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PASSIVE OPTICAL SAMPLE ASSEMBLY (POSA) FOR STS-1-- QUICK LOOK POST-MISSION REPORT

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INTRODUCTION

A passively deployed array of contamination-sensitive samples was mounted and flown in the cargo bay of the Space Shuttle Columbia (STS-1) during the first Orbital Flight Test (OFT-1), April 12-14, 1981. A similar array was mounted in a different location in the cargo bay at Dryden Flight Research Center during the postflight operations there prior to the "ferry flight" of Columbia back to Kennedy Space Center (KSC). Designated as the Passive Optical Sample Assembly (POSA), the arrays were flown to aid in the assessment of contamination hazards of the Shuttle cargo bay for future missions.

The POSA unit flown on the orbital phase of the mission was mounted on the Development Flight Instrumentation (DFI) pallet in the cargo bay of the Shuttle; it will henceforth be designated as the POSA/DFI unit. The POSA unit mounted for just the ferry flight will be designated as the POSA/FF. Samples in the POSA/DFI were subject to deposition of contaminants throughout prelaunch, ascent, orbital, descent, and ferry flight phases of the OFT-1 mission. Inclusion of the second POSA unit, POSA/FF, during the ferry flight phase of the mission provides a means of identifying contamination hazards peculiar to that single phase of the mission.

As experimental flight hardware, both POSA units are totally passive in nature. Each is a mounted array of five optical samples and three static-charged Teflon sheets (electrets). Circumstances led to the inclusion of only two electrets on the POSA/FF unit.[1] Tables 1 and 2 provide directories of the samples contained in the POSA units. All of the samples were subjected to a series of optical and analytical measurements at the Marshall Space Flight Center (MSFC) prior to delivery for installation at KSC and Dryden Research Center. The measurements were repeated in an identical manner at MSFC following retrieval of the flight hardware. A summary of the results of a comparison of these measurements constitutes the basis of this "quick-look" report; a more detailed analysis will follow in a separate publication at a later date.

DESCRIPTION OF HARDWARE

Each POSA unit consists basically of a rectangular holder with six cylindrical receptacles (1.09 in. wide, 0.187 in. deep) bored at equal spacing. Smaller (0.75 in. diameter) holes in each of the sample "slots" are counterbored completely through the holder so that effluents can reach front and rear surfaces of the samples.

1. Also, uv-grade fused silica was substituted for the CaF_2 window (sample D) for POSA/FF.

TABLE 1

PASSIVE OPTICAL SAMPLE ASSEMBLY (POSA)
DFI PALLET UNIT

Tray 012

Sample	Material
A	Magnesium Fluoride Overcoated Aluminum (MgF_2/Al)
B	Gold Mirror
C	1810 Å Filter
D	CaF_2 Window
E	Top: CaF_2 Window Base: Electret #9
F	Top: Electret #11 Base: Electret #10

TABLE 2

PASSIVE OPTICAL SAMPLE ASSEMBLY (POSA)
FERRY FLIGHT UNIT

Tray 05

Sample	Material
A	MgF_2/Al Mirror
B	Gold Mirror
C	1790 Å Filter
D	UV-Grade Fused Silica
E	CaF_2 Window
F	Top: Electret #14 Base: Electret #13

A retainer plate with six circular "apertures" is bolted over the sample holder, allowing maximum front-surface exposure of the samples while holding down the outer edges. During those phases of ground handling, transportation, and installation when exposure was not desired, a solid, rectangular cover plate with captive screws was attached to protect the samples. The POSA hardware was machined from 300 series stainless steel. A more detailed description of the POSA hardware, including assembly and handling specifications, is available in a prior publication [1].

POSA MISSION DETAILS

The POSA/DFI unit was mounted to the starboard rail of the DFI pallet (X_o = 1069) in the Shuttle cargo bay. In Shuttle coordinates, the array was mounted in the X,Y plane, with the samples' surface normal parallel to the Shuttle Z-axis. The cargo bay doors of the Shuttle were opened 2 hr, 35 min after launch.

The POSA/FF unit was separately mounted, postlanding at Edwards AFB, at a cargo bay location specified by X_o = 750, inside access door No. 44.

A summary of pertinent mission timeline details is provided in Table 3; for example, from Table 3, the samples of the POSA/DFI unit were exposed, uncovered, in the cargo bay for nearly a month prior to launch. Of course, during this period, the cargo bay doors were closed, with no access of personnel. With reference to both units, there were 9 days of exposure to the ambient cargo bay environment on the ground at Edwards AFB.

RESULTS--OPTICAL MEASUREMENTS

The POSA units were received at MSFC on May 7, 1981. They were photographed, as received, on May 8, and the postmission measurements were begun soon thereafter (Figs. 1 and 2). From inspection of Figures 1 and 2, the larger particulates (and/or fibers) can be readily observed on the reflective samples of both units; considerably greater amounts of particulates of smaller size can be seen on closer inspection and in magnified photographs. Visual inspection of the samples from both POSA units reveals no direct evidence of a contaminant film, with the single exception of the magnesium fluoride overcoated aluminum (MgF_2/Al) mirror of the POSA/DFI unit (sample position "A" in Figure 1). The smudge and droplet on this sample remain of as yet undetermined origin, in both chemical nature and point of time.

TABLE 3

POSA MISSION TIMELINE DETAILS

POSA/DFI (1981)	
MSFC Shipment	March 3
KSC Delivery	March 3
Installation	March 13
Cover Removed	March 17
Launch	April 12
Landing	April 14
POSA/FF (1981)	
MSFC Shipment	April 13
Edwards AFB Delivery	April 14
Installation	April 22
POSTLANDING PHASES (BOTH UNITS)	
Shuttle Departure (Edwards AFB)	April 23
Shuttle Arrival (KSC)	April 24
Cargo Bay Doors Open (OPF/KSC)	May 2
POSA Covers Installed/Units Removed	May 6
MSFC Arrival	May 7

Optical measurements of the POSA samples were performed on two separate instrumentation facilities. In the wavelength range 120 to 290 nm, specular, spectral reflectance and transmittance (at near-normal incidence) were measured in a reflectometer at the exit slit of a Seya-Namioka-type monochromator. A hydrogen discharge lamp was utilized

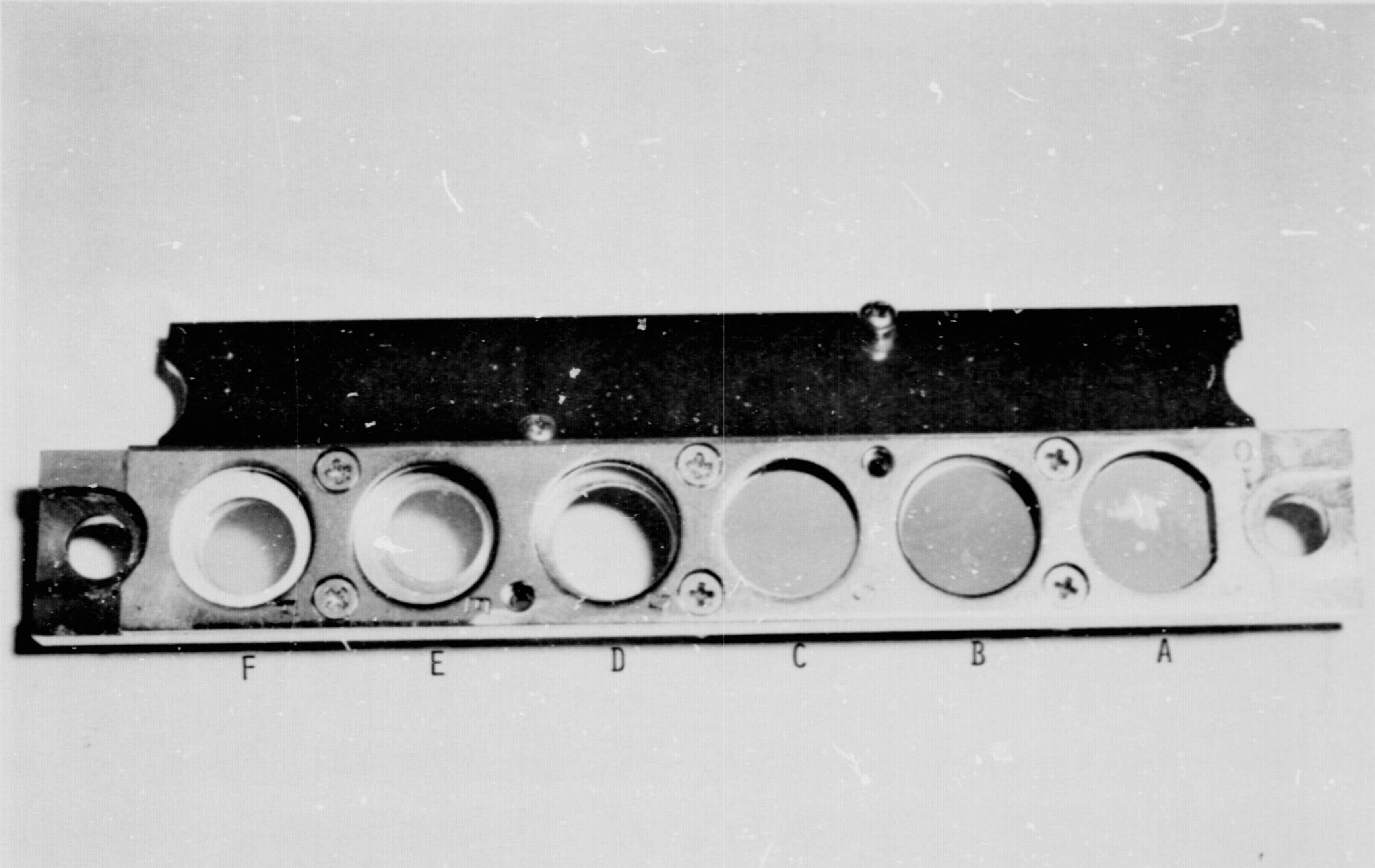

Figure 1. POSA/DFI postflight.

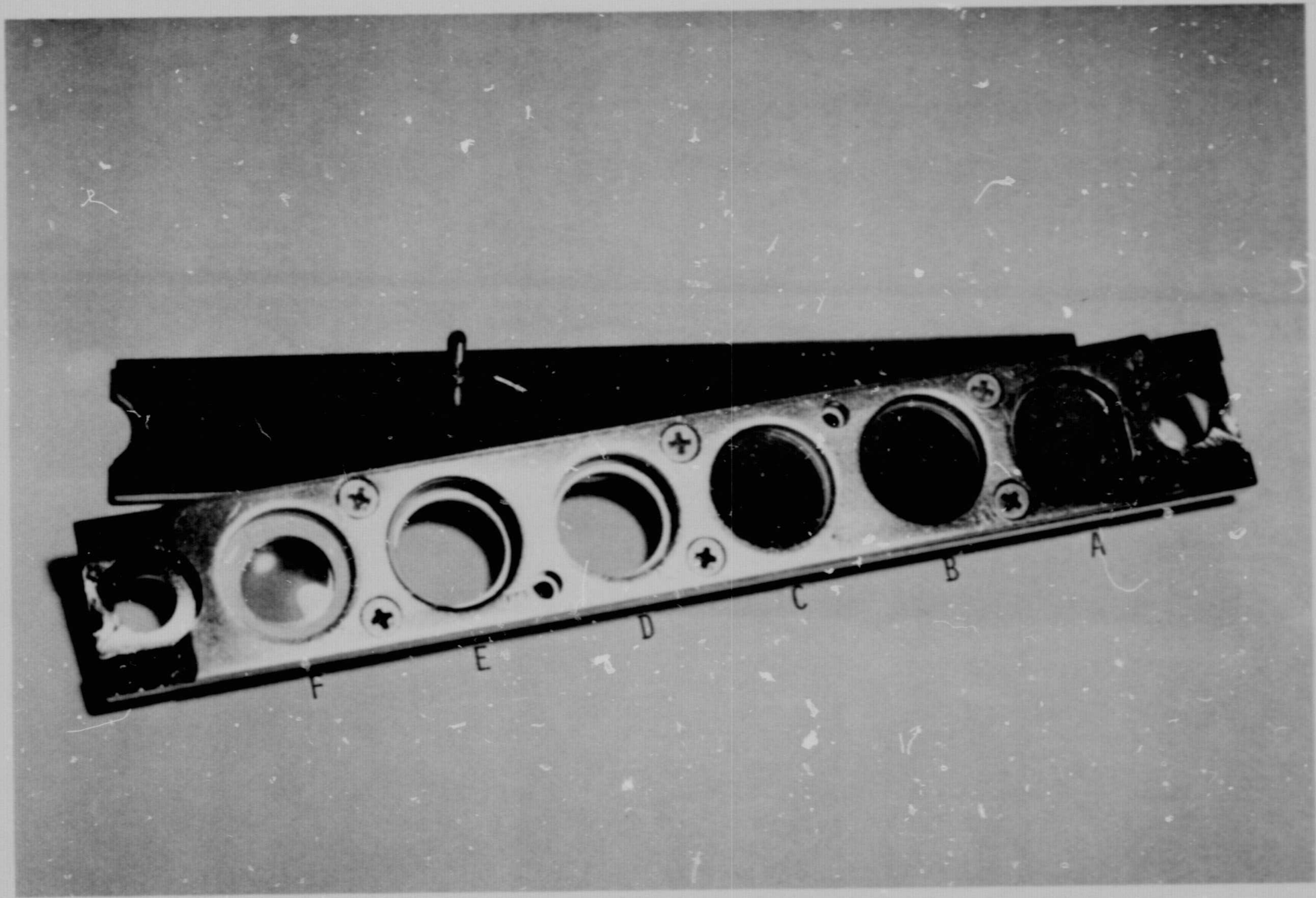

Figure 2. POSA/FF postflight.

as the source. The measurements were extended through 2.5 μm wavelength (overlapping slightly in the near uv) by measuring the diffuse reflectance and backscatter coefficient in a Beckman/Gier-Dunkle integrating sphere facility.

With the single exception of the smudged MgF_2/Al mirror from the POSA/DFI unit, none of the samples measured in the Gier-Dunkle facility (0.25 to 2.5 μm) indicate any significant degradation through that spectral range.

The smudged MgF_2/Al mirror from the POSA/DFI unit indicated, by diffuse reflectance measurements from 0.25 to 2.5 μm, a 10 percent relative increase in mirror absorptance. Backscatter measurements on this sample, in this range, indicated an increase more than double the original level, although the levels (0.02 preflight, 0.07 postflight) are, in magnitude, subject to large uncertainty.

In the range 120 to 290 nm, the measurements of specular, spectral reflectance of the smudged MgF_2/Al mirror indicate a generally uniform 9 to 10 percent relative decrease in reflectance. Measurements on the other samples of both POSA units basically indicate minimal (if any, significant) degradation at wavelengths longer than 200 nm, with patterns of apparent increased degradation at shorter wavelengths. A summary of the optical changes at selected, representative wavelengths is given in Table 4, where the parameter %Δ refers to the percent change in reflectance or transmittance at a given wavelength, computed as the difference of the prelaunch values and the postlaunch values, divided by the original value and expressed as a percentage.

Percentage changes in reflectance or transmittance of magnitude 5 percent or less must be viewed with caution because these levels approach the limits of uncertainty for the measurements. In summary of Table 4, it could be inferred that the reflecting optical samples may be degraded by the presence of thin film contaminant layers. Since the observed absorption increases inversely proportional to wavelength in the vacuum ultraviolet, the apparent degradation may be enhanced by interference effects with the reflecting mirror film. The results for the vacuum ultraviolet filters (1810 Å central λ for POSA/DFI, 1790 Å for POSA/FF) indicate, at first glance, similar degradation. These filters consist of multilayer, metallic thin film overcoats on magnesium fluoride substrates; however, the percentage changes in transmittance are subject to greater uncertainty than the comparable changes in reflectance for the mirrors simply because the filter transmittance values are low in magnitude (0 to 20 percent).

Measurements of transmittance of the transparent samples indicate no significant changes for samples of either the POSA/DFI unit or the POSA/FF unit.

TABLE 4

POSA RESULTS: OPTICAL MEASUREMENTS

Sample:	λ(Å)	%Δ_{DFI}	%Δ_{FF}
Magnesium Fluoride Over-coated Aluminum (MgF_2/Al) - Reflectance	1300	-9.4	-9.3
	1600	-9.4	-4.8
	2400	-8.8	-5.8
	2800	-9.0	0
Gold - Reflectance	1300	-21.9	-14.3
	1600	-8.1	-15.8
	2400	-13.3	-5.4
	2800	-5.7	-7.1
Calcium Fluoride (CaF_2) - Transmittance	1300	+3.7	No preflight measurement available
	1600	-1.3	-6.8
	2400	-1.1	+2.2
	2800	-1.1	+1.7
Fused Silica (SiO_2) - Transmittance	1600		0
	2400		0
	2800		-2.2
Calcium Fluoride (CaF_2) #2 - Transmittance	1300	-3.5	0
	1600	0	0
	2400	+1.1	0
	2800	-1.1	0
UV Filters - Transmittance		(1810 Å Filter)	(1790 Å Filter)
	1700	-10.0	-15.6
	1800	-4.8	+5.4
	2000	0	0
	2100	0	0

Measurements of the reflecting efficiency of the "back" sides (-Z) of the POSA samples in the vacuum ultraviolet were performed to assess directionality in the flow of effluents, if any. Since the magnitude of back-surface reflectance is very low for both the transparent samples and the reverse side of the reflecting mirrors, the measurement uncertainty is increased (± 10 percent). The data show, however, that no significant changes in the "back" surface reflectance of POSA/FF samples were measured, while for the "back" surface reflectance of POSA/DFI samples, there are 20 percent relative changes in the "back" surface reflecting efficiency, significantly pronounced above the background uncertainty level. This difference is probably an interference effect. The deposition on the "back" sides of the POSA/DFI samples is intuitively assumed to arise from outgassed products from the DFI pallet strut to which the POSA/DFI unit was mounted; the sample back side was exposed to the paint by a narrow gap due to the mounting spaces of the POSA unit.

RESULTS—PARTICLE ANALYSIS

The quantity and size distribution of particles on some of the samples of both POSA units have been measured using a white light, imaging, digital particle counting facility. Only partial results for the POSA samples are available at this time; three sets of particle counting scans have been completed. These include comparison scans of similar samples from the POSA/DFI unit and the POSA/FF unit. For all the samples measured to date, the results uniformly indicate a size distribution heavily weighted toward particles less than 10 μ in diameter, with the greater number of these less than 5 μ in diameter. The preliminary results indicate, further, that the type of sample surface may have a considerable influence on the number of adhering particles; particle counts on the ultraviolet filters of both POSA units exceed $10^5/cm^2$ for particle diameters less than 5 μ, while the comparable statistics for the MgF_2/Al mirrors were lower by a factor of 10^3. Most puzzling, at this time, are the preliminary results for the transparent calcium fluoride (CaF_2) samples of both POSA units; these samples appear virtually free of significant particle accumulation. Further measurements and analysis will clarify these preliminary results and will be published at a later date.

RESULTS—ELECTRET ANALYSIS

The electrets are made of Teflon-polytetrafluorethylene, $(C_2H_4)n$. Electrets are dielectrics with a permanent surface charge (approximately 10^{-8} Coulombs/cm^2 density) that gives them properties analogous to magnets by retaining electrically active particles and ions on their surface. Energy measurements are made in the X-ray energy range from 0.707 to

30 keV +0.170 keV (i.e., fluorine to silver) using an X-ray microprobe to analyze the effluents collected on the Teflon electrets. Thus, an elemental analysis and an estimate of the abundance of the elements are obtained.

Three electrets were included in the POSA/DFI for STS-1. One was placed under Sample E, the calcium fluoride "window." For this electret, the ion-attracting charged surface was oriented 180 degrees from the direction the CaF_2 sample faced, providing a measure of the directionality of effluent flow. The other two electrets were placed in sample slot "F" of the POSA holder (one facing "up", +Z, and the other facing "down", -Z) for directionality analysis.

Two electrets in the POSA/DFI, position E (down) and electret #10 position F down), showed no significant evidence of contamination present. Electret #11, also at position F but facing "up", showed a significant increase of Si and Al after X-ray microprobe analysis. On the ferry flight of Columbia from Edwards AFB, California, to Kennedy Space Center, Florida, no significant amount of Si was collected, but a significant amount of Al was measured on electrets 13 and 14 after the energy-dispersive analysis of the electrets (Table 5).

TABLE 5

COMPARISON OF CONTAMINATION DURING STS-1 ORBITAL FLIGHT AND FERRY FLIGHT

Electret No.	Description	Element	Relative Abundance	Total Counts ÷ Background
9	Cargo bay, STS-1, DFI pallet, position E (down)	Al	-	-
		Si	-	-
10	Cargo bay, STS-1, DFI pallet, position F (down)	Al	-	-
		Si	-	-
11	Cargo bay, STS-1, DFI pallet, position F (up)	Al	7700	2.4
		Si	900	2.3
13	Ferry flight return of Columbia from Edwards AFB to KSC (down)	Al	8300	2.4
		Si	-	-
14	Ferry flight return of Columbia from Edwards AFB to KSC (up)	Al	3830	1.7
		Si	-	-

CONCLUSIONS

The most probable cause of most of the optical degradation is particulate deposition since it is measured on both POSA units, and deposition of molecular films would not be expected in the ferry flight environment. However, based on reflectance data, there is indication of a molecular film on the gold sample. Reflectance data provide the most sensitive measurement for an absorbing molecular film because the rays pass through the film twice. Unfortunately, because of the smudge on the MgF_2/Al sample (DFI unit), it cannot be compared directly with the ferry flight sample for molecular deposition.

Also, a significant degradation was measured on the back side of samples with a large view factor to the painted DFI structure.

The particulate levels were very high in the ≤ 5 μm range for DFI and ferry flight mirror samples and less on other samples, indicating variations in adherence.

It is emphasized that these results are for unprotected samples subjected to all phases of the flight, including the ferry flight. STS-1 was subjected for many months to a relatively uncontrolled environment during manufacturing efforts. These results should not be applied directly to anticipated degradation of protected optics on future Space Shuttle missions.

REFERENCE

1. Linton, Roger C.: The Passive Optical Sample Assembly (POSA) on STS-1. NASA TM-82407, March 1981.

APPROVAL

PASSIVE OPTICAL SAMPLE ASSEMBLY (POSA) FOR STS-1 — QUICK-LOOK POSTMISSION REPORT

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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