

NEW RESULTS FROM FRECOPA ANALYSIS

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SUMMARY

This paper discusses new results from the ongoing analysis of the FRECOPA's (FRench COoperative PASSive payload) system hardware. FRECOPA (AO138) was one of the 57 experiments flown on the LDEF satellite. The experiment was located on the trailing edge (Tray B3) and was exposed to UV radiation (11,100 equivalent sun hours), \approx 34,000 thermal cycles, higher vacuum levels than the leading edge, a low atomic oxygen flux and minor doses of protons and electrons. Due to LDEF's extended mission (5.8 years), CNES decided to set up a team to analyse the FRECOPA system. Initial results were presented at the First Post-Retrieval Conference, June, 1991. This paper summarizes the results obtained since then.

INTRODUCTION

The first subject of our analysis is the study of the kinematic system. We observed damage on the DELRIN gears and lubricant ageing. The results are based on comparative appraisals between components after flight and those stored on ground in laboratory conditions. We also observed the aluminum surface treatment in the exposed areas and measured the thermo-optical properties changes. We also examined the welds on the FRECOPA structure. The second point is the analyses of shadows observed on the tray including one inside (canister shadow) and three on the back side of the tray (bolt, rivets and wire shadows). We used surface analysis techniques such as X ray, Rutherford Back Scattering (R.B.S.) and Electron Spectroscopy for Chemical Analysis (E.S.C.A.) to determine the origin of contaminations. We worked with the same techniques on the teflon glass fabric and painted areas used on the back side where we observed color changes. Now with all the results stored, we try to give an appraisal on the use of FRECOPA materials in LEO space environment.

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OPENING/CLOSING MECHANISM

It is composed of a stepping motor driving two screw nuts via a double 6-stage reduction set-up. The raising or lowering of the nuts, fixed to the canister, allows the canister to be opened or closed. The figure 1. illustrates a reduction set-up. Note that we alternated gears made of DELRIN and gears made of steel to avoid the risk of micro-welding and to ensure lubrication. Between metal parts (nut, screw), powdered MoS₂ was used as a lubricant. The whole opening mechanism operated correctly before and after the flight. The resistance couple was found to have increased by 50 % but there was still a safety margin of 22.

The motors

Appraisal of the motors (2 flight models and 1 ground model), carried out by the manufacturer, SAGEM, showed slight ageing of the materials - especially the paintwork - and oxidation on the stator of one of the motors. On dismantling, friction corrosion was also observed on the ball bearings. The inside of the motors appeared to be rather dirty but no free particles were found on the flight models.

The general behavior of the motors after use in space was very satisfactory.

The gears, screws and nuts

On all the mechanical parts, steel gears, bronze /Be screws and the steel nuts, no mechanical alterations were noted. On the exposed surface of the nuts, organic contamination had caused yellowing. On the DELRIN gears, however, all the parts exposed to UV radiation were discolored. Electron microscopy (as seen in fig. 2) showed extensive ageing of the material. The matrix was cracked and slight erosion was seen in this zone. Similar observations had already been made with other mechanical parts made of DELRIN in the FRECOA experiment.

The use of unprotected DELRIN in precision mechanical assemblies can therefore pose problems in space applications.

MoS₂ lubricant

There was MoS₂, used in powder form, on the screw and on the nut. No quantitative measurement had been made before the flight. Comparison between ground and flight models showed a great decrease of lubricant on the areas exposed to the environment. In the protected areas (nut threads and ball thrust bearing), however, the presence of MoS₂ was still observed.

This type of lubricant should therefore be used with a system of protection from the environment.

Thermal coating

The whole structure of the canisters was treated with black chromic anodizations to maintain thermal equilibrium and protect the metal surface.

All the exposed zones were subject to ageing with a change of colour (black becoming grey) and some areas were cracked.

In the places where the gears had acted as screens, their shadows were left on the underlying structure (as seen in fig. 3).

Fine measurements carried out in these zones to determine the alteration of the thermo-optical properties did not show significant variations.

The thermal coating showed signs of ageing; its use in long-term missions should be considered in relation to its exposure.

TIG welding

The structure carrying the boxes was welded using a TIG process (Tungsten Inert Gas).

Inspection of the welds showed one small corrosion spot which was attributed to insufficient rinsing after dye checking before flight.

We also observed a small crack attributed to ageing of the weld.

We concluded that these welded assemblies present good mechanical properties without alterations attributable to the space environment.

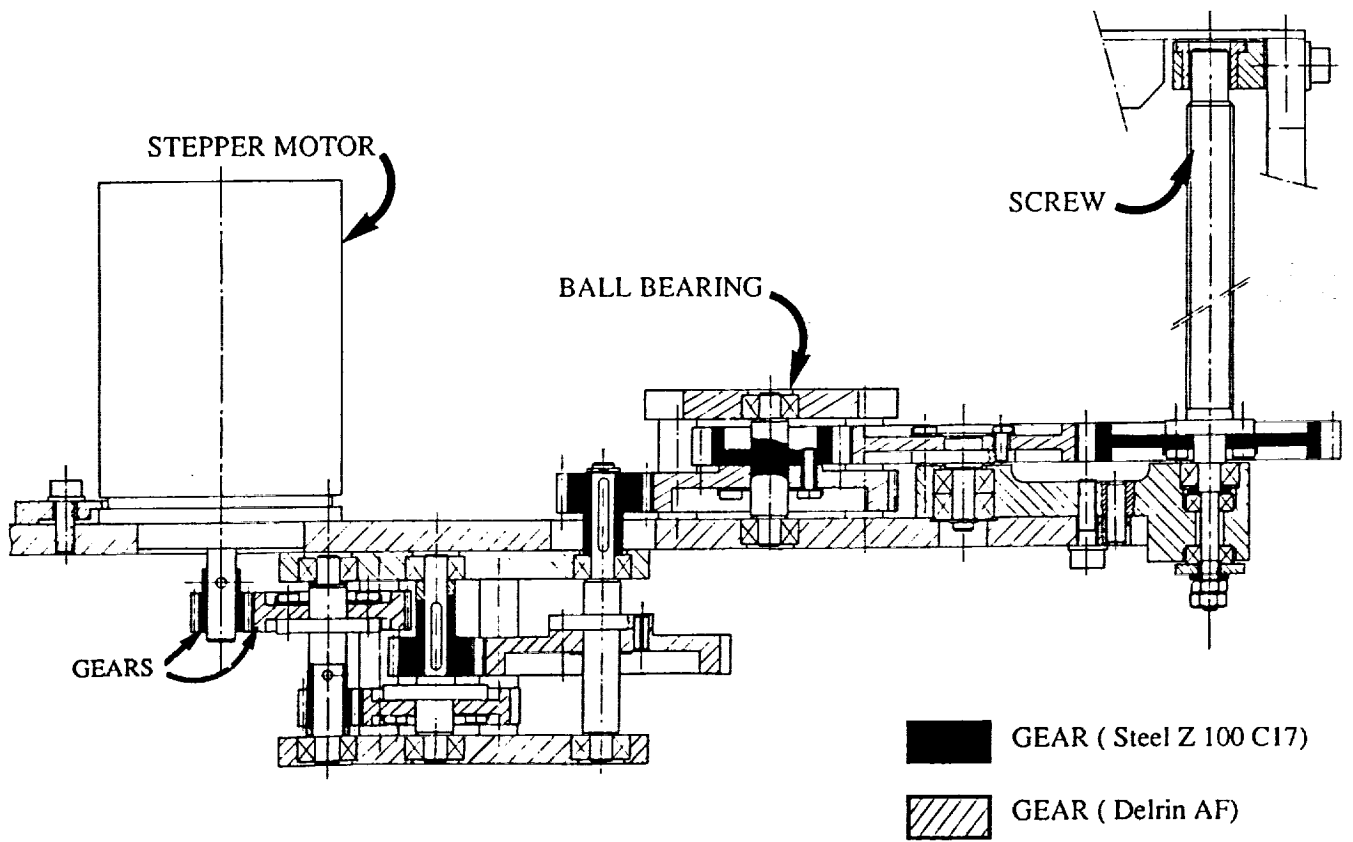
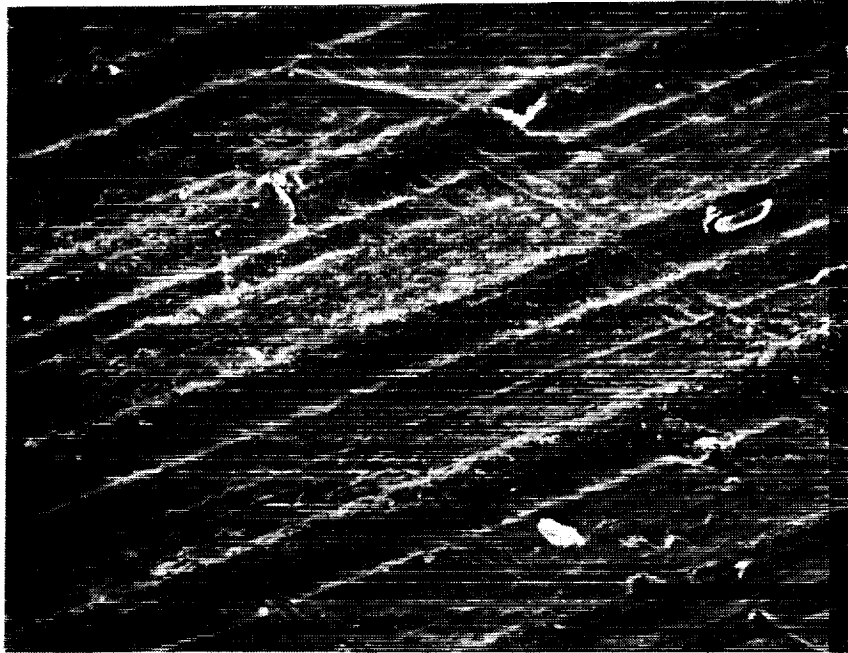
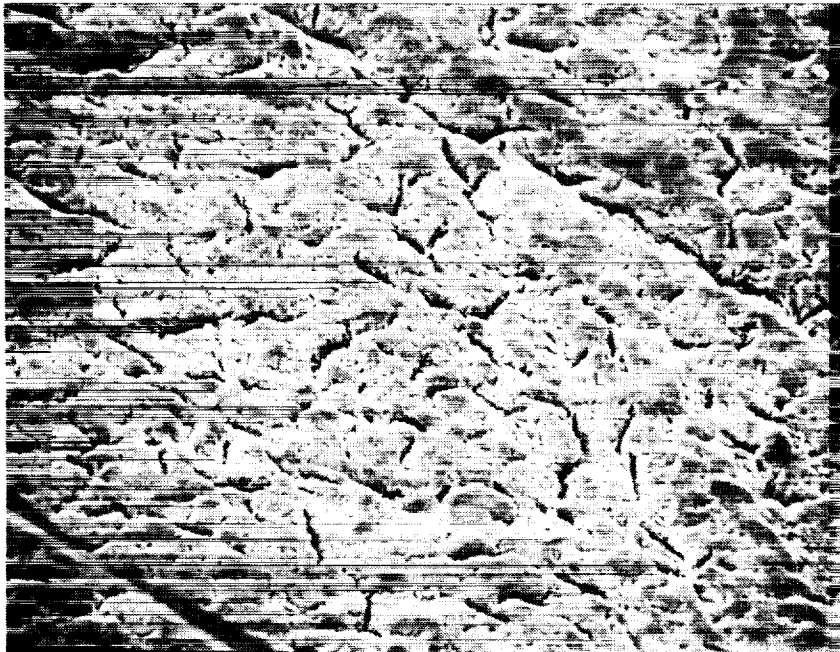


Figure 1. Kinematic reduction mechanism



100 μm

Reference sample



Flight sample

Figure 2. Delrin gears, SEM observations

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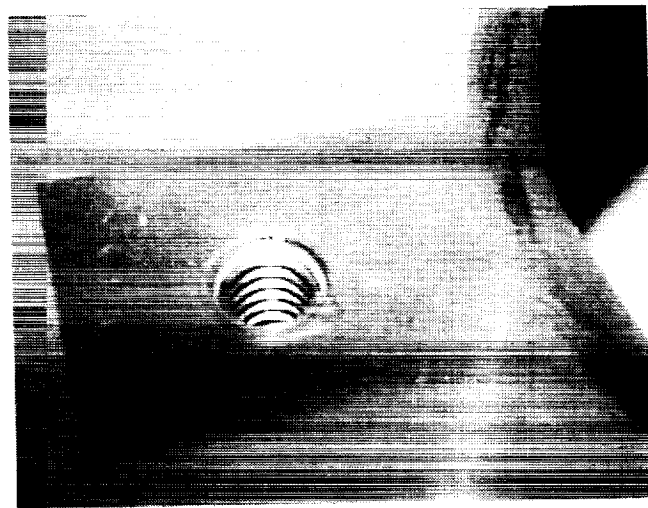
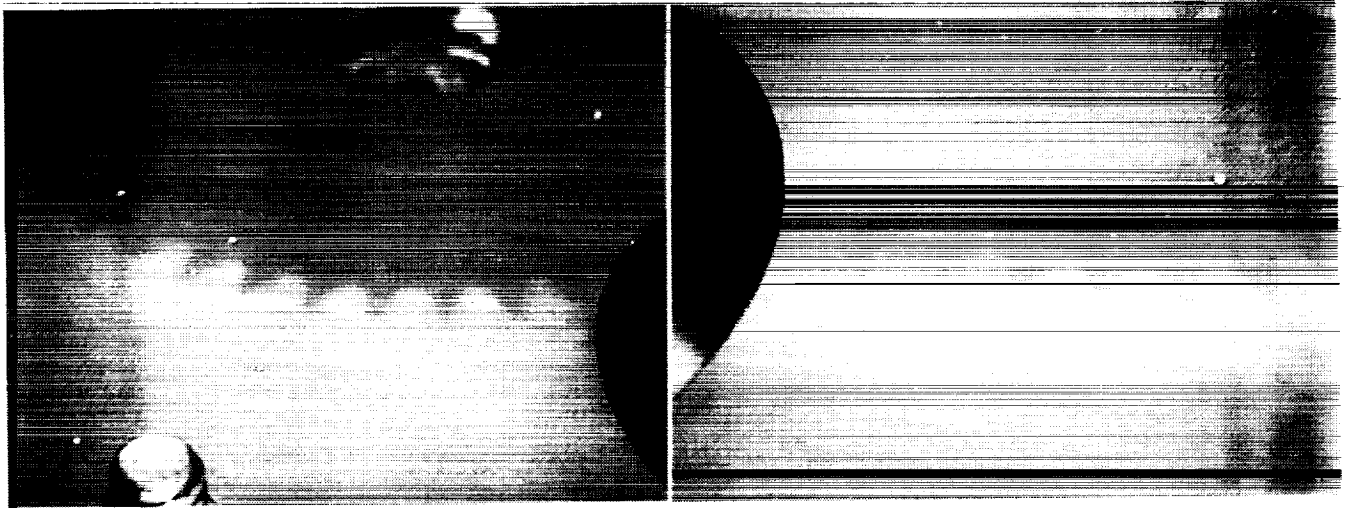


Figure 3. Gears and motor hold-down clip shadows on the main structure

FRECOPA SUPPORT STRUCTURE CONTAMINATION

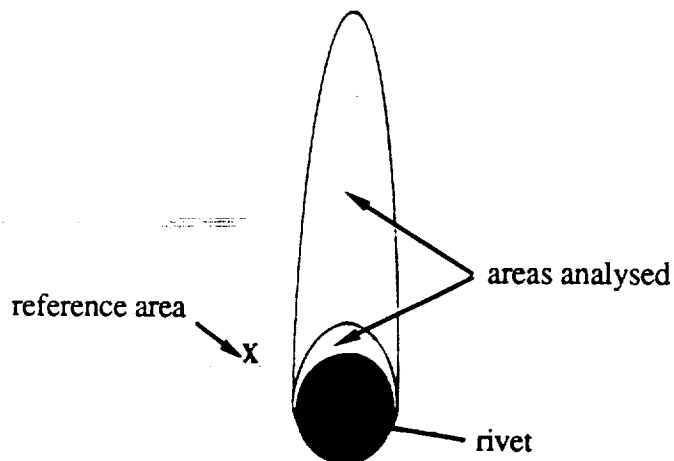
We observed numerous shadows caused by contamination deposited on the FRECOPA support structure. They were noted inside the structure as well as on the back surface which was protected from the direct environment. To study this problem, we used three complementary techniques for surface analysis : SEM (Scanning Electron Microscopy), RBS and ESCA. We also carried out thermo-optical measurements to study the influence of the layers of contaminants. Our aim was to gain a better understanding of the process, to determine the origin and the direction of the fluxes and, if possible, the materials responsible. Three zones were analyzed :

- the internal aluminum surface of the support where the shadow of one of the canisters was visible. This contamination was on just one of the sides and originated from outgassing of the organic materials present on the satellite, then condensing of the residues uniformly on all the cold parts during the night. At sunrise, under the effect of UV irradiation, the condensation is polymerized on the side that is lit up most rapidly. On the other, which warms up more slowly, it has the time to evaporate. As the canister acts as a screen, its shadow remains projected on the surface. The sample was taken from the exposed/contaminated zone. As reference, we sampled a zone protected from the direct environment.

- on the back surface, we took samples on the four thermal blankets protecting the inside of FRECOPA. They were made from PTFE-treated glass fabric with a layer of aluminized Mylar painted black on the surface analyzed. For this material, the reference was blankets which had remained in storage on the ground. Contamination was observed in the form of unequally distributed iridescence. Samples were taken from these areas.

On the structure, other samples analyzed concerned surfaces exposed to varying contaminant fluxes. Other zones (shadows of bolts and electric wires, as seen in fig. 4.) with difficult access presented the same signs of contamination.

- our third task was to analyse the multiple shadows around the rivets on the outer surface of the support (as seen in fig 5.). The reference zone was out of the shadows, the contaminated zone was inside the shadow or shadows (see figure below).



The various surfaces concerned are indicated in the figure 6.

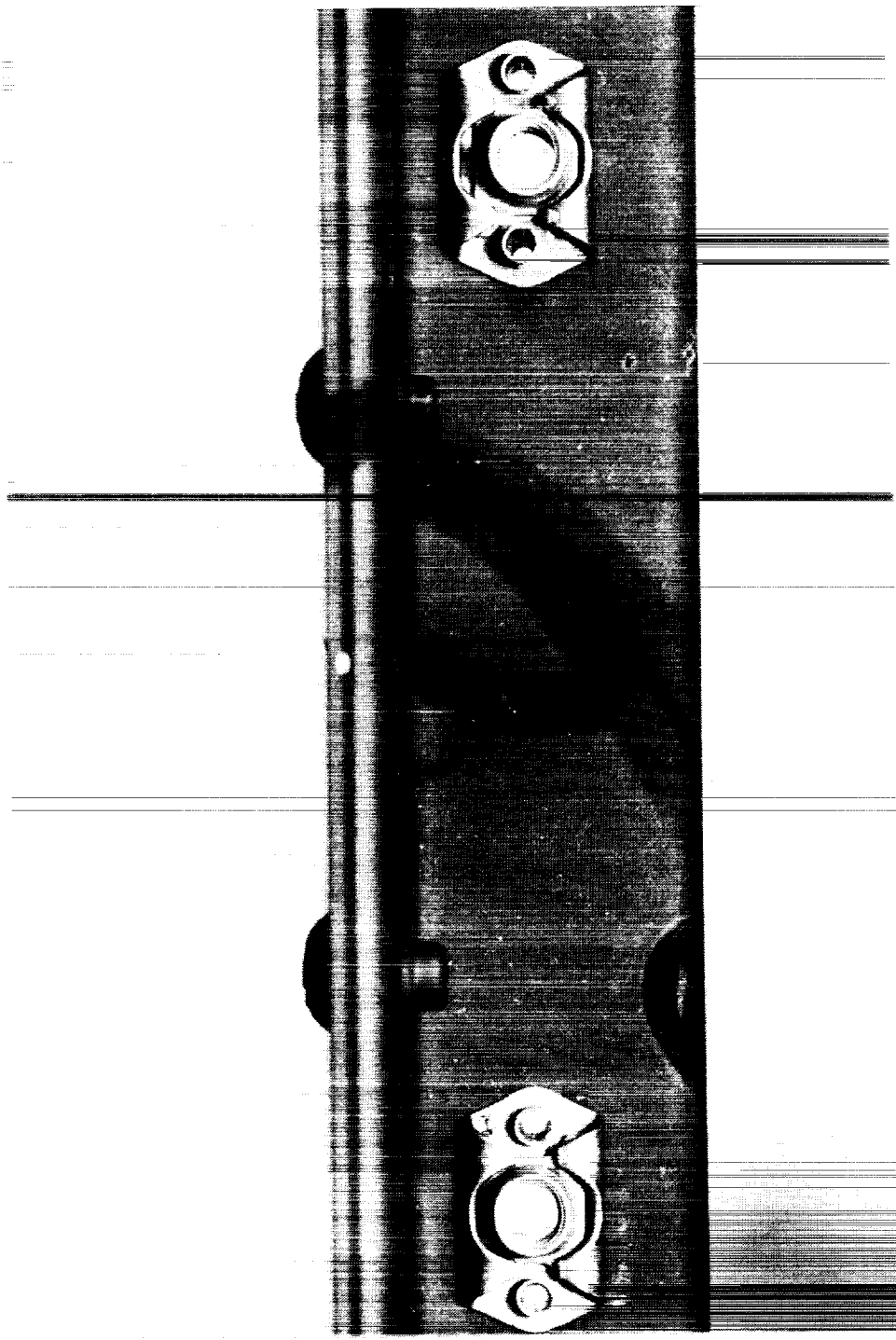


Figure 4. Bolt and wire shadows on the back face of the tray

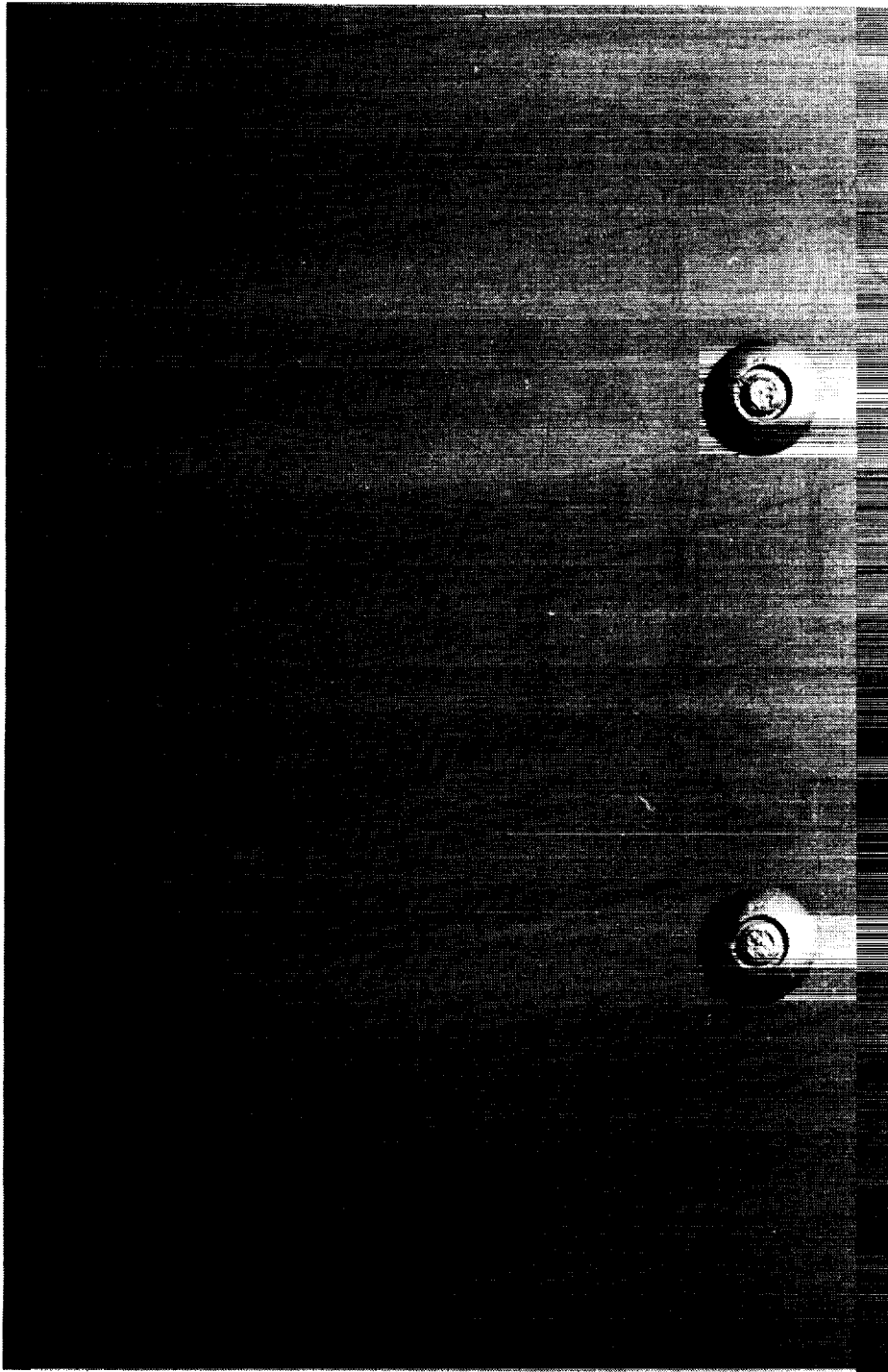


Figure 5. Rivets shadows on the lateral sides of the tray

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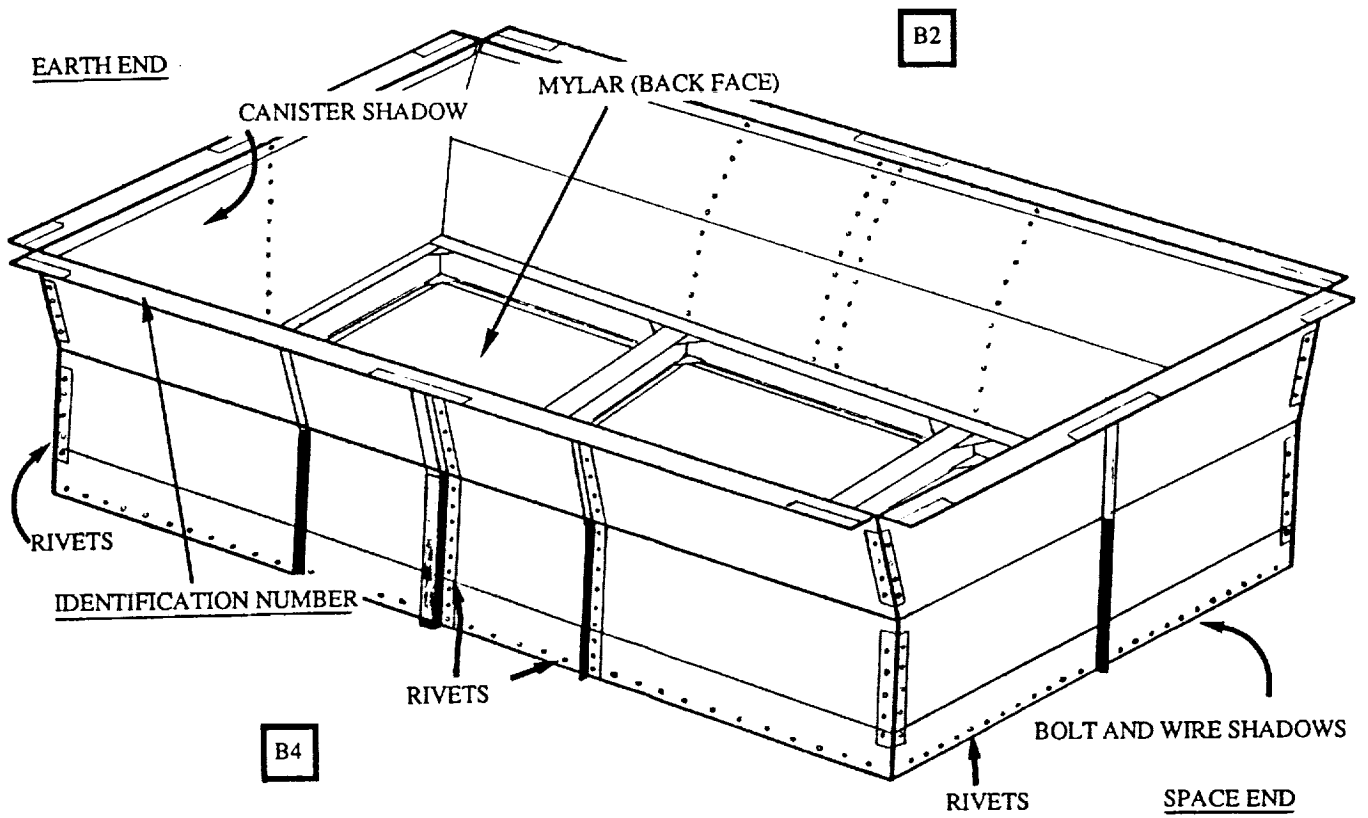


Figure 6. Areas analysed on the tray

The contaminations results are summarized in the table in figure 7. The following conclusions can be drawn from the table :

- very slight changes in thermo-optical properties. The only notable change is a 9 % increase in the solar absorptance value of aluminum.
- SEM gave very few results, probably owing to too great a thickness being analyzed.
- RBS gave some interesting informations :
 - . the Mylar was contaminated with a layer of SiO₂ and metallic elements (Ag, In)
 - . No change for yellowed aluminum.
 - . Presence of SiO₂ and heavy elements (Cu, Ag, In) on the light part of the right-angled bracket.
 - . Rivets: contamination with a layer of SiO₂ around the shadows (20 Å) and on the large dark area (30 Å) but no SiO₂ was detected on the white zone.
- ESCA gave certain additional informations :
 - . On the Mylar, there were two types of contamination : SiO₂ and CO or CO₂.
 - . For the yellowed aluminum : layer of SiO₂ with Ag underneath.
 - . Bracket: the whole bracket must have been contaminated by SiO₂.

Note should be made of the direction of contaminant flux visible around the rivets.

Multiple shadows indicate fluxes from several directions (as seen in fig 8.). The direction is from the inside of the LDEF towards space. We measured the variation of the rivet shadow angle on three of the surfaces of the support; on the fourth, this was impracticable (as seen in fig 9. for Earth and space end). The variations seem to indicate one or two sources of flux. A scale drawing (as seen in fig 10. for the space end) indicates the origin of the fluxes to be the inter-plate gaps (as seen in fig 11.) which must have let through atomic oxygen and UV radiation, which were able to react with the materials (silicone paint) present inside the satellite and/or draw in contaminants. The processes of material degradation and the chemical reactions are probably at the origin of the differences of thickness measured for the contaminants (SiO₂).

These results demonstrate that the problem of contamination can be more important than expected and that numerous contaminants can be found even inside the satellite, which would be very prejudicial for optics and for sensitive mechanisms.

CONCLUSIONS

In spite of the satisfactory operation of the FRECOPA experiment, our post-flight appraisals showed ageing of the organic materials, essentially under the action of UV radiation in our case. We noted erosion, discoloration and increased fragility calling into question the use of these materials unprotected. Moreover, their outgassing causes heavy contamination.

The findings also pose the problem of outgassing tests on the ground which seem, for the moment, to be insufficient to model the complex synergistics of the parameters of a space environment.

The behavior of metals appears to be satisfactory once problems of lubrication and micro-welding have been taken into account. The welded assemblies were totally satisfactory.

| | SITUATION | α / ε | X | R.B.S. | E.S.C.A. |
|-----------------------------------|------------------------------|--------------------------|-------------------------------------|---|---|
| Mylar (Ref) | Back Face | 0.98 / 0.92 | C,O,Si | C,O,Si,Ca | C (49%) O (23%) Si (28%) |
| Mylar (Flight) | Back Face | 0.98 / 0.92 | C,O,Si Na,Mg,Al S,P | C,O,Si,Ca P,Ge,Ag,In SiO ₂ | C 22%,O 50% Si 28%,S,N ----> SiO ₂ |
| Al (Ref) | Inside Tray | 0.47 / 0.186 | C,O,Na,Mg Al,Si,S,Cl,Cr Fe,Cu | Al,O,S,Ca,V Cr,Fe Al ₂ O ₃ | C,O,S,Al,Na Si after scouring |
| Al (yellow) | Inside Tray | 0.51 / 0.178 | C,O,Na,Mg Al,Si,S,Cl,Cr Fe,Cu | Al,O,S,Ca,V Cr,Fe Al ₂ O ₃ | C,O,S,Al,Na Si ----> SiO ₂ |
| right angle bracket (light) | Lower part of the tray | / | / | C,N,O,Si,Fe S,Ca,Cu,Ag,In SiO ₂ | C,N,O Si,S |
| right angle bracket (dark) | Lower part of the tray | / | / | C,N,O,Si,Fe S,Ca | C,N,O Si,S |
| Rivets | Sides | / | / | C,N,O,Si,Fe S,Ca,Cu,Ag,In SiO ₂ except light zone | / |

Figure 7. Surface analysis results



Figure 8. Fluxes directions

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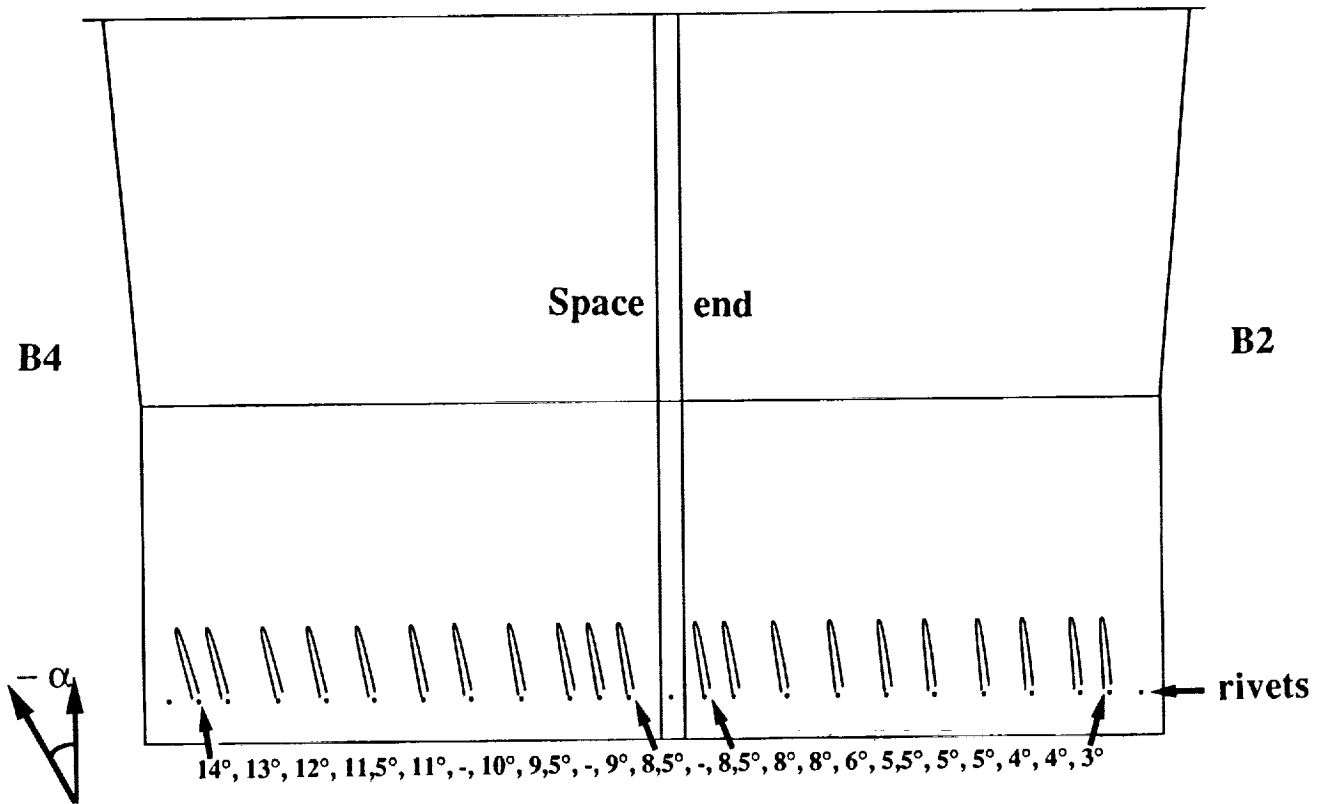
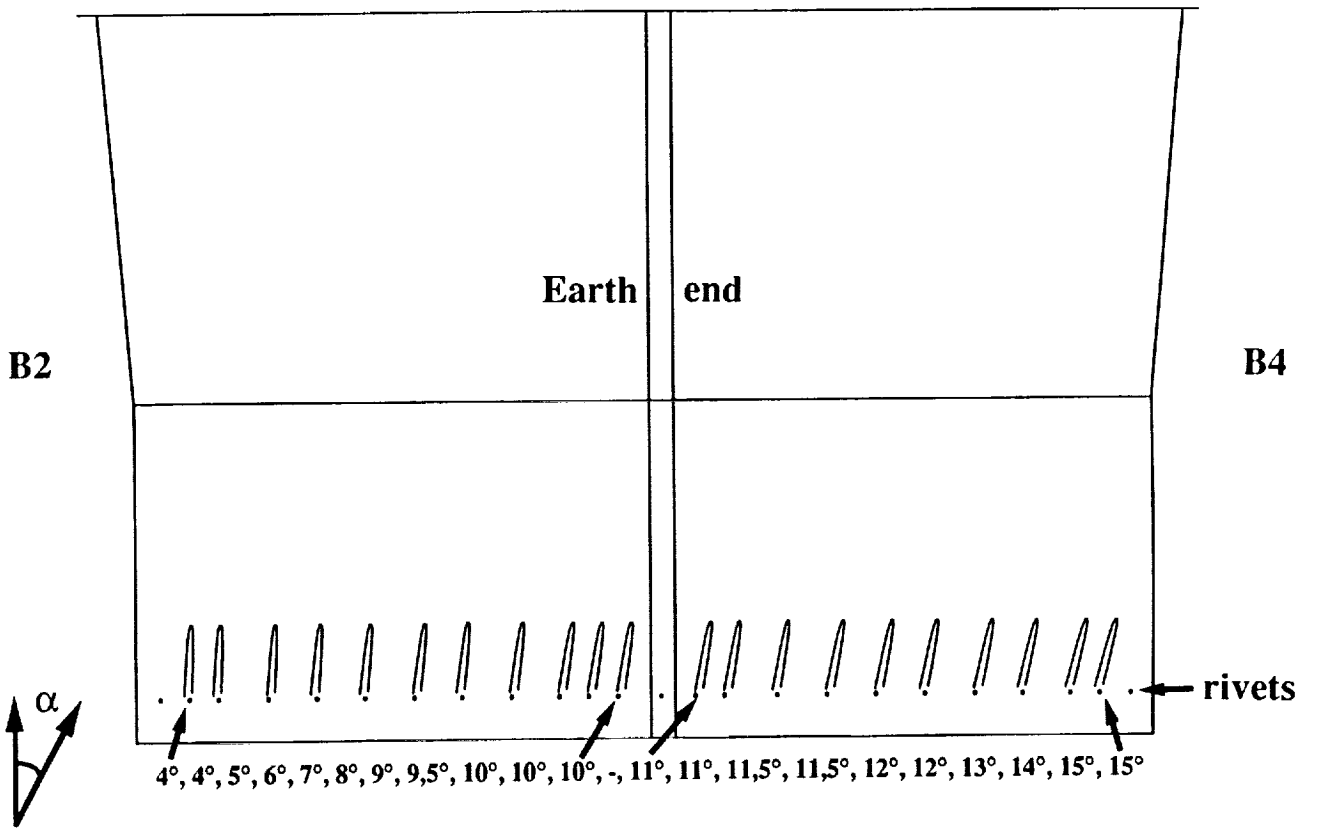


Figure 9. Angle measurements on rivets shadows

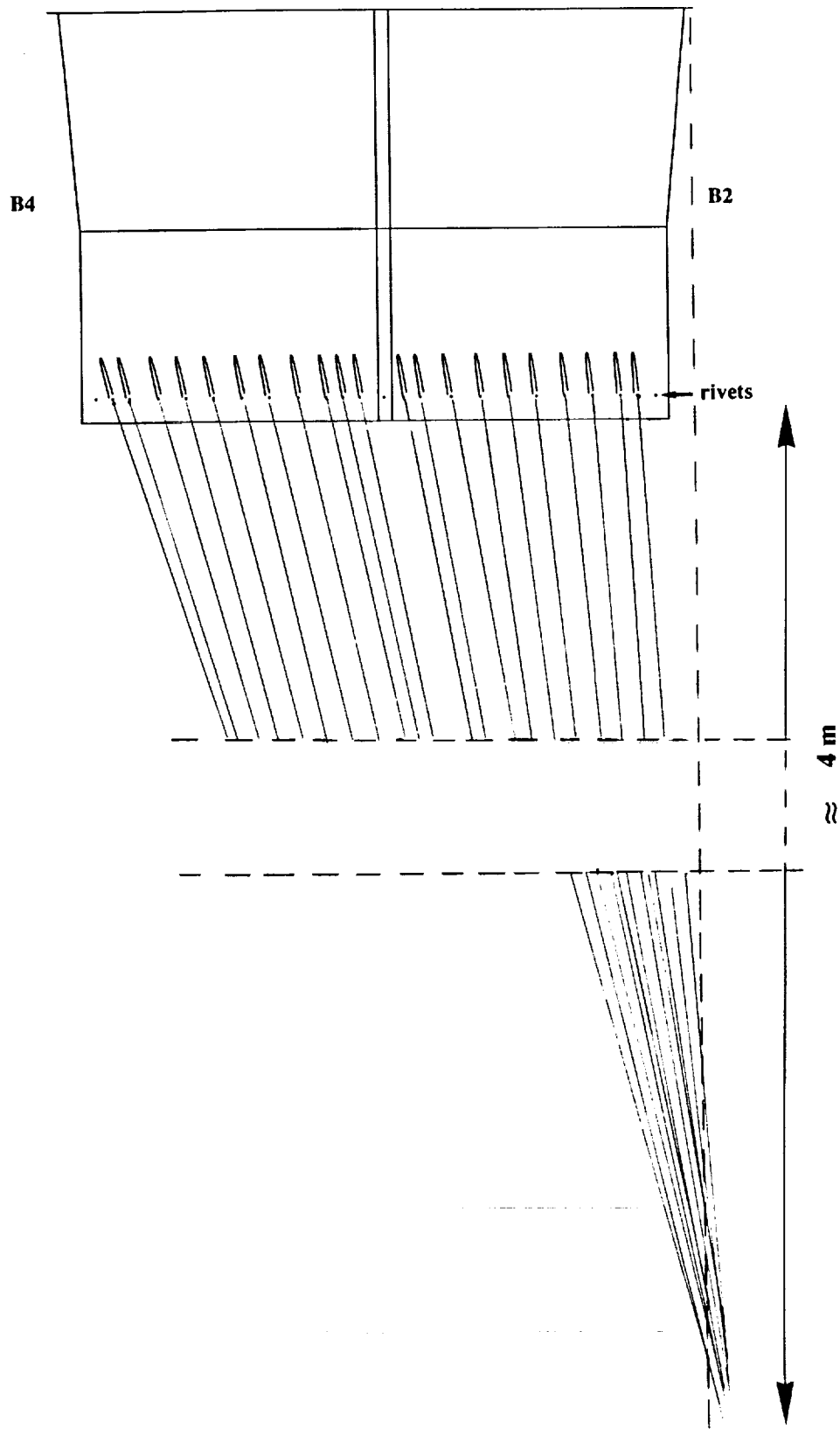


Figure 10. Origin of contamination flux (space end)



Figure 11. Gaps inter-trays on LDEF

(NASA photo)

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