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MATERIAL INSPECTION OF EURECA

FIRST FINDINGS AND RECOMMENDATIONS

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ABSTRACT

This paper gives the first results of the Post flight materials investigation on the European Retrievable Carrier (EURECA) after a stay of 11 months in LEO.
The paper will concentrate on the first findings after the visual inspection performed at KSC and Astrotech and give some general design recommendations for potential future Carrier flights.

INTRODUCTION

This materials investigation is part of the more general Post-flight technology Investigations Programme on EURECA initiated by the ESA Technical Directorate and fully supported by the ESA/EURECA project team.

This programme also includes a comprehensive meteoroid and debris investigation, inquiries into anomalies and failures at carrier and experiment level and some basic technology studies (Ref 1).

The material investigation is a joint effort between ESA/ESTEC Materials Division and DASA/ERNO materials specialists and consists of the following main activities :

- Visual inspection shortly after landing at KSC (in OPF and VPF facilities) and during the disassembly of the carrier at Astrotech. More detailed inspections are in the process of being performed at ESTEC and at different Experimenters sites.

- Photographic documentation of carrier and payload during these inspections. At this moment we have in total some 1200 photographs catalogued, 400 taken at KSC, the rest at Astrotech.

- Thermo-optical properties (α_p and ε_n) have been measured on some 100 positions over the spacecraft.

- Organic Contamination is measured using wipes and direct measurements. The analyses first concentrate on IR-spectroscopy and will be followed by more sensitive ESCA and AUGER methods.

- Degradation of material properties due to exposure to the LEO-environment (AO-effects, transmission losses in optics...)

- A database on the above has been developed by DASA/ERNO and contains already results of visual inspection, photographic documentation, α/ε measurements.

FIRST INSPECTION RESULTS

An overall EURECA configuration, experiment description and mission profile are given in Ref.2. A schematic view of the integrated spacecraft can be seen in Fig 1. The solar arrays , located on the +X and -X faces, are deployed to expose the radiator panels.

The majority of the experiments, except for the Inter Orbit Communication Antenna (IOC), are located on the top deck (+Z) either exposed or below the MLI tent. The multi-layer insulation consists of a Beta Cloth top layer and a number of layers of double sided Acrylic coated Aluminised Kapton (typically 20 layers). In order to avoid the contamination and degradation of the Beta Cloth, found during solar simulation testing, it was decided to use a silicone-free version of this material. Only some limited parts of the MLI were still consisting of the original silicone-containing material.

It should be mentioned that even the first thermo-optical measurements were taken only 4 weeks after retrieval and landing of the spacecraft. Some materials are liable to show a significant recovery effect. After UV and particle irradiation tests performed at CERT/DERTS in Toulouse a typical recovery of 0.1 within a few weeks after exposure to air has been found on PSG 120 FD paint. (Ref. 3.)

+Z face (sun-lit top face)

The Beta Cloth over the whole upper area is light brown in colour as a result of possible contamination and UV irradiation, the total solar exposure being ± 5000 e.s.h. This has led to an increase of the Solar Absorptance of 0.07 on most of the blankets and up to 0.26 in very contaminated areas. No appreciable change was found in the Normal Emittance values (see table 1).

There are signs of outgassing from within the spacecraft (see photos 1 to 5). These signs sometimes called "nicotine stains" or brown stains emanate from different unintentional venting holes, e.g. around Attitude and Orbit Control System (AOCS sensors), the Atomic Oxygen Sample Tray (AOST) experiment , Protein Crystallisation Facility (PCF) dome, the Advanced Solar Gallium Arsenide Array (ASGA) , GRAPPLE fixture etc.

The FEP tape (Sheldahl G401905 5 mil Silvered Perforated Teflon type A) on the AOCS sensors tower is heavily contaminated and typical shadowing effects can be seen.

On the Solar Constant and Variability Instrument (SOVA) the aluminised FEP-surface shows non-homogeneous brown stains with a particular pattern, apparently due to temperature gradients on the surface (see photo 6). It is believed that close to tape perforations and tape joints the temperature is higher as a result of the much higher α/ε-ratio and that therefore less condensation and subsequent degradation occurs.

On several optical instruments a degradation of the performances was reported during the flight. Contamination of the front optics was visible and will have contributed to these losses; however, it also appeared that several of the front filters showed failures at interfaces between the different layers. The pure contamination related degradation was highly wavelength dependent (see Fig. 2.).

The amber reflector / orientation patch is blackened as a result of UV irradiation.

The MAP SG11FD white paint on the Solar Spectrum Instrument (SOSP) is slightly tan coloured as a consequence of UV irradiation, resulting in an increase in α of 0.2 and an increase in ε of 0.015.

-Z face (bottom)

There are again signs of outgassing from within the spacecraft. This is very obvious on blankets, around battery boxes and around struts. An increase in α of up to 0.026 was recorded in the contaminated areas. The direct solar irradiation was low since the -Z face was earth oriented during the whole mission, except for a very limited time span, estimated at max 30 hrs, during manoeuvering in the first days of the mission. This could mean that the effect of Albedo UV-radiation in the degradation process cannot be neglected.

The baseplate of the Power Control Unit (PCU), painted in PSG 120 FD, which was recessed approx. 10 cm from the front face of the PCU was degraded (contamination + Albedo UV). The maximum resulting increase in α was 0.13. It is believed that this increase was mainly due to a polymerisation of a contaminant rather than a degradation of the paint itself.

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The four keel strut heaters show signs of overheating because of insufficient thermal contact (not bonded by adhesive, maintained by tie-wraps). This is under investigation by DASA/ERNO. Also the heaters from the keel cold gas thrusters show signs of degradation.

On the IOC antenna dish some marks from previous bonding of thermocouples were visible. Marks caused by possible cleaning prior to flight were accentuated by some environmental interactions (UV, Atomic Oxygen ?). Some iridescence on the black thermal blanket was visible as a result of contamination.

+X and -X faces

In general the Beta Cloth is less degraded than on the +Z face (top face), as can be expected from the smaller solar input. This has resulted in an increase of the Solar Absorptance of 0.02 on most of the blankets and up to 0.055 in more contaminated areas (close to ventings).

The EURECA signs (both on -X and +X) show some slight browning of the white paint (PSG120FD), resulting in a $\Delta\alpha$ of +0.07.

The green orientation patch has darkened.

Very prominent degradation of outgassing products is visible on PCF dome where the blanket meets the PSG120FD white paint (see photo 7). Some concentration effect of this degradation is due to multi-reflections in small V-grooves formed between both blanket and dome. The degradation on the top side (+Z) of the dome resulted in an increase in α varying between 0.13 and 0.20, while on the side this increase was limited to 0.04.

The PSG120FD white painted Aluminised Kapton foil from the MLI below the hydrazine thrusters is cracked and peeling due to mechanical and thermal stresses. Also disbonding of folded-over edges on these foils occurred.

The darkening of the MLI in the area of the PCF can be seen in photo 8 where the contrast is obvious between the shaded area below the strut of the payload tent and the exposed area.

+Y face

Here also there are signs of outgassing from within the spacecraft. They are particularly obvious below the Timeband Capture Cell Experiment (TICCE) and behind the Radiofrequency Ion Thruster Assembly (RITA) where there was an unintentional opening in the MLI cover that acted as a chimney (see photo 9). This has resulted in an increase of the Solar Absorptance of 0.06 on most of the blankets and up to 0.13 in very contaminated areas. No appreciable change was found in the Normal Emittance values (see table1).

The Aluminised FEP (Sheldahl G400900 perforated) on RITA has degraded, due to UV irradiation and Atomic Oxygen attack. Some crazing near perforation holes was visible on the sun-exposed side.
The degradation and splitting of the shrink sleeve surrounding the RF power supply cable of the thruster is mainly resulting from an improper thermal blanket design.

The SCUFF PLATE shows signs of ATOX degradation of the yellow Chemglaze Z853 and the black Z306 paint. The paint is powdering and faded. The paint shows a bad adhesion and is peeling from the substrate (see photo 10).

-Y face

There are signs of outgassing from within the spacecraft. They are particularly obvious behind the Wide Angle Telescope For Cosmic Hard X-rays (WATCH) and on the Freon line MLI, as shown in photo 11.

This has resulted in an increase of the Solar Absorptance of 0.06 on most of the blankets and up to 0.13 in very contaminated areas, similar to the +Y face. No appreciable change was found in the Normal Emittance values.

The GRAPPLE fixture shows signs of UV/ATOX degradation of the grey paint, a blend of Chemglaze black paint TT-C-542 type 2 and a Chemglaze white paint TT-C-542 type 1 (Ref. 4), with a shadowing effect, possibly from the grab arm. The paint is powdering and faded. NASA is investigating if outgassing from the RMS arm has discoloured the GRAPPLE plate.

Inside

The general appearance of the interior of the spacecraft was visibly clean and no apparent problems were noted on painted areas, harness or structure.

The Aluminium tape used to bond cables on the black painted top platform (behind TICCE) has disbonded in some areas.

CONCLUSIONS

Although there is an overall contamination and a noticeable degradation on the +Z face as a result of UV-irradiation, most visual degradation effects are due to venting through apertures from inside the spacecraft, such as e.g. overlaps between thermal blankets. This contamination has polymerised and has darkened under the action of solar Ultraviolet at these vent holes, resulting in the "nicotine stains", very well known from the LDEF after-flight visual inspections.

Also the Earth-facing surfaces showed some brown degradation. These surfaces were sun-lit only during some short manoeuvering periods (total estimated sun exposure < 20hrs). Although the UV in the albedo spectrum is very limited, one cannot exclude this effect totally.

The usefulness of shutters for optical experiments is well demonstrated by the SOSP experiment, where the contamination was confined to the upper side of the shutters rather than on the underlaying optical elements.

RECOMMENDATIONS FOR FUTURE EURECA-FLIGHTS

Since the primary mission objective was microgravity oriented, most of the experiments were built contamination insensitive. There were however some optics on-board that degraded heavily due to deposition and degradation effects. There are some simple measures that can be taken that will reduce the contamination potential for these critical surfaces, namely:

- As far as possible all optical apertures should be within a single plane.

- Use shutters for optical payloads when appropriate.

- No venting shall be allowed in the vicinity or in view of optical apertures, optics and cold surfaces.

- Venting should be directed as much as possible to the wake region.

- Control the thermal blanket design and manufacture to avoid undesired venting due to gaps between different elements. Overlaps, if used, should not be vent openings. It is preferable to have the edges butting to each other and tightly joined.

- A bake should be applied to the carrier, the harness, and the different experiments in order to assure a cleanliness level in conformance with the needs dictated by the most sensitive experiments or sub-systems and to avoid all cross contamination.

- Cleanliness and contamination control specifications (e.g. during manufacturing, testing, handling, packaging, storage) to the appropriate level shall be implemented not only on optical payloads, but on the whole spacecraft, including the non-sensitive payloads. This also includes a close follow-up by means of Critical Cleanliness Reviews at payload and spacecraft interface levels.

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We would also like to thank J. Guijt and T. Harper for the various analyses and interesting discussions towards the contamination work performed.

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Ref. 1 ;R. Aceti, G. Drolshagen, L Gerlach, G. Racca. Meteoroid and Debris Investigation on Eureca; ESA/ESTEC. First European Conference on Space Debris. ESA SD-01

Ref. 2. A. Dover, R. Aceti and G. Drolshagen ESA/ESTEC EURECA 11 Months in Orbit - Initial Post Flight Investigation Results . 3rd LDEF Post-Retrieval Symposium, Williamsburg , Virginia, Nov. 1993.

Ref. 3. ESA ESTEC contract 10023/92/NL/NJ
Etude ONERA/CERT/DERTS 439700.

Ref. 4. Private Communication from J. Beaman, Lockheed Engineering and Sciences Company.

TABLE 1. THERMO-OPTICAL VALUES

Face	Material	$\Delta\alpha_p$ Absorptance		$\Delta\varepsilon_n$ Emittance	
		Minimum $\Delta\alpha_p$ Post-flight	Maximum. $\Delta\alpha_p$ Post-flight	Minimum $\Delta\varepsilon_n$ Post-flight	Maximum. $\Delta\varepsilon_n$ Post-flight
+Z	Beta cloth	+ 0.067	+0.26	-0.004	+0.006
+Z	ASTRAL PSG120FD white paint on top of PCF dome	+0.188	+0.198	-0.020	-0.014
+Z	MAP SG11FD white paint on SOSP	+0.127	+0.194	+0.015	-----------
+X	Beta cloth	+0.024	+0.052	0	+0.005
+X	ASTRAL PSG120 FD	+0.001	+0.043	-0.001	-0.015
-X	Beta cloth	+0.02	+0.055	-0.010	+0.008
-X	ASTRAL PSG120FD white paint on thruster foils	+0.005	+0.06	-0.005	-0.007
+Y	Beta cloth	+0.06	+0.127	-0.004	-0.003
+Y	Chemglaze Z853 yellow paint on scuff plate	-0.062	--------------	+0.007	--------------
+Y	Chemglaze Z306 black paint on scuff plate	+0.030	--------------	+0.020	--------------
-Y	Beta cloth	+0.06	+0.13	-0.008	-0.002
-Y	Chemglaze Z853 yellow paint on scuff plate	-0.072	-0.043	-0.010	+0.020
-Y	Chemglaze Z306 black paint on scuff plate	+0.025	+0.030	+0.037	+0.048
-Z	Beta cloth	+0.012	+0.026	+0.005	+0.006
-Z	ASTRAL PSG120FD	+0.011	+0.131	0	+0.002

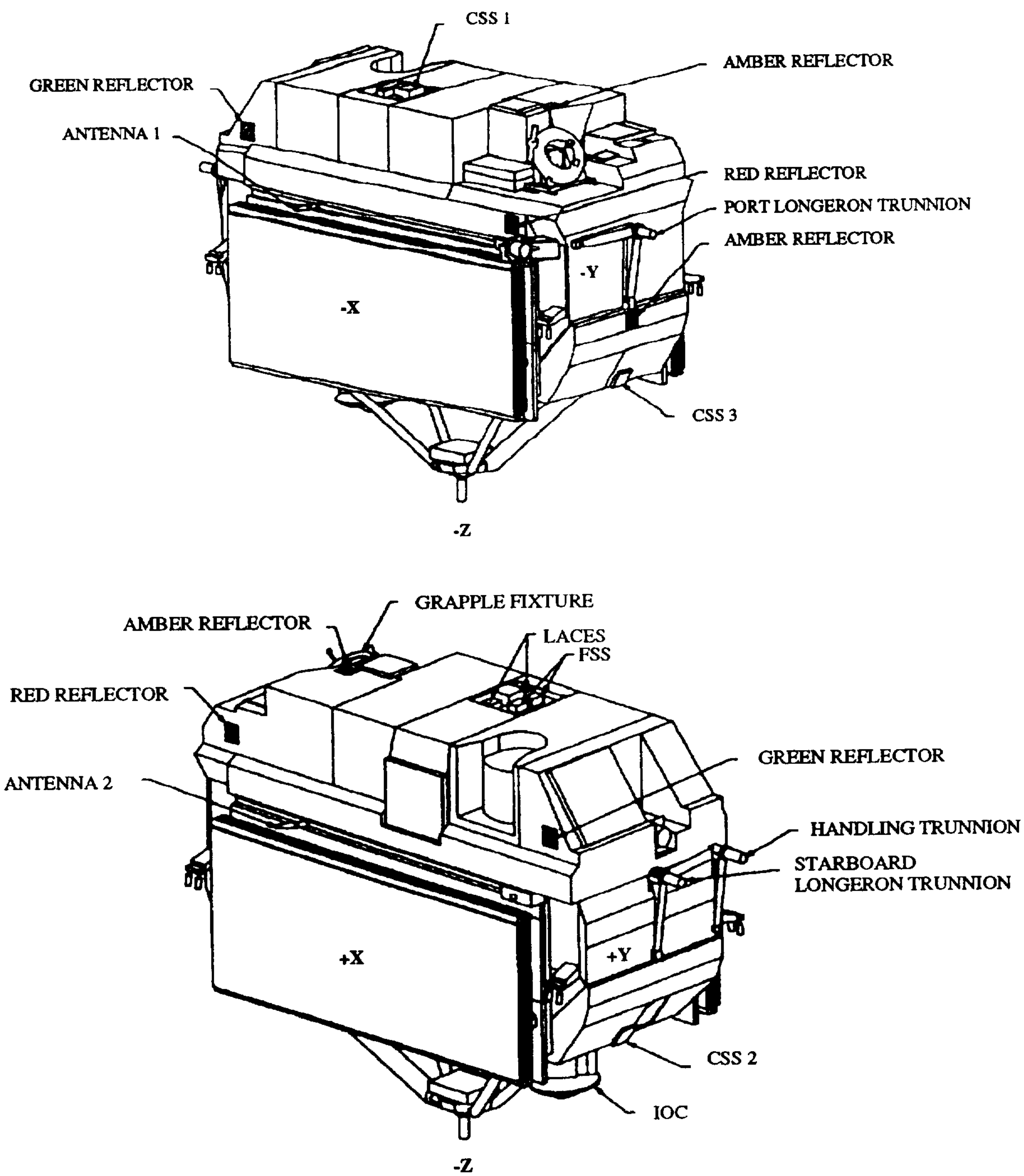
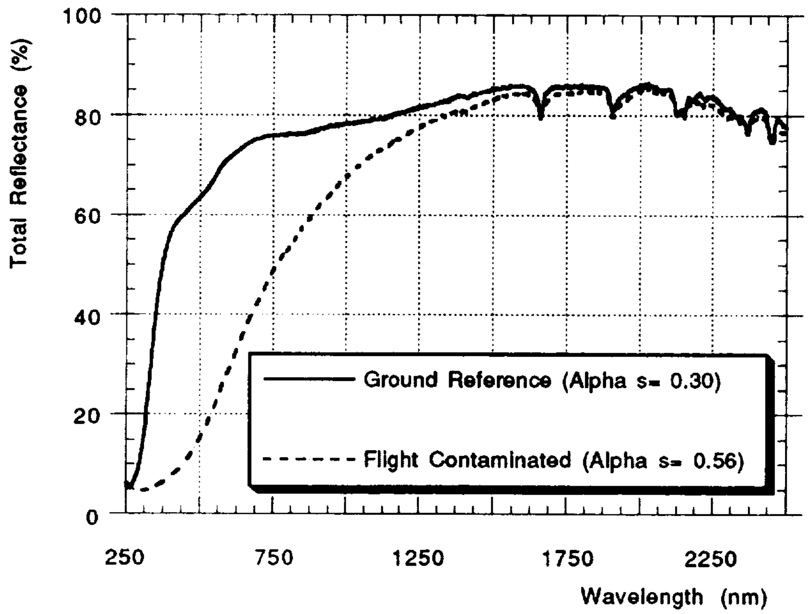


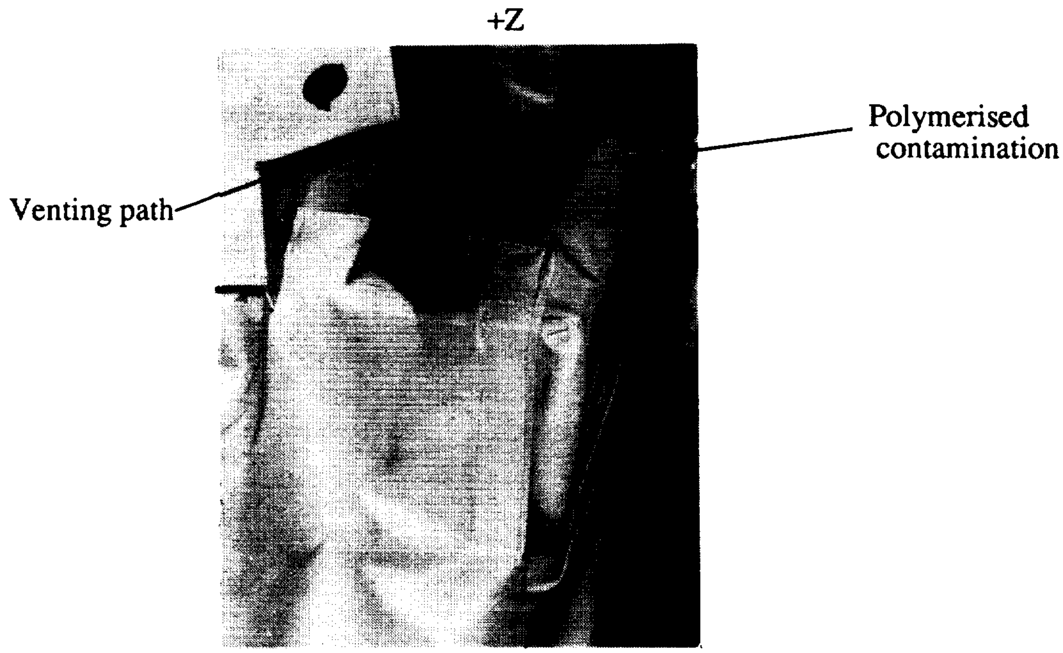
Fig. 1.
Schematic view of EURECA

Fig. 2 BETA CLOTH

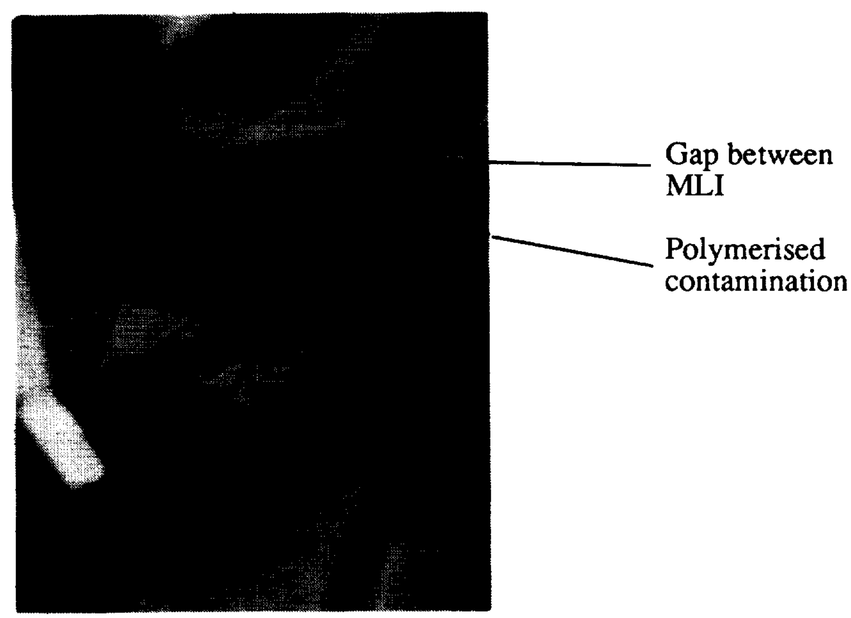


PHOTOGRAPH N° 1. View of AOCS sensor tower showing brown stain in top left-hand corner caused by venting of outgassed materials from within the spacecraft. (NASA photo)

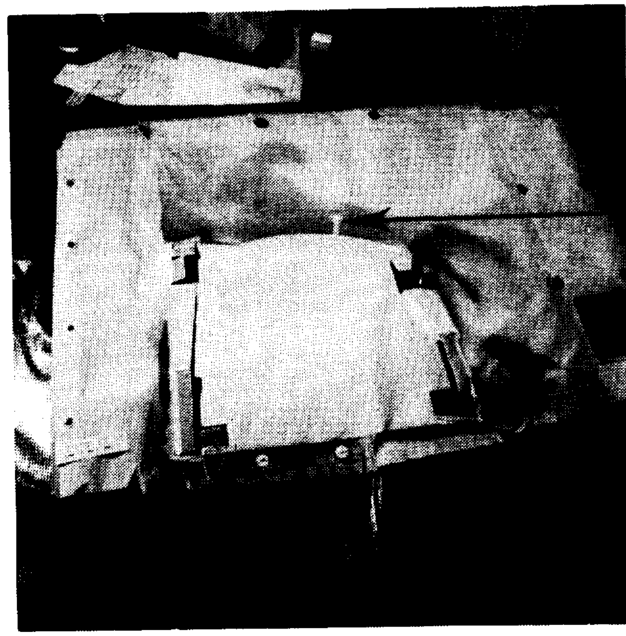
PHOTOGRAPH N° 2. View of venting path between MLI blankets. (NASA photo)



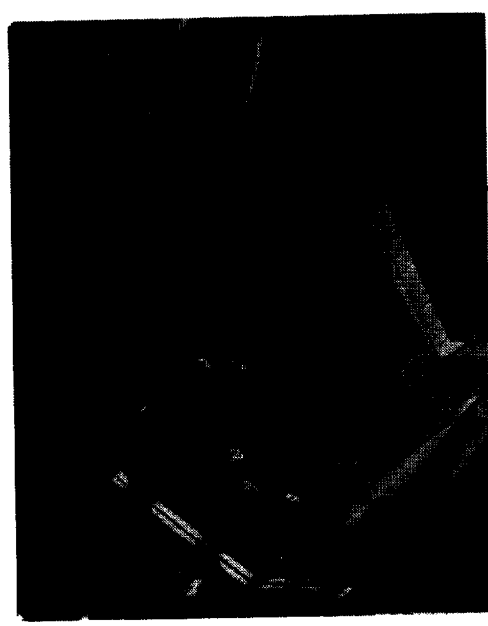
PHOTOGRAPH N° 3. View of brown stain caused by outgassed material being polymerised by UV irradiation after condensing on Beta cloth. (NASA photo)



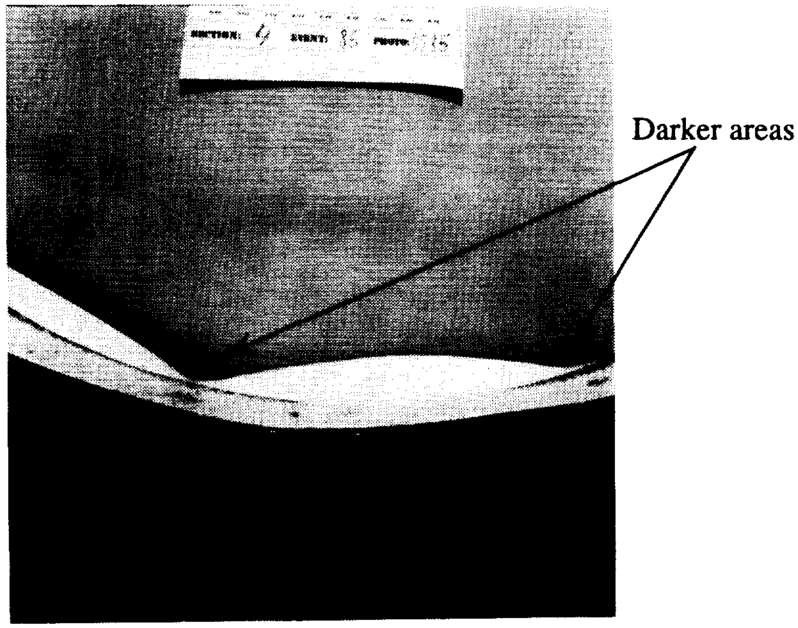
PHOTOGRAPH N° 4. View of brown stain emanating from within the spacecraft. This is typical of the many stains observed around the spacecraft caused by outgassed material venting from between the MLI. (NASA photo)



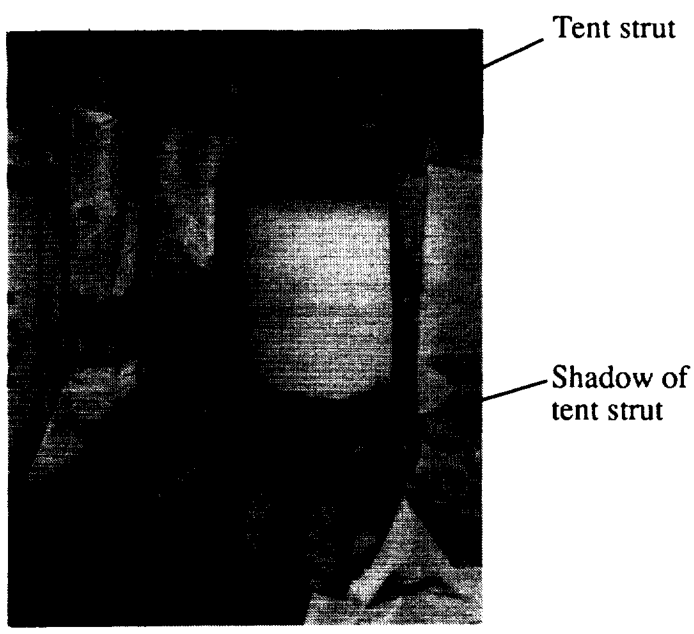
PHOTOGRAPH N° 5. View of UV degradation and outgassed material deposited and polymerised on the MLI surrounding the grapple fixture. Notice the image caused by the shadow of the grapple on the MLI. (DASA ERNO photo)



PHOTOGRAPH N° 6. View of SOVA experiment. Notice the non-homogeneous stains on the aluminised FEP tape due to temperature gradients on the surface at perforations and tape joints. (NASA photo)

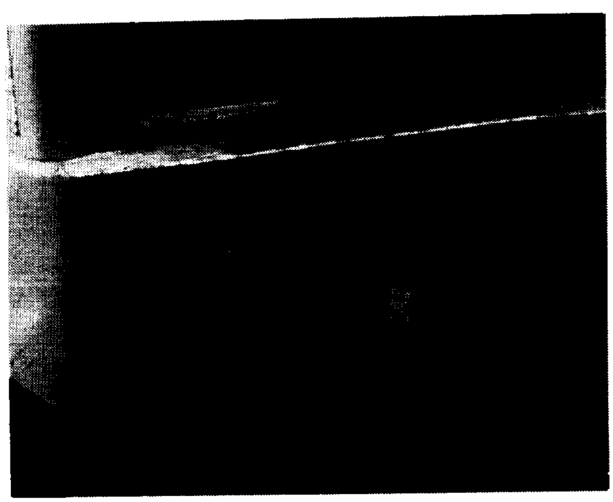


PHOTOGRAPH N° 7. View of UV degradation and outgassed material deposited and polymerised on the interface between the white PSG120FD paint on the PCF dome and the surrounding MLI. Notice darker areas caused by multi reflections in small V-grooves between blanket and dome. (DASA ERNO photo)

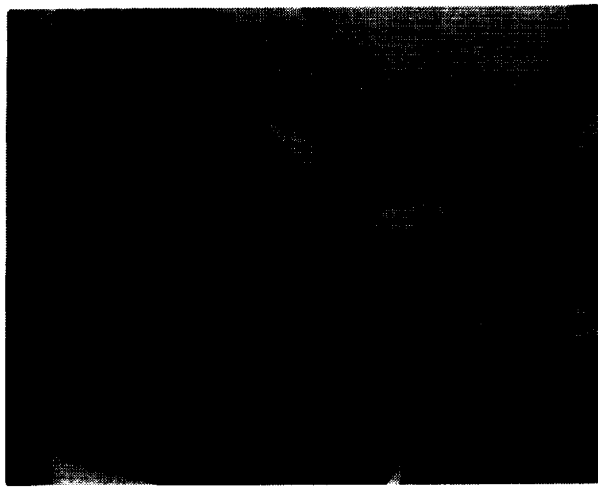


PHOTOGRAPH N° 8. View of PCF dome and the surrounding MLI. Notice the shaded area below the payload tent strut where the Beta cloth is not degraded by UV irradiation or polymerised contaminants. (NASA photo)

PHOTOGRAPH N° 9. View of RITA. Notice gap behind back plate which provides a chimney for outgassed materials to vent from within the spacecraft. (NASA photo)



PHOTOGRAPH N° 10. View of Chemglaze Z853 yellow paint peeling from -Y scuff plate. (NASA photo)



PHOTOGRAPH N° 11. View of outgassed material deposited and polymerised on the Freon pipe MLI. The material has emanated from the gap between the MLI blankets directly above the pipe. (NASA photo)

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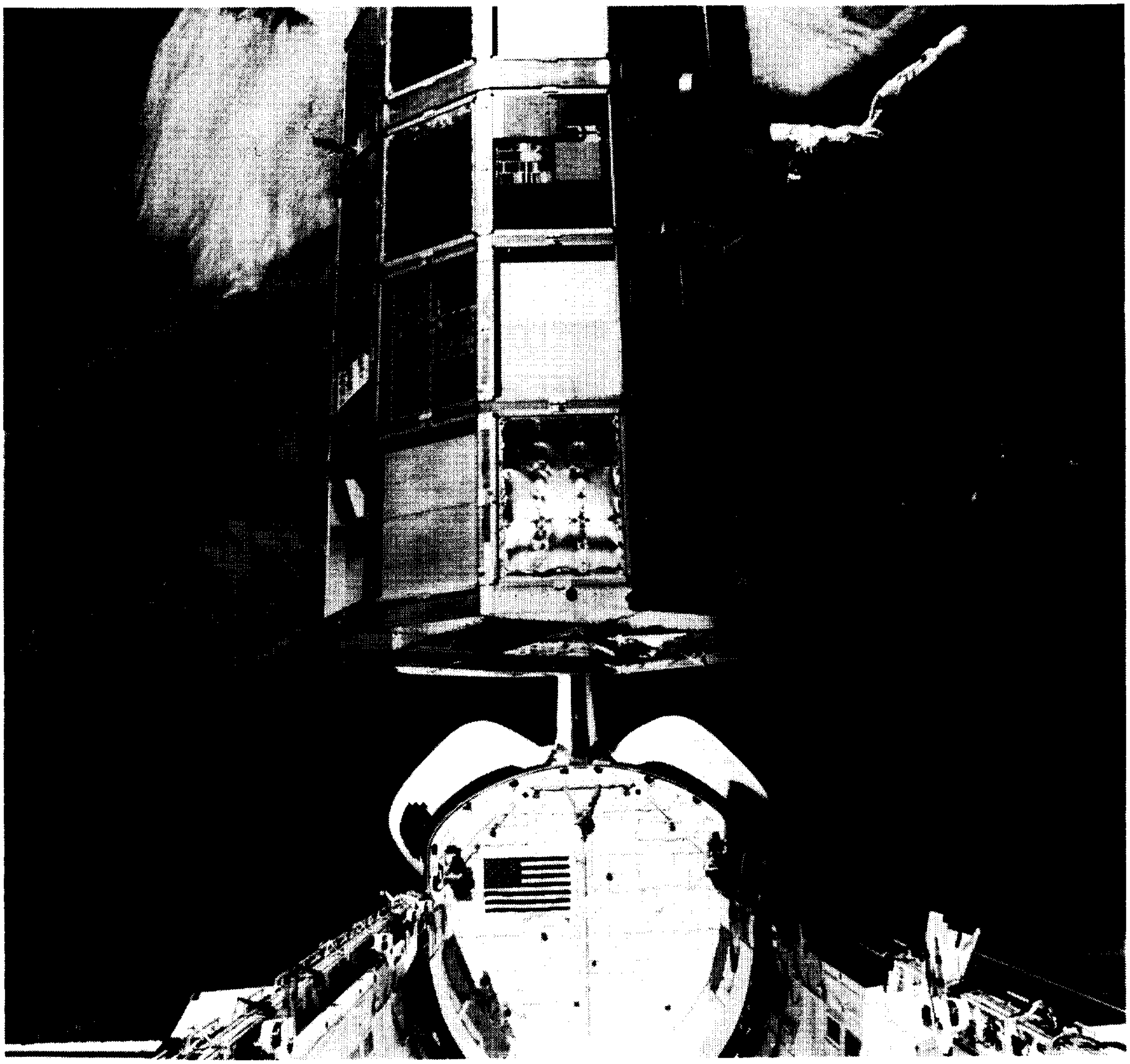

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