 3373)
1081	GTO	Saturn ring dynamics (see 3371, 3375)
1082	GTO	Helium abundances in Jovian planet upper atmospheres (see 3354)
1083	GTO	Dynamics of planetary upper atmospheres (see 3376)
1084	GTO	Lunar occultations with the HST
1085	GTO/X	Rotation periods of cometary nuclei
1086	GTO	Do Neptune and Pluto have rings?
1087	GTO/X	Eclipses and occultations by Pluto and Charon
1088	GTO	Small satellites in the Uranian system
1089	GTO	Captured satellites of the Jovian planets
1090	GTO	Periodic variations in DQ Herculis stars (see 3257)
1091	GTO	UV pulsations from X-ray pulsars
1092	GTO	Eclipses of cataclysmic variable stars (see 3238)
1093	GTO	Observations of ZZ Ceti stars
1094	GTO	Search for optical variability assoc. with black holes (see 3255)
1095	GTO	Variability of high luminosity stars (see 3252)
1096	GTO	Gravitational lenses (part I) (see 3250)
1097	GTO	X-ray binaries (see 3234,3256)
1098	GTO	Remnant stars in SNRs (see 2953,3251)
1099	GTO	Active galactic nuclei (see 3248)
1100	GTO/X	Evolution of the nuclei of planetary nebulae
1101	GTO	Optical and UV observations of radio pulsars (see 3253)
1102	GTO	UV light and polar. variations in Beta Cephei stars
1103	GTO	Vis/UV light curves of short period RR-Lyrae stars (see 3254)
1104	GTO	High speed photometry of GBS 0526-66
1379	OV	Detector dark count test
1380	OV	MSC Focus and aperture mapping test (phase I)
1381	SV	Target acquisition test (see 3071-3074)
1382	OV	Pulse height distribution test
1383	SV	Time resolved photometry
1384	SV	Color transformation test (see 2769,2770)
1385	SV	Photometric performance test
1386	SV	Instrumental polarization test
1387	SV	Stokes parameter test
1389	SV	Short-term photometric stability
1391	GTO	Gravitational lenses (part II)
1474	SV	Photometric performance test
1499	OV	Command response test
1500	OV	Detector data test
1501	OV	Data integrity test
1502	OV	High voltage turn-on test
1503	OV	MSC coarse FGS/HSP alignment (phase II)
1504	OV	MSC fine FGS/HSP alignment (phase III)
1524	SV	MSC fine FGS/HSP alignment (phase III) (see 2948-2951)
1526	SV	MSC aperture mapping test (phase I) (UV) (see 3093, 3119, 3120)
2113	OV	Memory dump

2201	OV	Safe-to-oldhold
2749	SV	RIU polling on/off test
2768	SVD	Pulse height distribution test
2769	SV	Color transformation test
2770	SVD	Color transformation test
2771	SV	Stellar occultation by planetary rings
2772	SVD	Stellar occultation by dark lunar limb
2773	SVD	Stellar occultation by planetary atmospheres
2948	SV	MSC fine FGS/HSP alignment (phase III) (UV2)
2949	SV	MSC fine FGS/HSP alignment (phase III) (UV1)
2950	SV	MSC fine FGS/HSP alignment (phase III) (VIS)
2951	SV	MSC fine FGS/HSP alignment (phase III) (POL)
2952	GTO	X-ray binaries (see 3249)
2953	GTO/X	Remnant stars in SNRs (see 1098,3251)
3006	SAO	Effect of centering errors on HSP photometry
3007	SAO	Effect of jitter on HSP photometry
3069	OV	10.2/Bright earth test
3071	SV	Target acquisition test (POL)
3072	SV	Target acquisition test (UV1)
3073	SV	Target acquisition test (UV2)
3074	SV	Target acquisition test (VIS)
3093	SV	MSC aperture mapping test (phase I) (VIS) (see 1526)
3119	SV	MSC aperture mapping test (phase I) (VIS) (visit 2) (see 1526)
3120	SV	MSC aperture mapping test (phase I) (VIS) (visit 3) (see 1526)
3140	SV	MSC fine FGS/HSP alignment (phase III) (nelson plan) (see 1504)
3152	OV	MSC aperture mapping test (phase II/III) (jwp plan)
3233	OV	MSC aperture mapping test (phase II/III) (jwp plan) (see 3152)
3234	GTO	X-ray binaries (see 1097,3256)
3238	GTO	Eclipses of cataclysmic variable stars (see 1092)
3248	GTO	Active galactic nuclei (see 1099)
3249	GTO	X-ray binaries (see 2952)
3250	GTO	Gravitational lenses (part I) (see 1096)
3251	GTO	Remnant stars in SNRs (see 1098,2953)
3252	GTO	Variability of high luminosity stars (see 1095)
3253	GTO	Optical and UV observations of radio pulsars (see 1101)
3254	GTO	Vis/UV light curves of short period RR-Lyrae stars (see 1103)
3255	GTO	Search for optical variability assoc. with black holes (see 1094)
3256	GTO	X-ray binaries (see 1097,3234)
3257	GTO	Periodic variations in DQ Herculis stars (see 1090)
3319	GTO	Opportunity occultations by small bodies (see 1079)
3354	GTO	Helium abundances in Jovian planet upper atmospheres (see 1082)
3362	OV	HSP prop 3233 visit 2
3363	OV	HSP prop 3233 visit 3
3371	GTO	Saturn ring dynamics (later cycles, see 1081, 3375)
3373	GTO	The size and composition of planetary ring particles (see 1080)
3375	GTO	Saturn ring dynamics (cycle 1, see 1081, 3373)
3376	GTO	Dynamics of planetary upper atmospheres (later cycles, see 1083)
3377	SV	Pol detector test
3382	SV	Revisit of 1385 to obtain 13th and 15th, but not 9th, mag targs

Appendix B - PMT High Voltage Turn-On Investigation

7/17/90 S. Ellington

This report summarizes the results of tests done to date in an effort to determine the cause of the noise counts observed in HSP when minimum voltage is applied to the PMT. Several plausible causes of the noise have been investigated. Some of the possible causes have been effectively ruled out, while two of them are consistent with the test results.

1. Flight PMT Noise Description

Noise counts were recorded during several tests of the flight PMT in orbit. These tests were performed with high voltage set to the minimum value (about 1475 Volts), and the PAD threshold set to the normal operating value of 20. There was no significant light at the PMT. At this high voltage setting, there is less than 200 Volts across the PMT dynodes, which is normally much too low to cause any counts.

During these tests, noise counts increased from about 200 counts/sec immediately after high voltage turn-on to about 2,00 counts/sec 37 seconds later, when the test was terminated. The increase in count rate resembled an exponential rise until the last few seconds of the test, when it increased more slowly. Analog (CVC) data showed fluctuations, but no significant change in average value. The amplitude of the analog data fluctuations did not change significantly during the test.

2. Test Equipment Description

The HSP Engineering Model instrument with an unpotted flight spare PMT Assembly were used for some tests. Data was collected with the HSP EGSE. Operation of this instrument closely simulates that of the flight instrument.

A PMT Test Circuit was also constructed. It consists of a flight- type Photomultiplier Tube (Hamamatsu R666S) in a metal enclosure, with a tube socket, dynode resistors, and corotron. It is electrically equivalent to the flight PMT Assembly, but is unpotted. The PMT Test Circuit was tested for normal noise level, dark count, and response to light. It's performance appeared similar to the flight unit.

Noise sensitivity measurements were made with a detector system identical with that used in HSP. It has an engineering model Preamp and PAD, with auxiliary circuits to provide a manually adjustable PAD threshold and an interface to a laboratory frequency counter. This system responds precisely as the flight electronics do, while providing more flexibility.

Corotron tests were performed with a simple breadboard circuit, a well as with the flight spare PMT Assembly and the PMT Test Circuit.

3. Corotron Oscillation

Tests of 3 different corotron voltage regulators showed that in the PMT circuit they became unstable and produced a relaxation oscillation at low operating currents. The current at which they became unstable ranged from 6.8 to 8.0 microamp at room temperature. The critical current decreases about 3 percent at -5 deg. C, the approximate temperature of the flight PMT. The absolute minimum corotron current in the flight PMT Assembly is 12 microamp, so it is not likely that this type of oscillation is present unless another failure has occurred.

In tests with both the flight spare PMT Assembly and the PMT Test Circuit, the high voltage was reduced below the normal minimum value of 1475 Volts to deliberately induce corotron oscillation when connected to HSP detector electronics. Both the HSP Engineering Model instrument and the separate detector system were used. The corotron was monitored during these tests to verify that oscillation was taking place. No noise counts were observed because of corotron oscillation. This is not surprising, because the rise and fall times of the voltage across the corotron during oscillation are more than a factor of 100 too long to couple sufficient current into the Preamp through the capacitance of the PMT.

Corotron oscillations do not appear to be a likely cause of the PMT noise because the operating current is well above the minimum value at which oscillation occurs, the rise and fall times are much too long, and deliberately induced oscillations didn't produce any noise counts.

4. Discharge in Parallel with Corotron

In normal operation, even at minimum PMT voltage, 1300 Volts appears across the corotron. Because the lead spacing is only 2.7 mm (0.105 inches), a parallel discharge path is possible. Because the dynode resistors are in series with the corotron, even a very low voltage discharge across the corotron would not cause the High Voltage Power Supply to shut down at minimum voltage. (A discharge from high voltage to return or chassis would almost certainly cause the HVPS to shut down.) Because the corotron is within the potted portion of the PMT Assembly, such a discharge would probably indicate a potting failure.

Because of the large voltage across the corotron, a parallel discharge could produce very large voltage fluctuations at the PMT cathode. The repetition frequency of the discharge depends on the breakdown and sustaining voltages of the path and, of course, the time constant of the components in the PMT Assembly. The minimum frequency is about 35 Hz, while a frequency of 2 kHz requires that the difference between the breakdown and sustaining voltages be around 10 Volts. These values are consistent with the measured frequency of PMT noise in the flight instrument of 200 Hz to 2 kHz.

A simple spark gap was added to the PMT Test circuit in parallel with the corotron to measure the effect of such a discharge. The spark gap was at atmospheric pressure, so it was not expected to behave precisely as would a discharge around a potted corotron in vacuum. However, periodic discharges were easily induced, which produced extremely large voltages at the preamp input. (A small capacitor was installed in place of the PMT, to avoid possible damage to the PMT.) Peak voltage at the preamp input was measured at 5 to 20 Volts (sic), depending on the size of the gap. (The normal PMT operating PAD threshold is about 150 microvolts.] Count rates of 50 Hz to 1.3 kHz were observed as the size of the gap was reduced. There was no sign of increase in frequency with time with a fixed gap.

5. Erratic Dynode Resistor

One possible cause of the PMT noise is erratic fluctuations in the value of a dynode resistor. Failure of the connection at the end of one of these metal film resistors, perhaps caused by potting stresses, could result in fluctuation of the resistance.

Tests were performed on the PMT Test Circuit with the detector system. The connection at the PMT cathode of the first dynode resistor (R1) was erratically opened and closed. PAD threshold was set to 20. Very large numbers of counts were observed. When a resistor was placed in parallel with the switch, it was found that fluctuations in the value of R1 as small as 10 K Ohms (out of 1.33 Megohms) caused a few noise counts. These tests clearly show that a noisy dynode resistor is a possible cause of the flight PMT noise.

6. PMT Test Circuit Characteristics

Performance of the PMT Test Circuit was measured to verify that its behavior was similar to that of the flight PMT Assembly. Dark count and light count (at low light levels) were measured at various high voltage settings, with the PAD threshold set to the normal flight unit operating value of 20. Average anode current was also measured. No dark or light counts were observed with the high voltage below 1700 Volts. The maximum signal to noise ratio was observed with the high voltage set to about 1880 Volts. At this setting, the dark count was about 10 counts/sec, and the average dark current was about 3 nA.

PMT interelectrode capacitances were measured both directly with an RLC meter and indirectly by injecting current pulses into various electrodes. The equivalent coupling capacitance from photocathode to anode is about 2 pf, while capacitance between various other electrodes ranges from 2 to 7 pf.

7. Conclusions

Two possible causes of the PMT noise have been identified: A discharge in parallel with the corotron and an erratic dynode resistor. The corotron instability at low current has essentially been ruled out. No other PMT Assembly has ever shown noisy behavior at minimum voltage, so it is clear that some kind of failure has occurred in the flight unit.

Although either type of failure is can producing the noise observed, the discharge appears more likely. Metal film resistors are generally reliable, and the potting material used in the PMT Assembly (Dow Corning 93-500) is a soft silicone that does no greatly stress components. But, this potting material does have poor adhesion characteristics, so it is possible that it has separated from the surface of the glass corotron envelope, creating a small void containing a small amount of gas released from the material itself. The voltage across the corotron could easily cause a discharge to occur in such a void. Because the dynode resistors are in series with the corotron, the discharge would not cause the HVPS to shut down when the voltage is set to the low end of the range. The change in count rate with time while power is applied could be a result of a change in pressure within the void caused by the heat generated by the discharge.

Tests performed so far have not replicated the increase in count rate with time observed in the flight instrument. This could be because the precise characteristics of the discharge path, or an erratic resistor, have not been duplicated. Of course, there still could be another unidentified mechanism responsible for the noise. If one assumes that one of the above mechanisms IS the cause, it is possible to evaluate the possible effects of further operation of the flight unit. If there is an erratic resistor, operation at higher voltage should cause no harm, and could cause the resistor to become more stable.

However, it appears more likely that there is a discharge across the corotron within a void in the potting material. In this case, operation for a longer period or at higher voltage could result in formation of a permanent conductive path across the corotron, which would render the detector inoperable. It is possible that there is some operating sequence that would clear the discharge path without damage, but further investigation is required to determine whether this is possible. Until such investigation is completed, we must assume that any further PMT operation presents a risk of permanent damage.

7. Further Investigation

Replication of the behavior observed in the flight PMT would greatly increase confidence that the true failure mechanism has been identified. The increase in count rate with time is the obvious characteristic that has not yet been reproduced in laboratory tests.

Because the discharge within the potted portion of the PMT Assembly is the most likely failure mechanism, further investigation should be directed toward producing this type of discharge. Models representing the corotron, and possibly other PMT Assembly high voltage components, would have to be potted and subjected to various types of thermal and mechanical stresses intended to produce small voids in the appropriate places. Since the flight PMT Assembly was potted about 8 years ago, aging of the material may be important, but there may be no way to quickly simulate this aging.

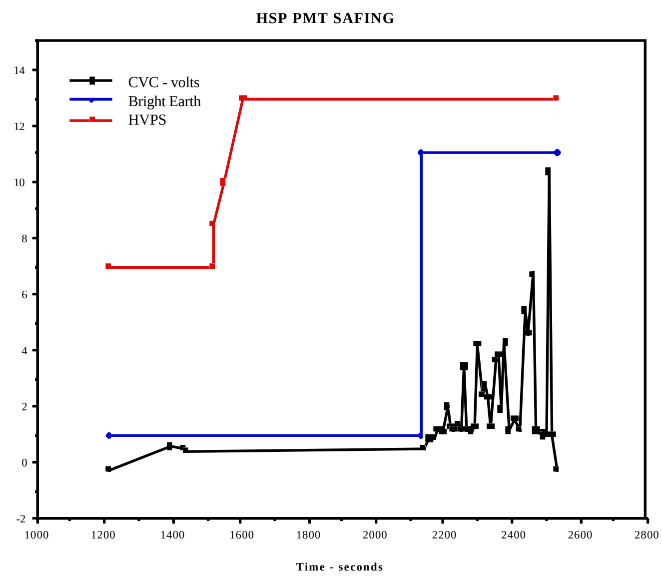
This investigation would be time-consuming, and there can be no guarantee of success. But, at this point it appears to be the only possible way to positively identify the failure mechanism, and determine if there is any way to restore the flight unit to normal operation.

Note: Subsequent to this report, the PMT was operated briefly at a higher voltage, 1900 volts, and no evidence of the "noise" was seen. Subsequent operations were restricted to voltages above 1900 volts and no further anomalous behavior has been seen.

Appendix C - PMT Bright Object Safing Report

HSP 1379 PMT Detector Dark Count test started as scheduled on day 231 beginning at 01:22:25 GMT. At 90:231:01:42:10 UTC HSP entered SAFE MODE due to Bright Object Protection. Analysis of the near real time engineering data shows VCVAMP5 at 10.34 volts just before BOP was tripped indicating that the PMT had been pointed at a bright target. Looking at the PASS HST Occultation Schedule Report, the V1-axis was occulted by the bright Earth at the time of safing. Although HSP was not in a data collection mode at this time, the high voltage had been ramped to it's full operate level of 2184 v. Note that the V1-axis was not occulted by the bright Earth at the time the first data collection scheduled.

The PMT appears to have behaved nominally.



The times of the significant events are as follows:

HVPS #5 ramped up to operate level 01:25:18
HST V1 axis crosses bright earth terminator 01:35:17

V374; VCVAMP5:

V374; VCVAMP5 = -0.25279999 S/C= 80237852. UT= 231 1 20 10
V374; VCVAMP5 = 0.54701805 S/C= 80239292. UT= 231 1 23 10
V374; VCVAMP5 = 0.49702942 S/C= 80239612. UT= 231 1 23 50
V374; VCVAMP5 = 0.39705217 S/C= 80239692. UT= 231 1 24 0
V374; VCVAMP5 = 0.49702942 S/C= 80245292. UT= 231 1 35 40
V374; VCVAMP5 = 0.84694982 S/C= 80245452. UT= 231 1 36 0
V374; VCVAMP5 = 0.89693844 S/C= 80245532. UT= 231 1 36 10
V374; VCVAMP5 = 1.1968702 S/C= 80245612. UT= 231 1 36 20
V374; VCVAMP5 = 1.1468816 S/C= 80245692. UT= 231 1 36 30

V374; VCVAMP5 = 1.0968930 S/C= 80245772. UT= 231 1 36 40
V374; VCVAMP5 = 1.9966882 S/C= 80245852. UT= 231 1 36 50
V374; VCVAMP5 = 1.2468588 S/C= 80245932. UT= 231 1 37 0
V374; VCVAMP5 = 1.1968702 S/C= 80246012. UT= 231 1 37 10
V374; VCVAMP5 = 1.3468361 S/C= 80246092. UT= 231 1 37 20
V374; VCVAMP5 = 1.1968702 S/C= 80246172. UT= 231 1 37 30
V374; VCVAMP5 = 3.3963697 S/C= 80246252. UT= 231 1 37 40
V374; VCVAMP5 = 1.1968702 S/C= 80246332. UT= 231 1 37 50
V374; VCVAMP5 = 1.1468816 S/C= 80246412. UT= 231 1 38 0
V374; VCVAMP5 = 1.2468588 S/C= 80246492. UT= 231 1 38 10
V374; VCVAMP5 = 4.1961880 S/C= 80246572. UT= 231 1 38 20
V374; VCVAMP5 = 2.4465859 S/C= 80246652. UT= 231 1 38 30
V374; VCVAMP5 = 2.7465177 S/C= 80246732. UT= 231 1 38 40
V374; VCVAMP5 = 2.2966199 S/C= 80246812. UT= 231 1 38 50
V374; VCVAMP5 = 1.2468588 S/C= 80246892. UT= 231 1 39 0
V374; VCVAMP5 = 3.6463130 S/C= 80246972. UT= 231 1 39 10
V374; VCVAMP5 = 3.7962787 S/C= 80247052. UT= 231 1 39 20
V374; VCVAMP5 = 1.8967110 S/C= 80247132. UT= 231 1 39 30
V374; VCVAMP5 = 4.2461762 S/C= 80247212. UT= 231 1 39 40
V374; VCVAMP5 = 1.1468816 S/C= 80247292. UT= 231 1 39 50
V374; VCVAMP5 = 1.5967792 S/C= 80247452. UT= 231 1 40 10
V374; VCVAMP5 = 1.1968702 S/C= 80247532. UT= 231 1 40 20
V374; VCVAMP5 = 5.4459033 S/C= 80247692. UT= 231 1 40 40
V374; VCVAMP5 = 4.5960970 S/C= 80247772. UT= 231 1 40 50
V374; VCVAMP5 = 6.7456079 S/C= 80247852. UT= 231 1 41 0
V374; VCVAMP5 = 1.1468816 S/C= 80247932. UT= 231 1 41 10
V374; VCVAMP5 = 1.0968930 S/C= 80248012. UT= 231 1 41 20
V374; VCVAMP5 = 0.94692707 S/C= 80248092. UT= 231 1 41 30
V374; VCVAMP5 = 1.0469043 S/C= 80248172. UT= 231 1 41 40
V374; VCVAMP5 = 10.344789 S/C= 80248252. UT= 231 1 41 50
V374; VCVAMP5 = 0.99691570 S/C= 80248332. UT= 231 1 42 0
V374; VCVAMP5 = -0.25279999 S/C= 80248412. UT= 231 1 42 10

V340; VHVPSM5:

V340; VHVPSM5 = 1399.6000 S/C= 80237916. UT= 231 1 20 18
V340; VHVPSM5 = 1941.1608 S/C= 80240316. UT= 231 1 25 18
V340; VHVPSM5 = 2029.8647 S/C= 80240556. UT= 231 1 25 48
V340; VHVPSM5 = 2127.9058 S/C= 80241032. UT= 231 1 26 47
V340; VHVPSM5 = 2202.6040 S/C= 80241232. UT= 231 1 27 12
V340; VHVPSM5 = 2197.9353 S/C= 80241452. UT= 231 1 27 40
V340; VHVPSM5 = 2202.6040 S/C= 80241740. UT= 231 1 28 16
V340; VHVPSM5 = 2197.9353 S/C= 80242476. UT= 231 1 29 48
V340; VHVPSM5 = 2202.6040 S/C= 80242716. UT= 231 1 30 18
V340; VHVPSM5 = 2197.9353 S/C= 80242932. UT= 231 1 30 45
V340; VHVPSM5 = 2202.6040 S/C= 80243412. UT= 231 1 31 45
V340; VHVPSM5 = 2197.9353 S/C= 80243628. UT= 231 1 32 12
V340; VHVPSM5 = 2202.6040 S/C= 80243916. UT= 231 1 32 48
V340; VHVPSM5 = 2197.9353 S/C= 80244388. UT= 231 1 33 47
V340; VHVPSM5 = 2202.6040 S/C= 80244628. UT= 231 1 34 17
V340; VHVPSM5 = 2197.9353 S/C= 80245812. UT= 231 1 36 45
V340; VHVPSM5 = 2202.6040 S/C= 80246308. UT= 231 1 37 47
V340; VHVPSM5 = 2197.9353 S/C= 80246556. UT= 231 1 38 18
V340; VHVPSM5 = 2202.6040 S/C= 80246796. UT= 231 1 38 48
V340; VHVPSM5 = 2197.9353 S/C= 80247516. UT= 231 1 40 18
V340; VHVPSM5 = 2202.6040 S/C= 80247756. UT= 231 1 40 48
V340; VHVPSM5 = 2197.9353 S/C= 80247936. UT= 231 1 41 10
V340; VHVPSM5 = 1399.6000 S/C= 80248440. UT= 231 1 42 13

Note the V374 output began to increase at the time of bright earth terminator crossing and varied over a large range until the safing event occurred. Variations in the brightness of the earth over a range of a factor of at least ten can be reasonably expected.

In summary, we currently feel that safing occurred due to a bright Earth occultation of the V1-axis while HSP Detector 5 High Voltage was on and at it's full operate level of 2184 volts. As a result, the maximum current limit of 80% was exceeded which tripped HSP Bright Object Protection. The standing operating procedure for this detector must be changed such that it does not view the bright earth while the high voltage is at standard operating levels.

Appendix D - HST Flight SMS sequence

The flight SMS sequence is listed below. Interruptions in the "in continuity with", usually associated with safemode recoveries, are indicated by ******.

901241k3
901252k1
901271m1r
901283m3
901312m4
901323m6
901352m2
901363m1
901382m3
901392m3
901402m8
901413m5
901432m5
901452m8
901463m4
901482m6

******

901492n2
901503n2
901522n4
901534p3
901562p4
901584a8
901613a3
901634aa
901662b3
901673b2
901694a4
901713b2
901733b3
901753b2
901773b3
901794b6

******

901882a3
901893c1
901915a4
901953a6
901974a3
902005c8
902045a9
902085ab
902125e4
902165b5
902205a7
902245c1
902287a1

******

902332a1
902344a7
902384a6
902419a5
902494a6
902537ab
902607d2
902677ab
902747bf
902817b8
902885a3
902932aa
902957a9
903027ac
903097e1

******

903104a2
903133b2
903167b3
903237cb
903307bgr
903377d6
******

903422a3r
903447b9
903517e8
903587e7
903657d2
******

910022a1r
910034a1r
910077c9
910147e4
910217bd
910287d2
910357e7
910427d6
910497e7
910567g1
910637c2
910707c6
910777d4
910847f2
910917bc
910987c9
911057d5
911127e4
911197b8
911267c1

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911276a2r
911337c8
911407ah
911477c3
911547d3
911617ca
911687bg
911757b1
911827af
911897al
911967d4
912037acr
912107b3
912177d5r
912247c7
912317e2
912387c1
912457d5
912527e5
912597b1
912667c4
912737c6
912807ai
912877d1
912947b4
913017b5
913087d4
913157aa
913227c4
913297b7

Appendix E - HSP Filter and Aperture Diagrams

Appendix F - OV Timelines