N93-12789

LONG DURATION EXPOSURE FACILITY
M0003-5
RECENT RESULTS ON POLYMERIC FILMS

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INTRODUCTION

The M0003-5 polymeric film specimens orbited on the LDEF M0003 Space Environment Effects on Spacecraft Materials were a part of a Wright Laboratories Materials Directorate larger thermal control materials experiment. They were selected from new materials which emerged from development programs during the 1978-1982 time frame. Included were materials described in the technical literature which were being considered or had been applied to satellites. Materials that had been exposed on previous satellite materials experiments were also included to provide data correlation with earlier space flight experiments. The objective was to determine the effects of the LDEF environment on the physical and optical properties of polymeric thin film thermal control materials, the interaction of the LDEF environment with silvered spacecraft surfaces and the performance of low outgassing adhesives. Sixteen combinations of various polymeric films, metallized and unmetallized, adhesively bonded and unbonded films were orbited on LDEF in the M0003-5 experiment. The films were exposed in two separate locations on the vehicle. One set was exposed on the direct leading edge of the satellite. The other set was exposed on the direct trailing edge of the vehicle.

The purpose of the experiment was to understand the changes in the properties of materials before and after exposure to the space environment and to compare the changes with predictions based on laboratory experiments. The basic approach was to measure the optical and physical properties of materials before and after long-term exposure to a low earth orbital environment comprised of UV, VUV, electrons, protons, atomic oxygen, thermal cycling, vacuum,debris and micrometeoroids. Due to the unanticipated extended orbital flight of LDEF, the polymeric film materials were exposed for a full five years and ten months to the space environment.

LDEF M0003 SUB-EXPERIMENTS

The individual experiments listed below were supplied by the organization named and integrated into the flight hardware trays by Aerospace Corporation. Deintegration was accomplished by the same organization.

#	NAME	ORGANIZATION
1	RADAR CAMOUFLAGE MATERIALS & EO SIGNATURE COATINGS	AVIONICS LAB
2	LASER OPTICS	WEAPONS LAB
3	STRUCTURAL MATERIALS	WEAPONS LAB
4	SOLAR POWER COMPONENTS	PROPULSION LAB
5	THERMAL CONTROL MATERIALS	MATERIALS LAB
6	LASER COMMUNICATION COMPONENTS	SPACE DIVISION/ McD-D ASTRONAUTICS
7	LASER MIRROR COATING	NAVAL WEAPONS CTR
8	COMPOSITE MATERIALS, ELECTRONIC PIECE PARTS, FIBER OPTICS	BOEING AEROSPACE
9	THERMAL CONTROL, ANTENNA, COMPOSITE MATERIALS, COLD WELDING	LOCKHEED MISSILE & SPACE CORP.
10	ADVANCED COMPOSITE MATERIALS	FLIGHT DYNAMICS LAB AEROSPACE CORP.
11	CONTAMINATION MONITORING	AEROSPACE CORP.
12	RADIATION DOSIMETRY	AEROSPACE CORP.
13	LASER HARDENED MATERIALS	McD-D ASTRONAUTICS
14	QUARTZ CRYSTAL MICROBALANCE	BERKLEY INDUSTRY
15	THERMAL CONTROL MATERIALS	AEROSPACE CORP.
16	ADVANCED COMPOSITE MATERIALS	AEROSPACE CORP.
17	RADIATION DOSIMETRY	AEROSPACE CORP.
18	THERMAL CONTROL COATINGS	AEROSPACE CORP.
19	ELECTRONIC DEVICES	AEROSPACE CORP.

LDEF/WL/ML EXPERIMENT
THERMAL CONTROL MATERIALS
M0003-5

THERMAL CONTROL MATERIALS

A Series	
Pigmented Coatings	44
Metallized Polymer Films	28
Quartz Fabrics	8
B Series	
Optical Solar Reflectors (second surface)	8
Gold Mirrors (first surface)	4
Silver Mirrors (first surface)	6
Aluminum Mirrors (first surface)	4
C Series	
Metallized Polymeric Films	8
Metallized Bonded Films	14
Clear Films	10
Total	134

LDEF IN THE ORBITER PROCESSING FACILITY

Fifty seven experiments were placed in a low earth orbit aboard LDEF on April 7, 1984 for a planned one year mission.The LDEF vehicle was recovered on January 12, 1990 from a degrading orbit by the Space Shuttle Columbia. After a landing at Edwards Air Force Base, California, the Space Shuttle, with LDEF still contained inside, was transported to Kennedy Space Center, Florida. LDEF was removed from the shuttle bay in the Orbiter Processing Facility (OPF) in late January 1990.

The photograph shown in figure 1 shows the extensive damage done to some experiments on the leading edge side and the space end of the vehicle.The M0003 experiment is located near the center of the vehicle at the scuff plate.

Figure 1. LDEF in Orbiter Processing Facility

LDEF in SAEF II

After completion of activities in the Orbiter Processing Facility, LDEF was transported to the Spacecraft Assembly and Experiment Facility II (SAEFII). This facility provided a controlled, clean working environment for the principal investigators and other observers to examine the various experiments. The photograph shown in figure 2 shows only a portion of the leading edge side of LDEF. The M0003 experiment is located to the far left of the photograph near the scuff plate.

Figure 2. LDEF in SAEF II

M0003-5 LEADING EDGE EXPERIMENT

The M0003-5 experiment was located in a 3 " deep leading edge tray designated as D9. It contained a variety of thermal control pigmented coatings, metallized polymer films, clear films and mirrors. The photograph in figure 3 shows the preflight layout of the materials. The polymer films are the horizontal strips shown in the upper left portion of the mounting hardware.

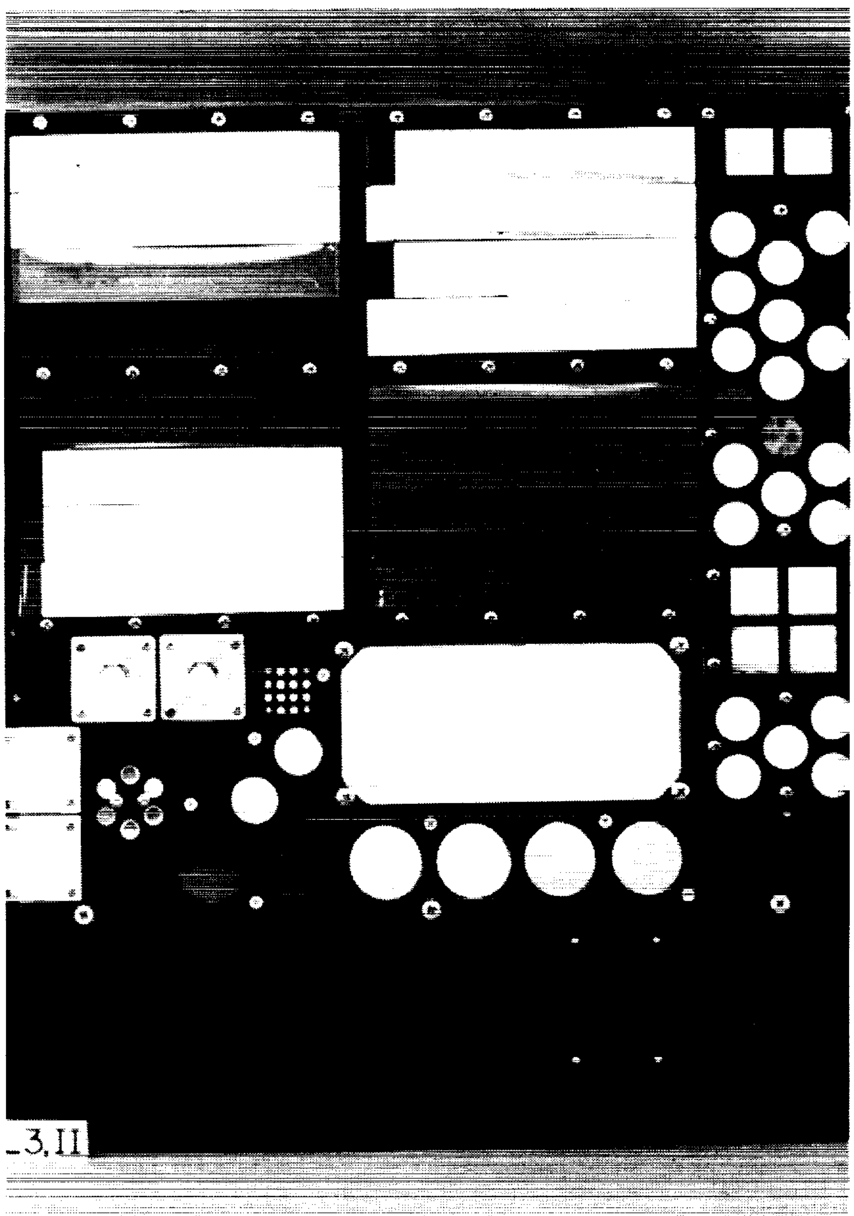

Figure 3. M0003-5 Pre flight Leading Edge Tray Experiment

RECOVERED LEADING EDGE M0003 TRAY

A photograph of the recovered M0003 leading edge tray originally located in the D9 position is shown in figure 4. Among the various areas of visible damage, note the condition of the polymeric films portion of the M0003-5 experiment located in the lower left quadrant of the tray. Physical damage, discoloration and bonding separation and tearing has occurred. Atomic oxygen probably caused the physical damage, radiation caused the discoloration and the debonding probably occurred as a result of thermal cycling.

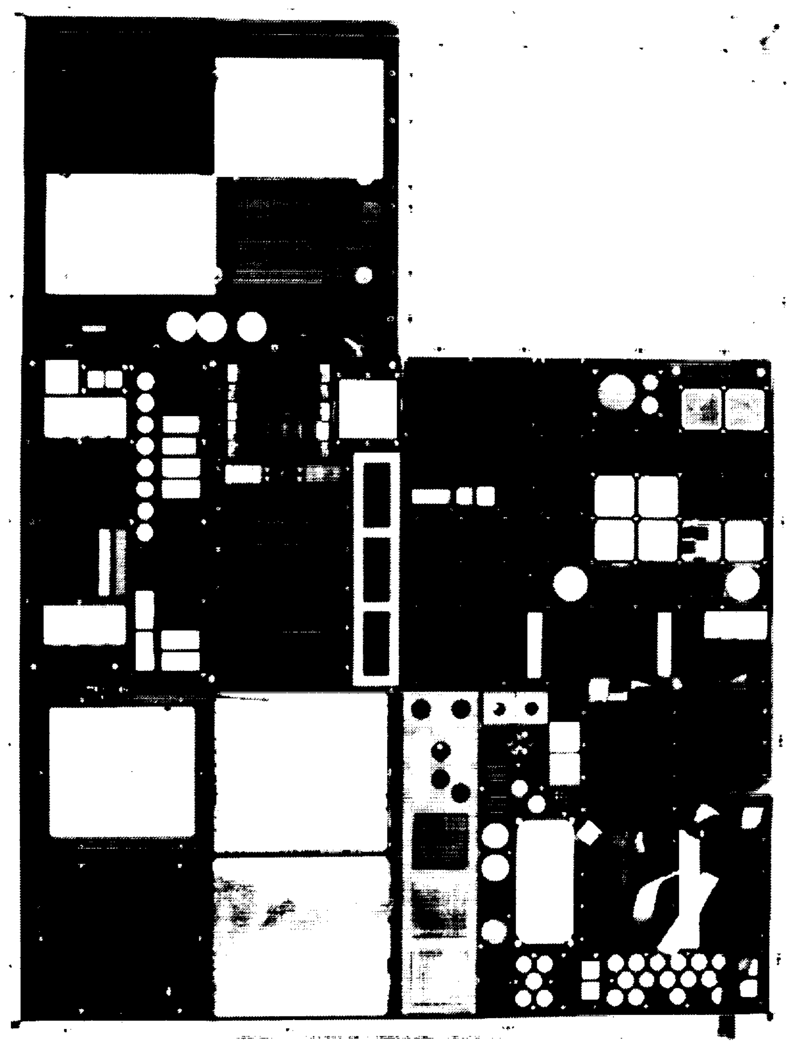

Figure 4. M0003 Post Flight Leading Edge Tray

LDEF/M0003 IN SAEF II

The photograph in figure 5 shows the M0003 experiment and the surrounding trays on LDEF in SAEF II. Note the extensive damage to the experiment located in tray D10 immediately above the D9 M0003 experiment tray. Also observe the serious damage that occurred to the M0003-1 experiment located in the lower right quadrant of the M0003 tray. Damage is also evident to the M0003-5 polymer film materials.

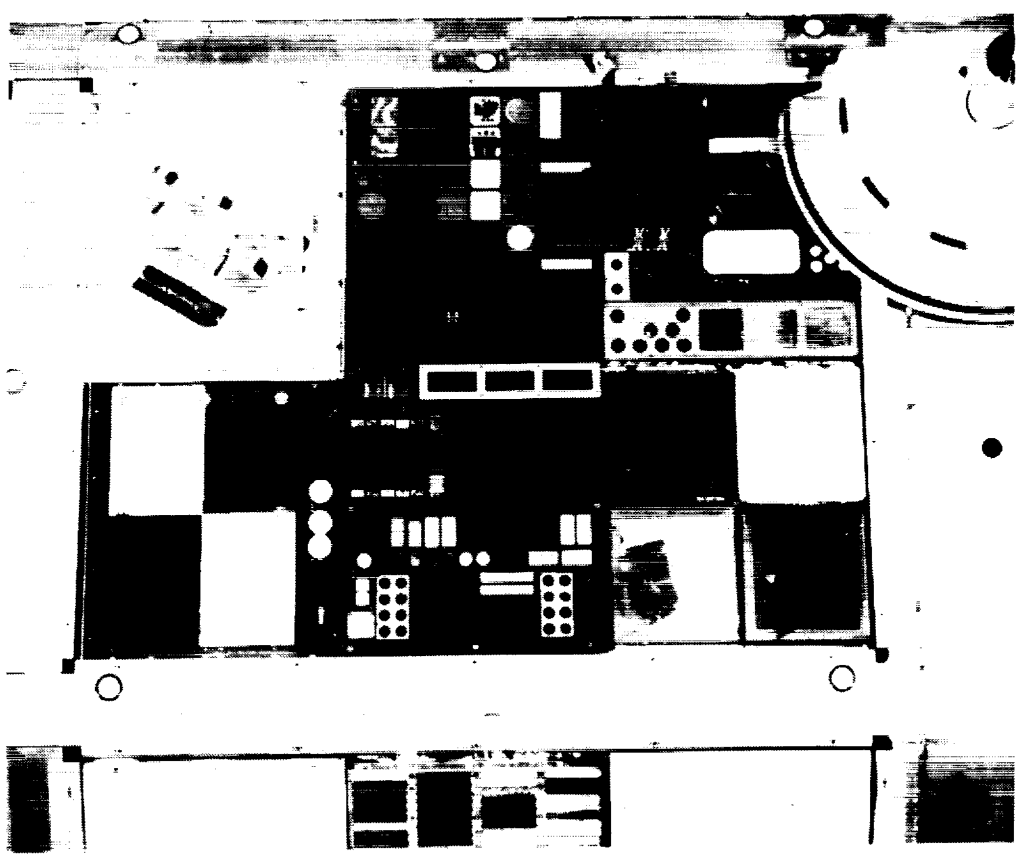

Figure 5. LDEF/M0003 IN SAEF II

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

M0003-5 POST FLIGHT LEADING EDGE TRAY CLOSEUP

The photograph in figure 6 below shows a closeup of the M0003-5 experiment materials. Note the extensive damage to the polymeric film strips. There is obvious physical damage, discoloration and debonding and tearing of the polymer film materials. There is apparent scarring due to probable AO impingement deflected from the scuff plate. Most of the intact films on the leading edge were partially covered by the scuff plate.

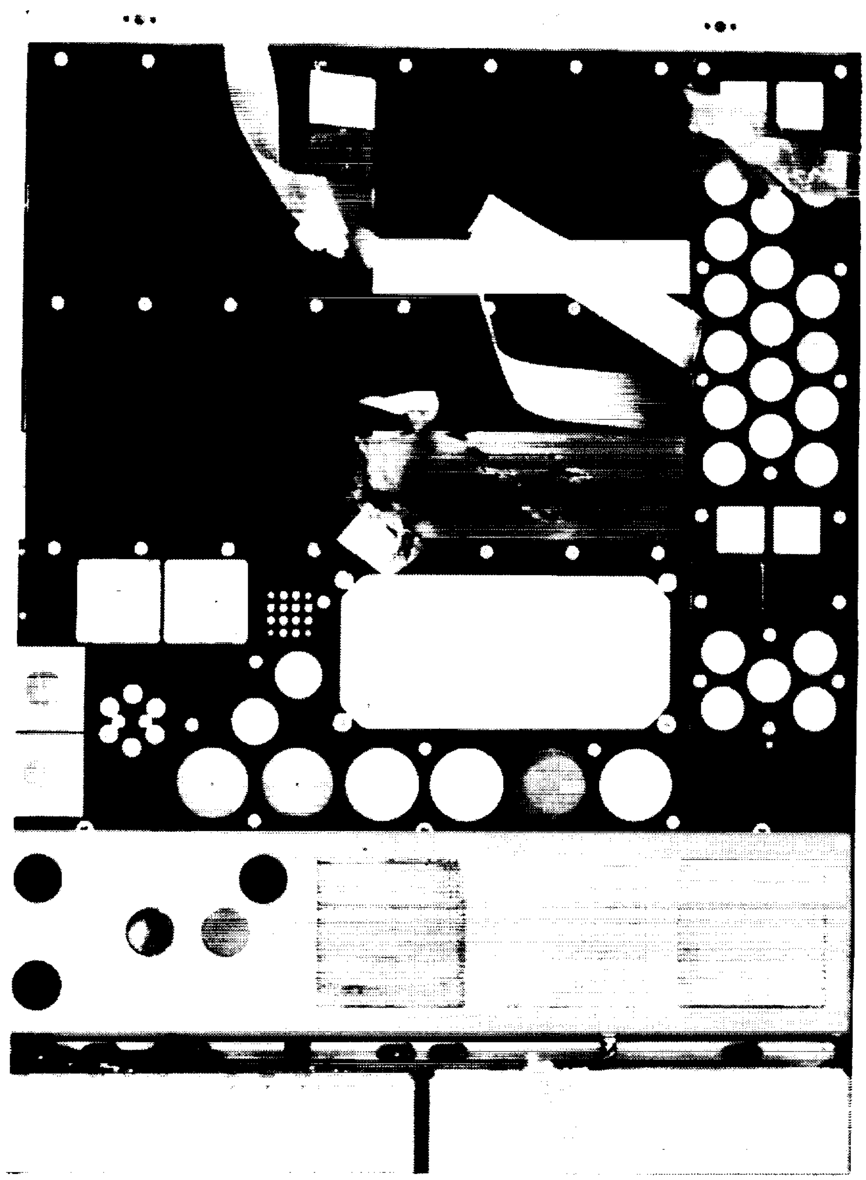

Figure 6. M0003-5 Post Flight Leading Edge Tray Closeup

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

M0003-5 PREFLIGHT TRAILING EDGE EXPERIMENT

The photograph in figure 7 shows the preflight polymeric film materials in the trailing edge tray. The polymer films are the horizontal strips shown in the upper and lower left portion of the mounting hardware.

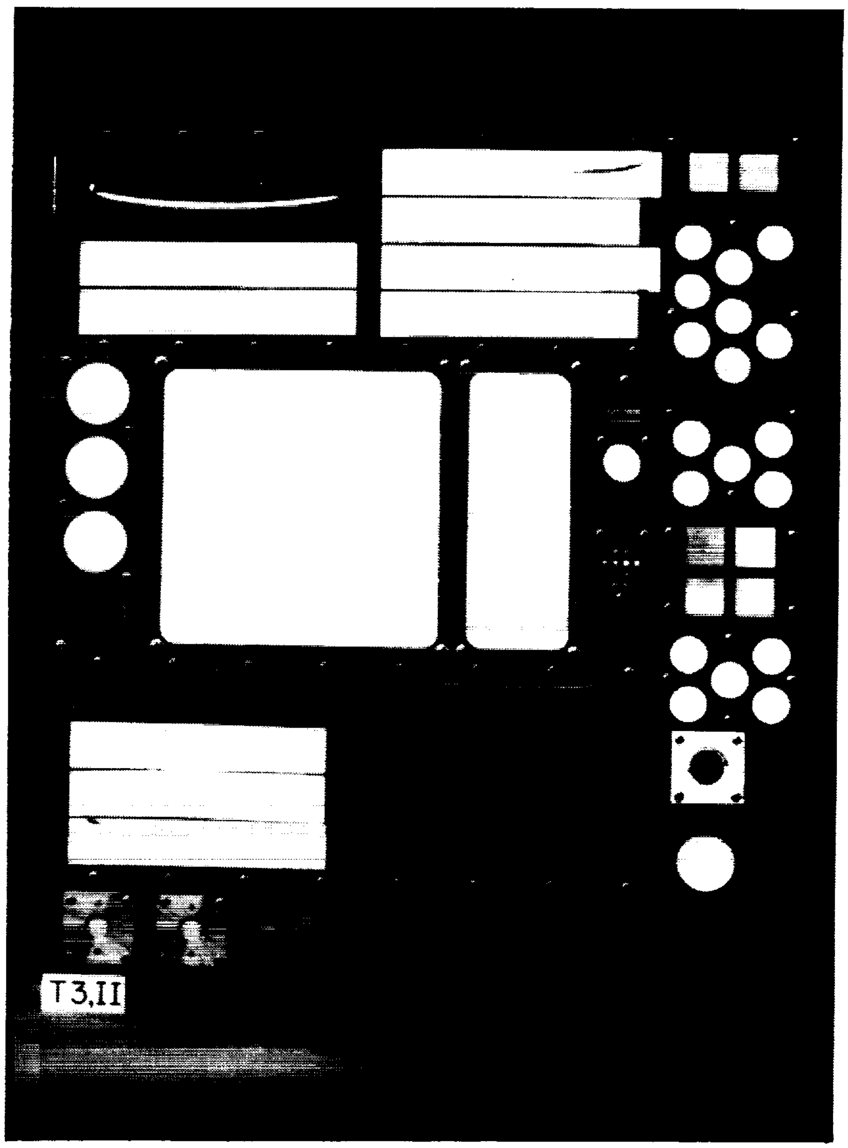

Figure 7. M0003-5 Preflight Trailing Edge Experiment

RECOVERED POST FLIGHT TRAILING EDGE M0003 TRAY

The photograph in figure 8 shows the post flight materials in the recovered trailing edge tray. Among the various areas of visible damage, note the condition of the M0003-5 polymeric film strips located in the upper right quadrant of the tray. The damage is primarily due to contamination, radiation and debonding and tearing of the polymeric films.

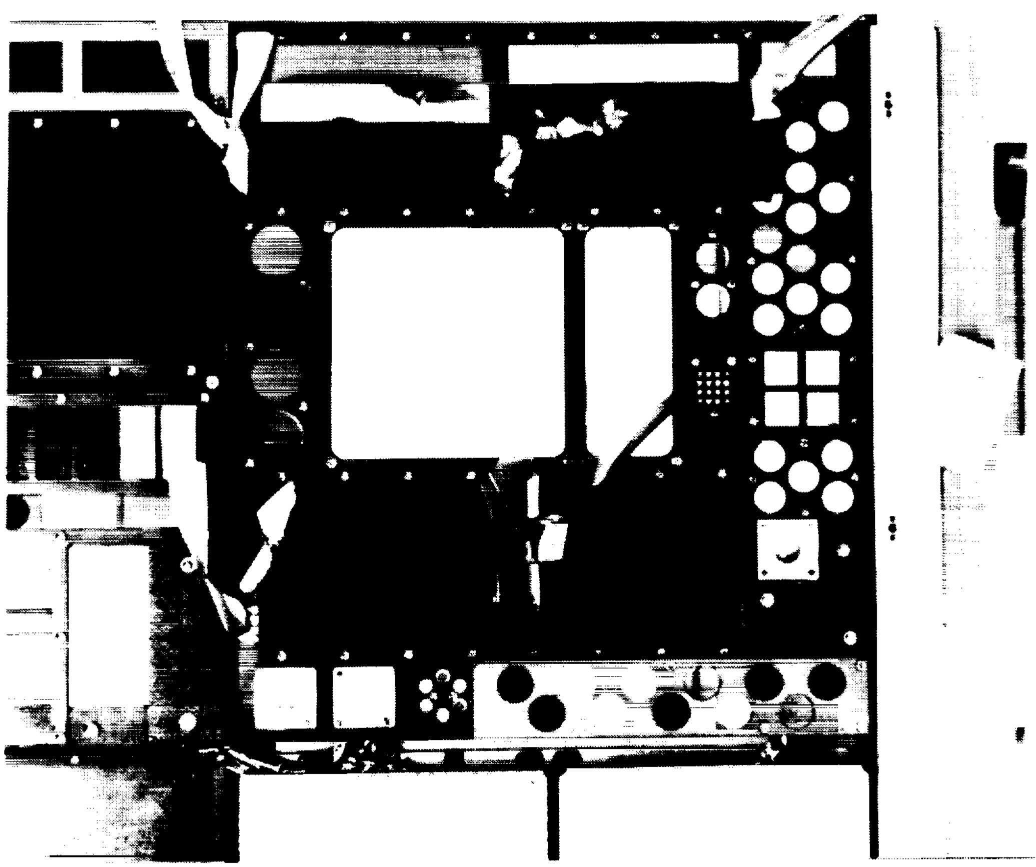

Figure 8. M0003 Post Flight Trailing Edge Tray

M0003-5 POST FLIGHT TRAILING EDGE TRAY CLOSEUP

The photograph in figure 9 below shows a closeup of the M0003-5 experiment materials. Note the extensive damage to the polymeric film strips. There are obvious physical changes, radiation damage, contamination. and debonding and tearing of the polymeric film materials.

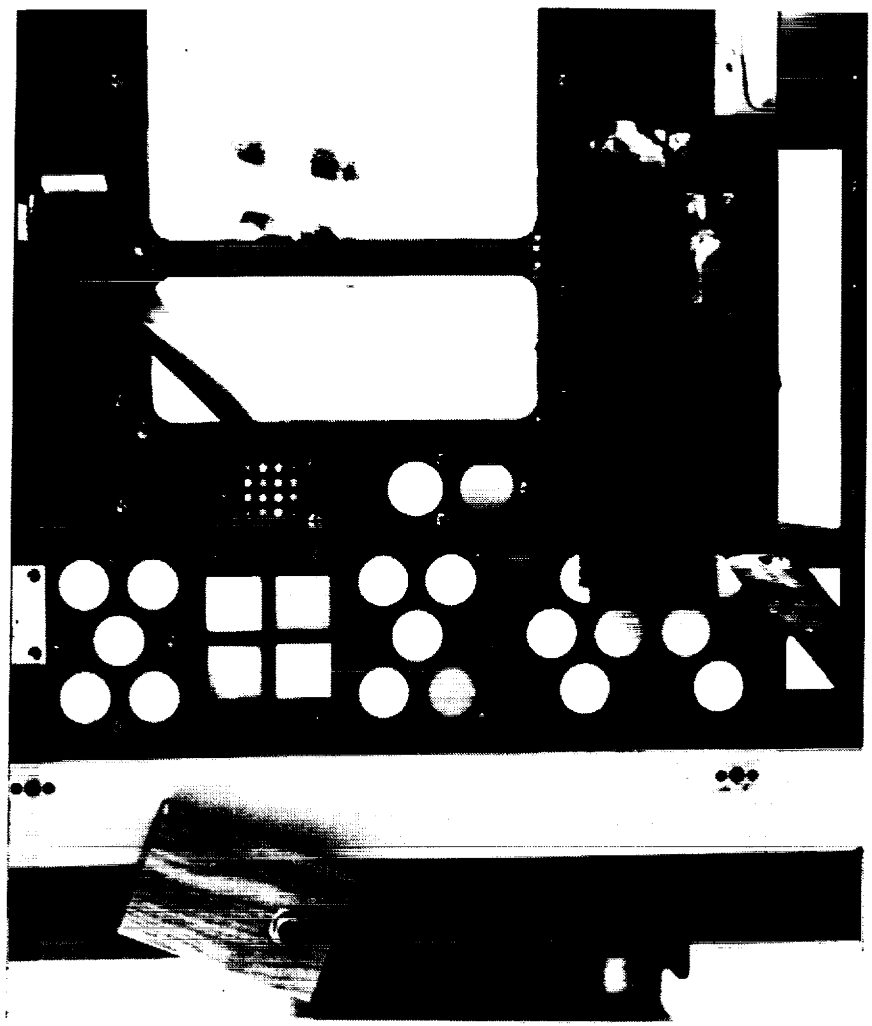

Figure 9. M0003-5 Post Flight Trailing Edge Tray Closeup

KAPTON/Al 1mil

Control C1-C3 (Laboratory Specimen)
The specimen top surface has surface scratches and dust. A weave pattern from the protective cloth used during storage is visible on the surface. There was no apparent change in the metallic surface.

C3-L3 (Leading Edge Specimen)
Fifty percent of the metallized Kapton strip is missing. It is golden yellow and has circular surface stains, vertical lines in the film and cracks through the film. The edge of the exposed strip is torn and ragged. The unexposed Al metallized surface is bright, shiny, and reflective.

C3-T3 (Trailing Edge Specimen)
The exposed Kapton surface is bright, shiny, reflective and apparently undamaged. Some debris is present on the surface. The Kapton surface is wrinkled and bunched near the left side of the film. The unexposed metallized layer is bright, shiny, reflective and apparently undamaged.

A comparison photograph of the specimens is illustrated in figure 10 and figure 11 compares the UV-Vis-NIR reflectance changes in the materials.

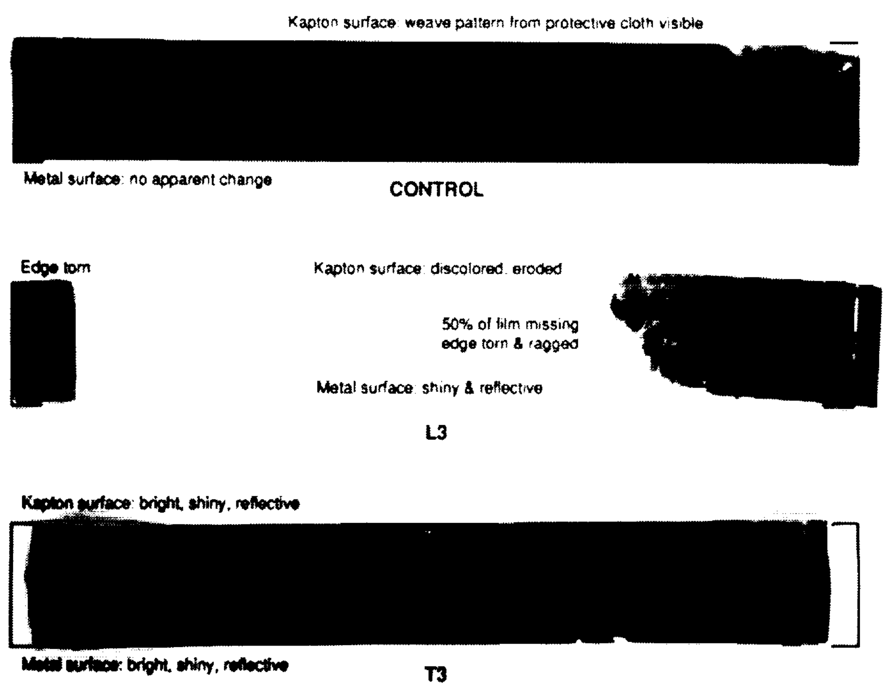

Figure 10. Comparison of Kapton/Al 1 mil Specimens

KAPTON/Al 1mil

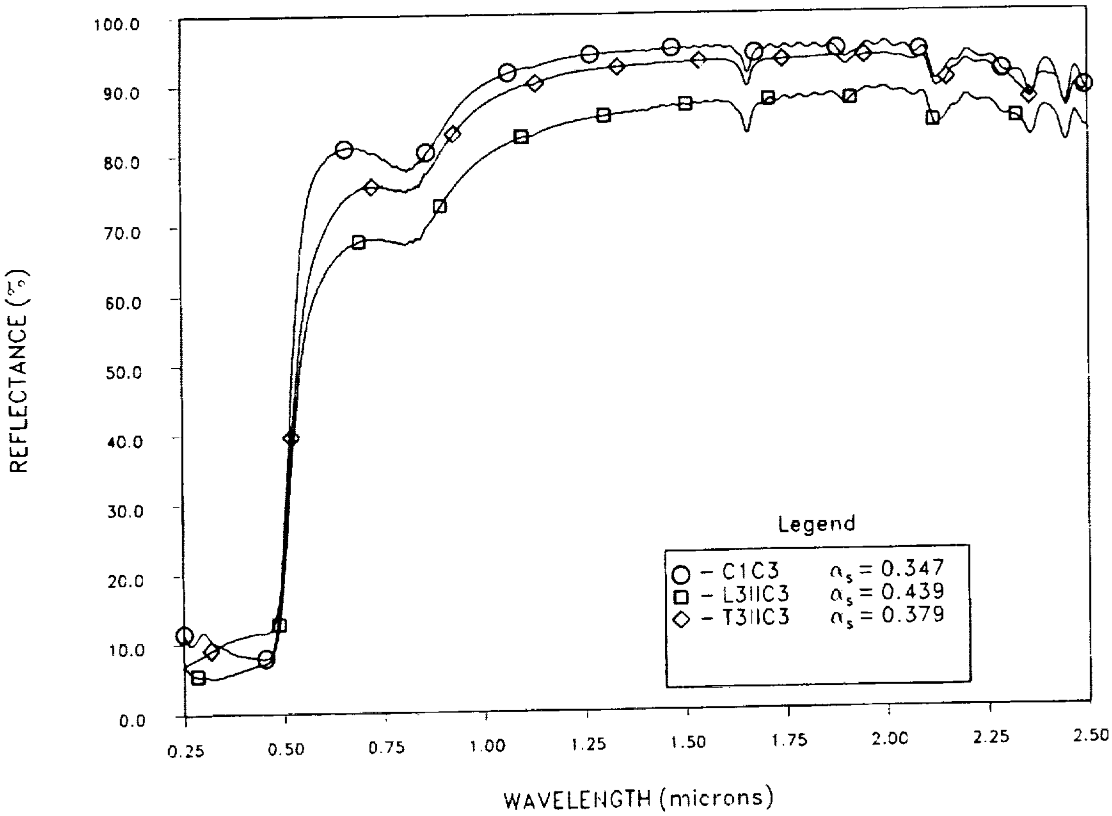

Figure 11 Comparison Reflectance Curves of Kapton/Al 1mil Specimens

FTIR SPECTRA UNAVAILABLE

KAPTON/Al 5 mil

Control C1-C4 (Laboratory Specimen)
A weave pattern from the protective cloth used during storage is visible on the surface. The metallized surface has scratches and dust and pinholes present.

C4-L3 (Leading Edge Specimen)
The metallized Kapton strip is severely discolored. The Kapton surface has large, dark, non-reflective and abraded areas. Some areas remain shiny and reflective. The surface has longitudinal lines. There are multiple probable impact sites. The separated end of the strip appears eroded. The unexposed Al metallized Kapton surface is bright, shiny and reflective. There are two small sites where the aluminum delaminated from the Kapton film.

C4-T3 (Trailing Edge Specimen)
The Kapton surface is shiny, reflective and appears undamaged. There is debris present on the surface. The metallized layer is bright, shiny, reflective and appears undamaged.

A comparison photograph of the specimens is illustrated in figure 12 and figure 13 compares the UV-Vis-NIR reflectance changes in the materials.

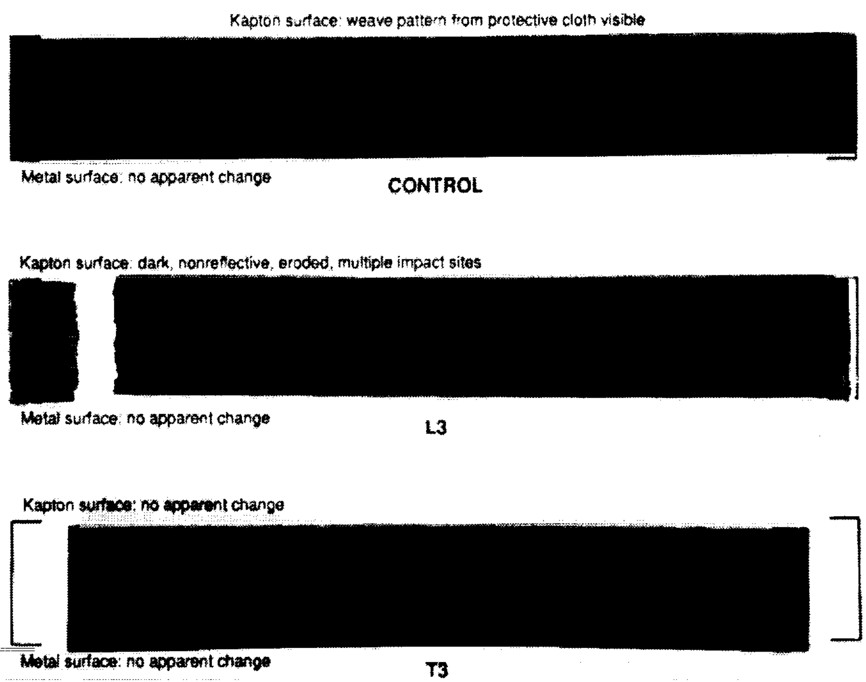

Figure 12. Comparison of Kapton/Al 5 mil Specimens

KAPTON/Al 5 mil

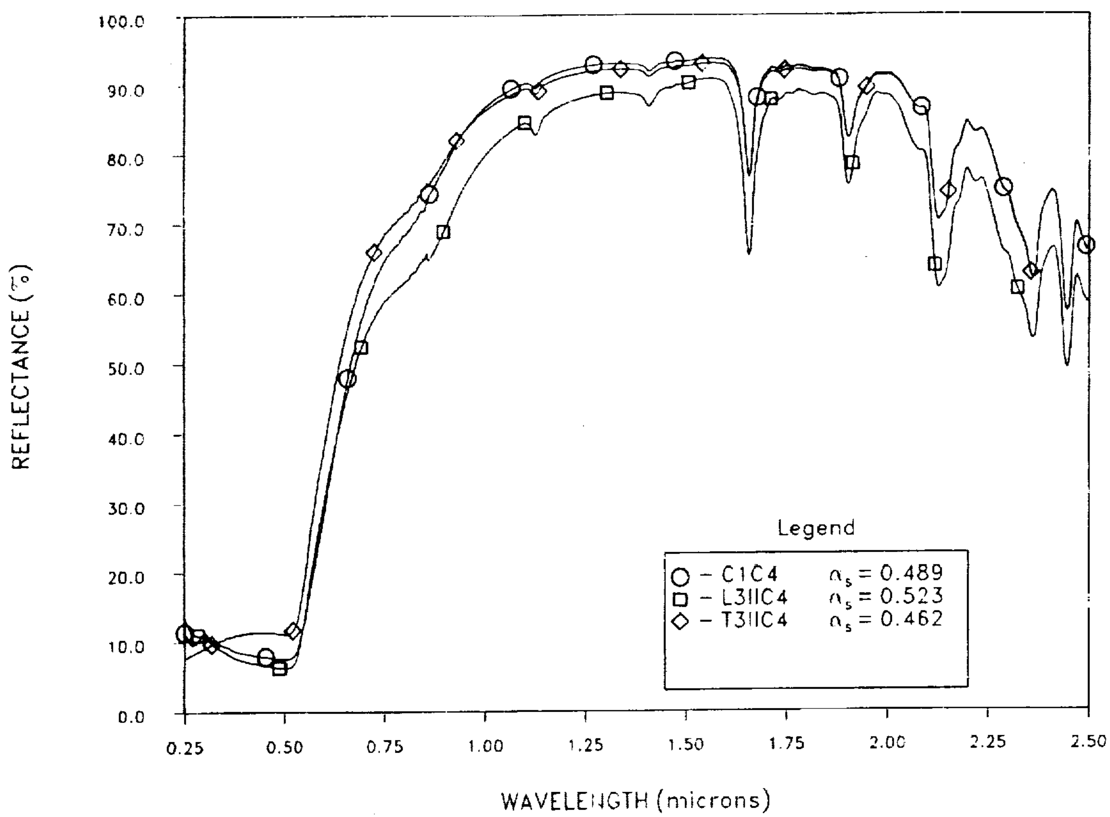

Figure 13. Comparison Reflectance Curves of Kapton/Al 5 mil Specimens

FTIR SPECTRA UNAVAILABLE

POLYPHENYLSULFONE R-5000 10 mil

Control C1-C16 (Laboratory Specimen)
Specimen is in good condition.

C16-L3
The polyphenylsulfone film surface has a deep yellow color with longitudinal lines or cracks. In the center of the film, there are three large irregularly shaped whitish areas with surrounding diagonal scratches. One irregular shaped hole is present. There are several probable impact sites with circular white rings surrounding them. There are also several dark stains or smears on the surface. The unexposed surface of the strip is shiny and reflective.

C16-T3
The polyphenylsulfone is discolored a dark brown, but is transparent. Debris is present on the surface. Other than discoloration, no apparent damage is visible.

A comparison photograph of the specimens is illustrated in figure 14 and figure 15 compares the UV-Vis-NIR reflectance changes in the materials

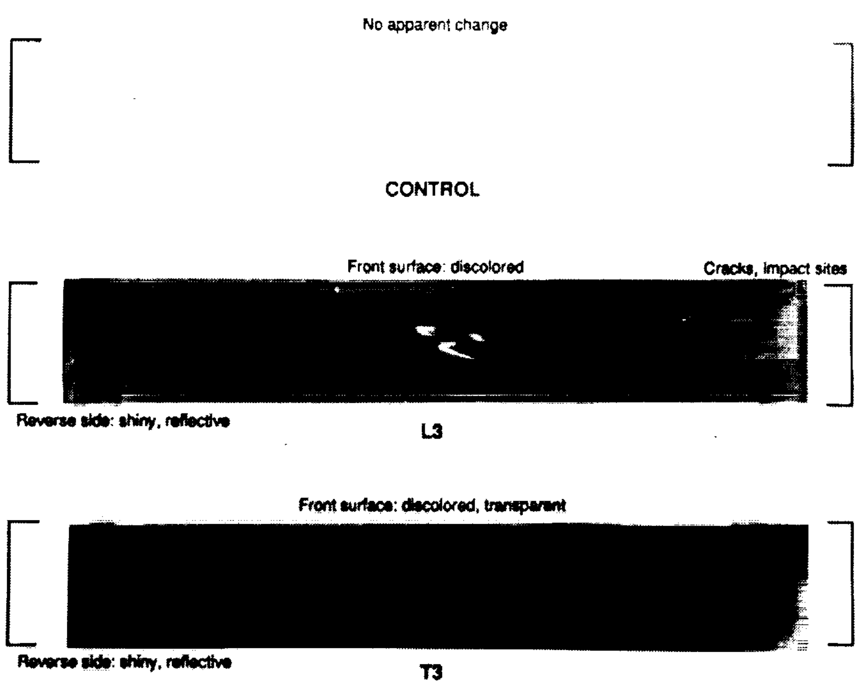

Figure 14. Comparison of Polyphenylsulfone 10 mil Specimens

POLYPHENYSULFONE R-5000 10 MIL

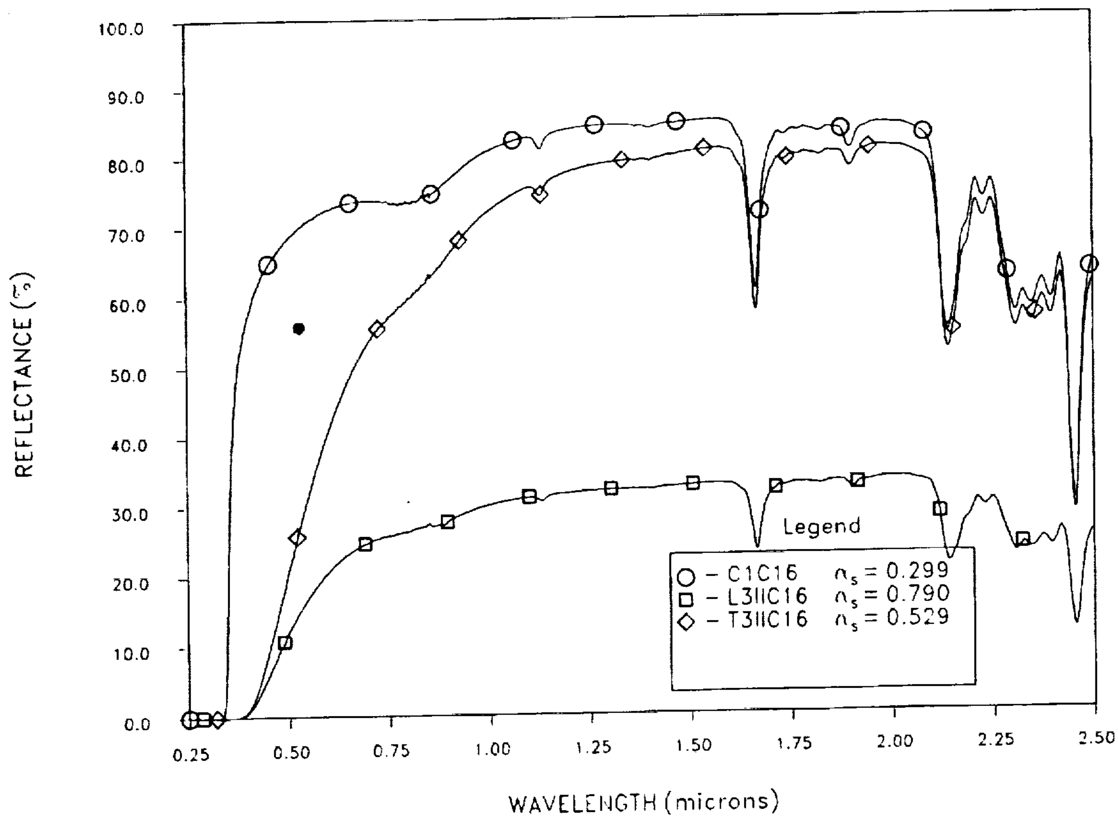

Figure 15. Comparison Reflectance Curves of Polyphenylsulfone 10 mil Specimens

FTIR SPECTRA UNAVAILABLE

FEP/Ag/INCONEL 5 mil

Control C1-C2 (Laboratory Specimen)
The specimen has surface scratches, dust and pinholes in the metallized coating.

C2-L3 (Leading Edge Specimen)
The metallized FEP strip is torn, coiled, wrinkled and discolored. The FEP surface is shiny, reflective and semitransparent with a surface haze. The metallized surface of the FEP is crazed, flaked and has a black powdery appearance. Some metallization remains in the coiled area.

C2-T3 (Trailing Edge Specimen)
The exposed surface of the FEP film is torn, stained and slightly discolored, with a probable slight haze. The metallized surface of the FEP is cracked, crazed and peeling. A substantial amount of the metallized layer has flaked away, and the area is essentially transparent. The ends of the strip show some discoloration, but little flaking or peeling.

A comparison photograph of the specimens is illustrated in figure 16 and figure 17 compares the UV-Vis-NIR reflectance changes in the materials.

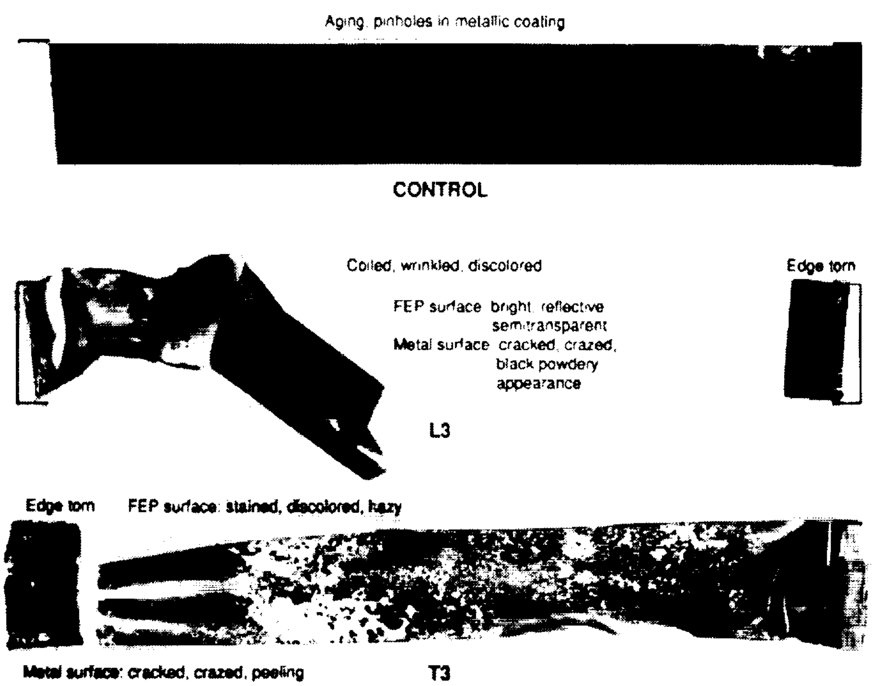

Figure 16. Comparison of FEP/Ag/Inconel 5 mil Specimens

FEP/Ag/INCONEL 5 mil

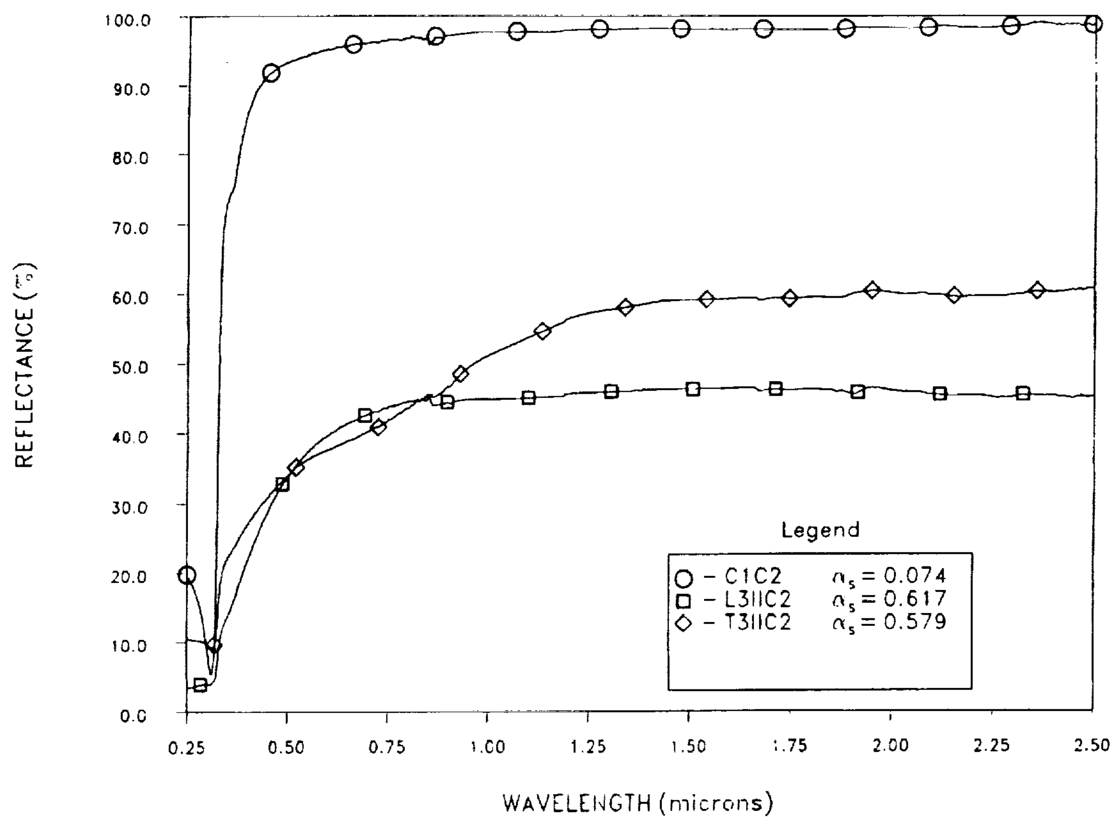

Figure 17. Comparison Reflectance Curves of FEP/Ag/Inconel 5 mil Specimens

FTIR SPECTRA UNAVAILABLE

LEADING EDGE POLYMERIC FILMS MOUNTING

The photograph shown in figure 18 illustrates the front surface of the leading edge polymer film mounting plate prior to removal of the polymer films. It should be noted that in many cases the lapped adhesive bonds failed or the polymer film was separated from one side of the mounting plate by tearing. The debonding and tearing of the films was probably due to thermal cycling effects. Scarring due to probable AO impingement deflected from the scuff plate is evident. The RTV 560 + 12% graphite adhesive failed in all cases.

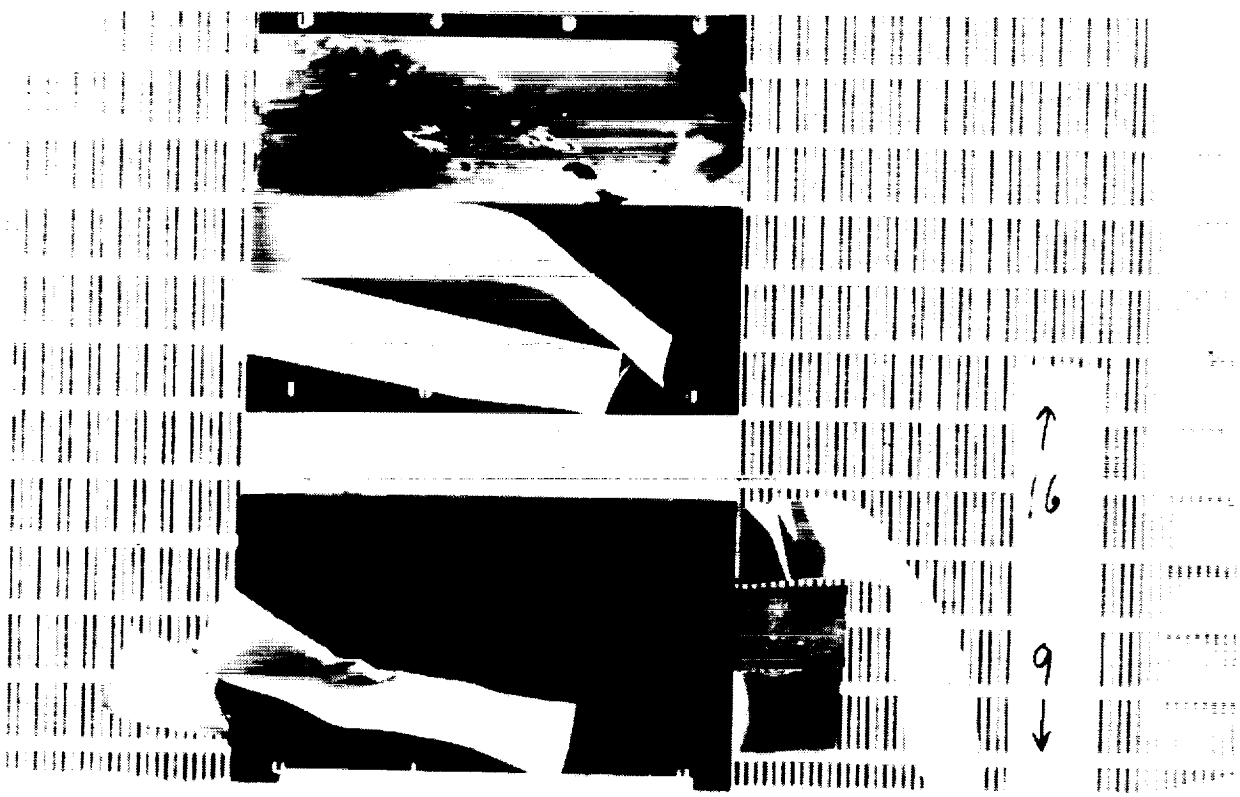

Figure 18. Polymer Film Leading Edge Front Surface Plate

LEADING EDGE POLYMERIC FILMS MOUNTING

The photograph shown in figure 19 illustrates the rear face of one of the leading edge polymer films mounting plates prior to removal of the polymer films. It should be noted that the original adhesive bonding of the films to the mounting plate has not been visibly affected.

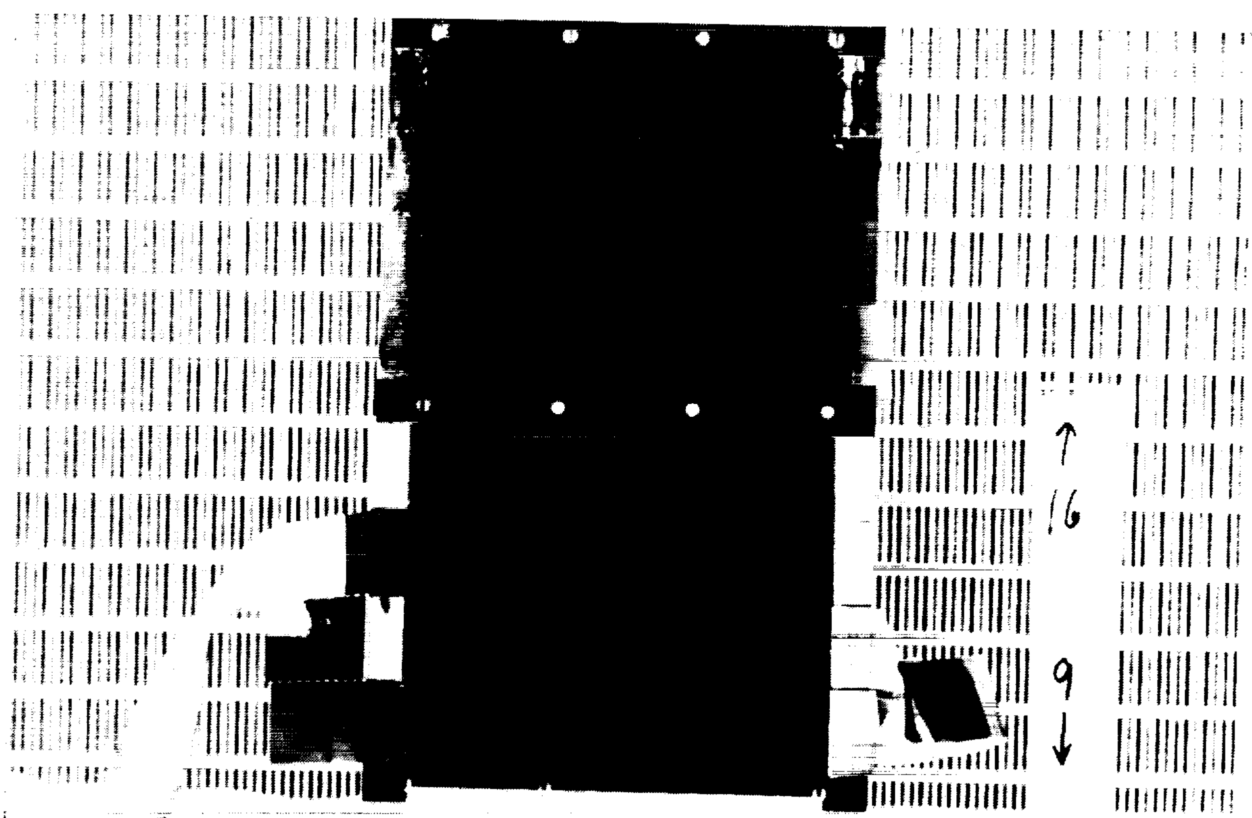

Figure 19. Polymer Film Leading Edge Rear Surface Plate

TRAILING EDGE POLYMERIC FILMS MOUNTING

The photograph shown in figure 20 illustrates the front surface of one of the trailing edge polymer film mounting plates prior to the removal of the polymer films. It should be observed that two of the lapped adhesive bonds failed and one film was separated from one side of the mounting due to tearing. The debonding and tearing were probably caused by thermal cycling effects. The RTV 560 + 12% graphite adhesive failed in all cases.

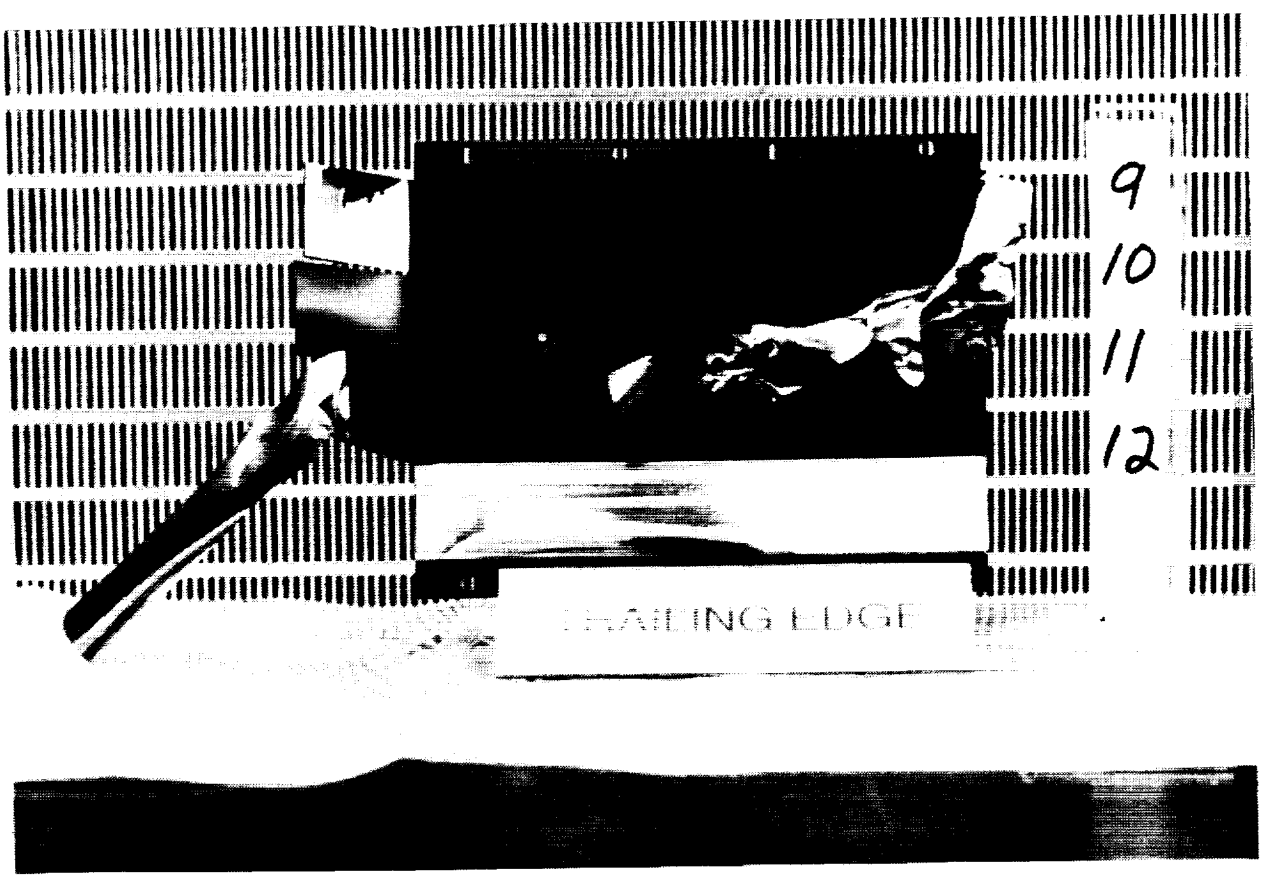

Figure 20. Polymer Film Trailing Edge Front Surface Plate

TRAILING EDGE POLYMERIC FILMS MOUNTING

The photograph shown in figure 21 illustrates the rear face of one of the trailing edge mounting plates prior to removal of the polymer films. It should be noted that the original adhesive bonding of the films to the mounting plate has not been visibly affected.

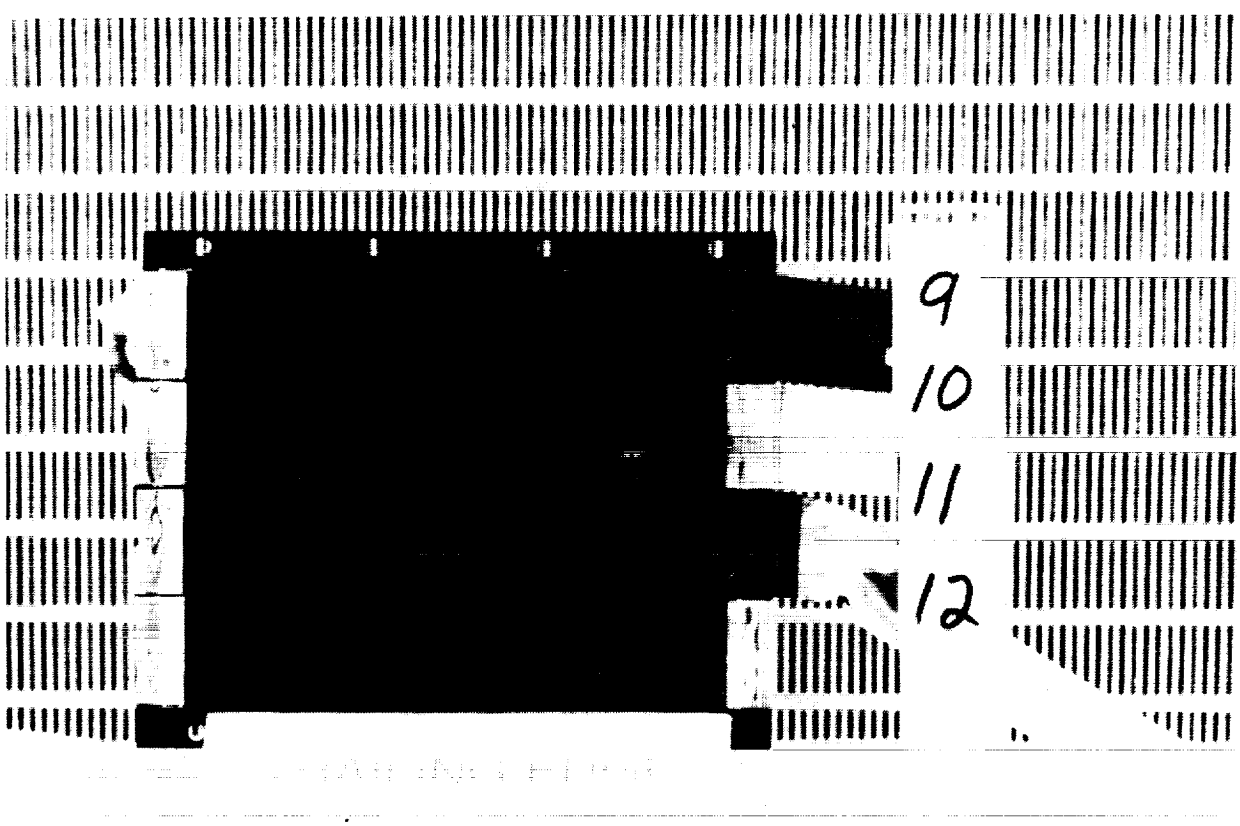

Figure 21. Polymer Film Trailing Edge Rear Surface Plate

FEP/Ag/INCONEL/RTV 560 + GRAPHITE/KAPTON 5 mil

Control C1-C9 (Laboratory Specimen)

Specimen has surface scratches. There are small areas of yellow discoloration near the bond area. The metallized coating has pinholes. Some pinholes have tarnish rings surrounding the pinhole site.

C9-L3

The metallized FEP strip is curled, coiled and discolored. The FEP exposed surface in the unbonded area is shiny, reflective and semitransparent. The FEP surface over the bonded area does not differ from the rest of the strip. The exposed Kapton surface is apparently undamaged. The RTV 560 adhesive bond between the FEP/Ag/Inconel and the Kapton/Al failed completely. The RTV 560 remained adhered to the Kapton surface. There is no visual evidence of an adhesive residue on the Inconel surface of the FEP. The metallized surface of the FEP is crazed, flaked and has a black powdery appearance. The metallized face of the Kapton is bright, reflective and appears undamaged.

C9-T3

The FEP is wrinkled, curled and distorted. The FEP surface is shiny and reflective with a milky haze. The adhesive bond between the FEP/Ag/ Inconel and the Kapton Al failed completely. The RTV 560 + 12% graphite adhesive remained adhered to the Kapton/Al tab, and is intact . The metallized layer of the FEP is reflective, but darker in color. The exposed Kapton is bright, shiny and reflective.

A comparison photograph of the specimens is illustrated in figure 22 and figure 23 compares the UV-Vis-NIR reflectance changes in the materials.

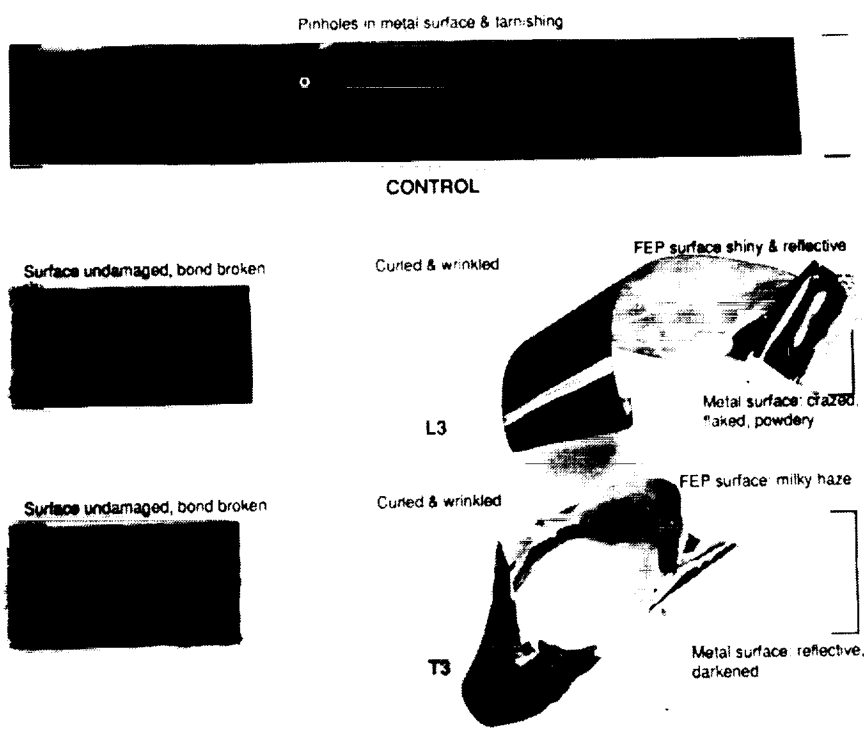

Figure 22. Comparison of FEP/Ag/Inconel/RTV 560 + Graphite/Kapton 5 mil

FEP/Ag/INCONEL/RTV 560 + GRAPHITE/KAPTON 5 MIL

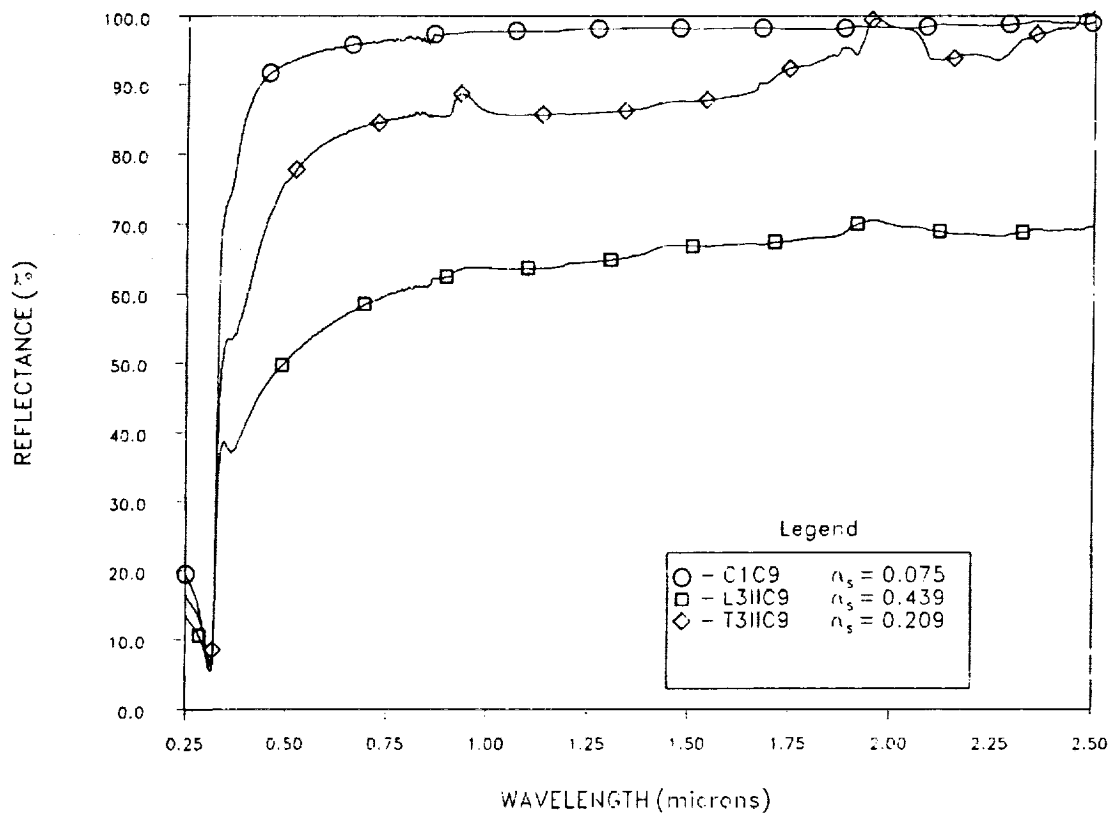

Figure 23. Comparison Reflectance Curves of FEP/Ag/Inconel/RTV 560 + 12% Graphite/Kapton/Al 5 mil Specimens

FTIR SPECTRA UNAVAILABLE

FEP/Ag/INCONEL/EC57C/KAPTON/Al 5 mil

Control C1-C6 (Laboratory Specimen)

Specimen has scratches and dust. Severe scratches in bonded area. Pinholes are present in the metallized coating.

C6-L3 (Leading Edge Specimen)

The metallized FEP strip is torn, coiled and discolored. The FEP exposed surface in the unbonded area is shiny, reflective and semitransparent. The FEP exposed surface over the bonded area has a milky appearance with possible surface erosion and yellow brown surface stains. The exposed Kapton surface is discolored and eroded. The EC57C adhesive bond between the FEP/Ag/Inconel and the Kapton/Al is intact. The metallized face of the FEP is crazed and flaked and has a black powdery appearance. The metallized face of the FEP in the bond area is intact. The Al metallized face of the Kapton is bright, reflective and appears undamaged.

C6-T3 (Trailing Edge Specimen)

The film strip is torn and curled. The FEP surface appears hazy and milky. The metallized side of the FEP film is darkened and hazy. There are some areas of black powdery smears. The adhesive bond is intact. The FEP surface over the bond area has a slight yellow discoloration. The Kapton tab is shiny, reflective and appears undamaged. The metallized side of the Kapton is also bright, shiny and appears undamaged.

A comparison photograph of the specimens is illustrated in figure 24 and figure 25 compares the UV-Vis-NIR reflectance changes in the materials.

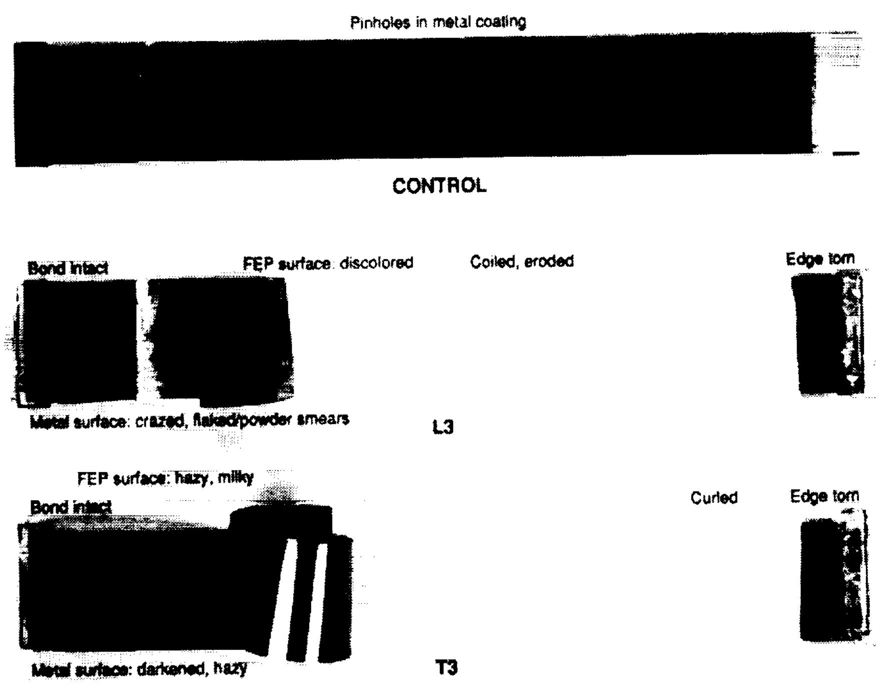

Figure 24. Comparison of FEP/Ag/Inconel/EC57C/Kapton/Al 5 mil

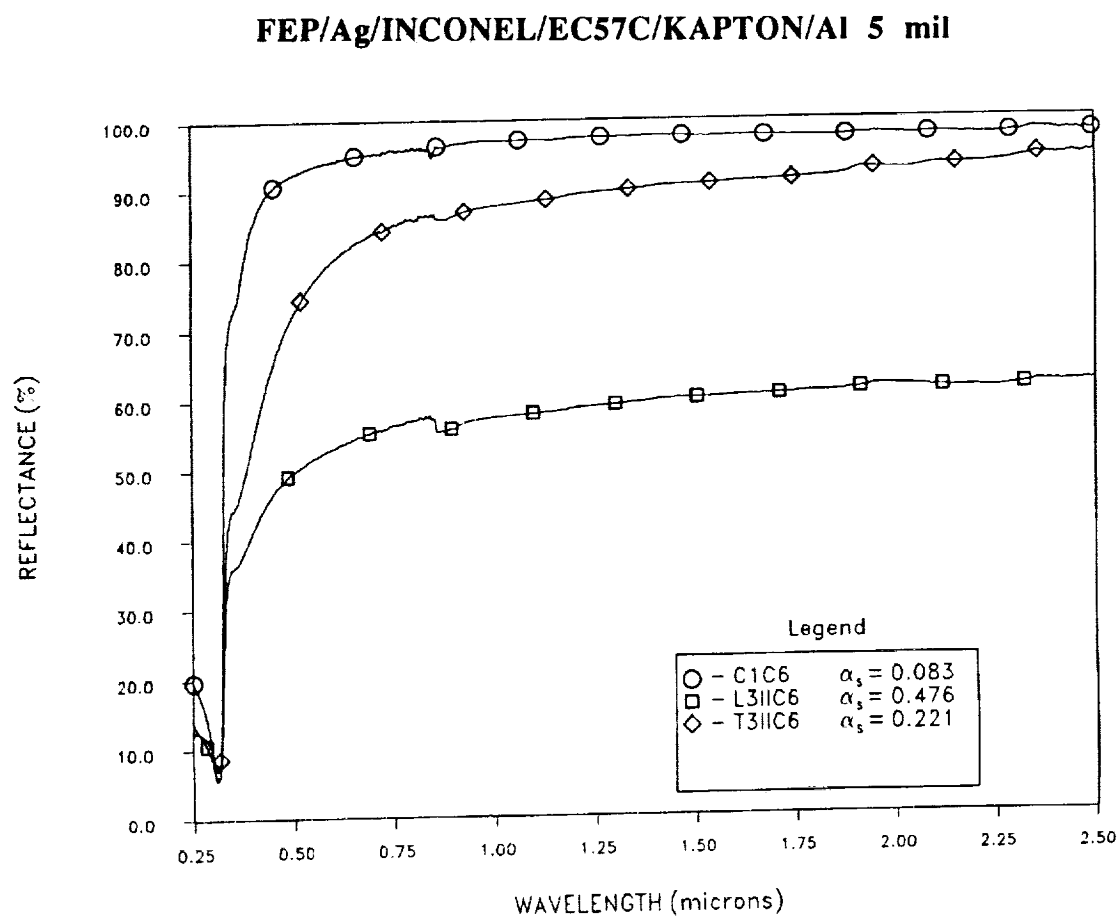

Figure 25. Comparison Reflectance Curves of FEP/Ag/Inconel/EC57C/Kapton/Al 5 mil Specimens

FTIR SPECTRA UNAVAILABLE

Control C1-C11 (Laboratory Specimen)
Specimen has surface scratches. Pinholes are present in the metallized layer.

C11-L3
The metallized FEP strip is torn, curled and discolored. The FEP surface is shiny, reflective and semi-transparent. The FEP surface over the bonded area has a milky appearance and whitish smears. The exposed Kapton surface is dull, discolored and possibly eroded. The Y966 adhesive bond between the FEP/Ag/Inconel and the Kapton/Al is intact. The metallized surface of the FEP is crazed, flaked and has a black powdery appearance. The metallized face of the FEP in the bond is intact. The Al metallized surface of the Kapton is bright, reflective and apparently undamaged.

C11-T3
The FEP film is torn, shiny, reflective and may have a slight haze. The FEP film is wrinkled and distorted near the bond site. The adhesive bond between the FEP/Ag/ Inconel and the Kapton/ Al is intact. The metallized surface of the FEP is shiny, but may have darkened. The Kapton surface is bright, shiny and undamaged. The aluminized surface of the Kapton is shiny and reflective.

A comparison photograph of the specimens is illustrated in figure 26 and figure 27 compares the UV-Vis-NIR reflectance changes in the materials.

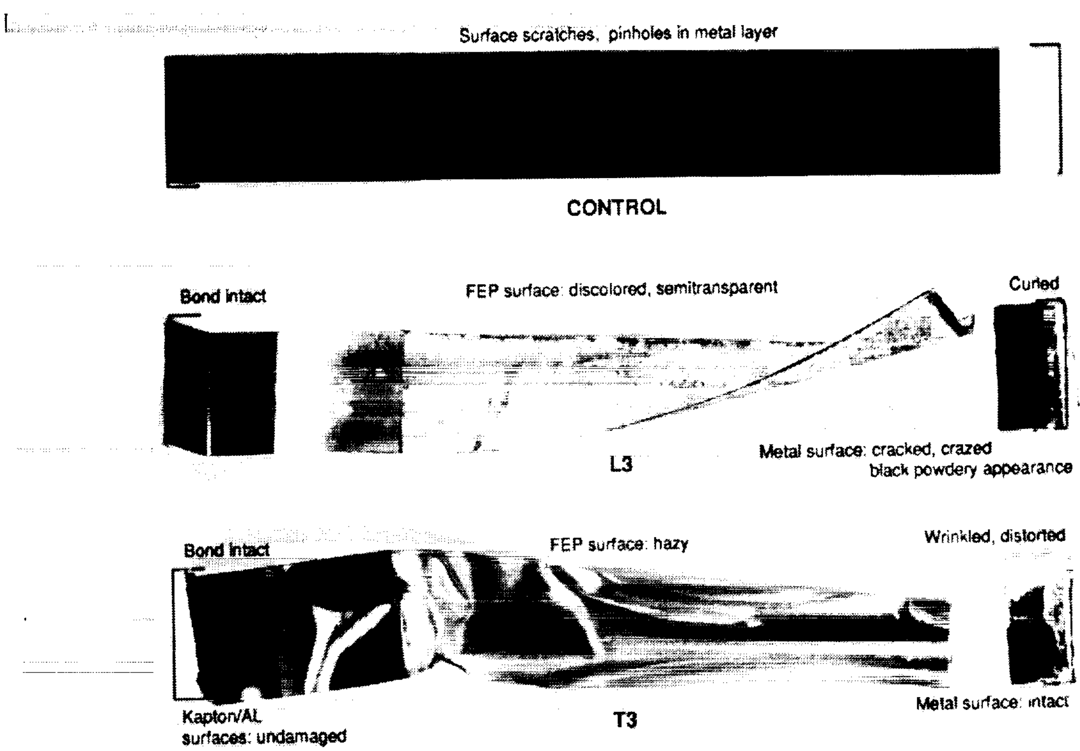

Figure 26. Comparison of FEP/Ag/Inconel /Y966/Kapton/5 mil

FEP/Ag/INCONEL/Y966/KAPTON 5 mil

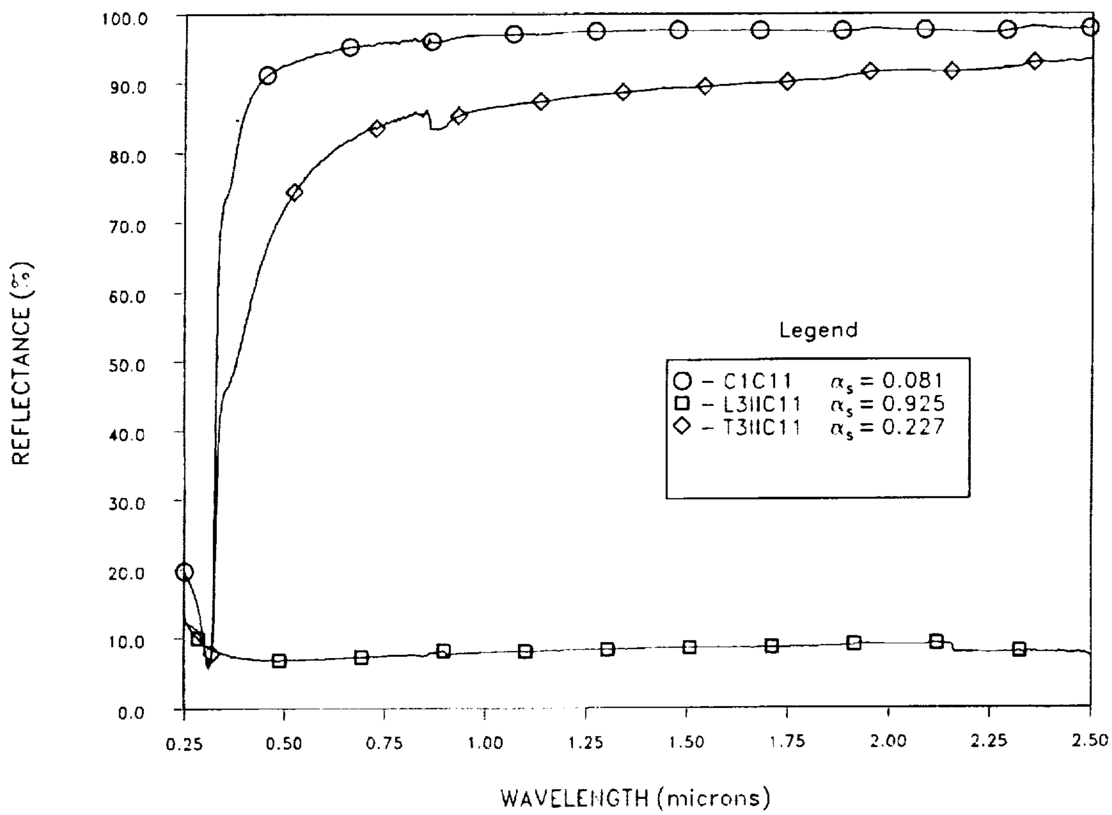

Figure 27. Comparison Reflectance Curves of FEP/Ag/Inconel/Y966/Kapton 5 mil Specimens

FTIR SPECTRA UNAVAILABLE

OBSERVATIONS

1. 14 out of 32 polymer film strips exhibited adhesive bond separation or tearing due probably to thermal cycling.

2. The EC57C and Y966 adhesive bonds remained intact.

3. Kapton/Al materials exhibited probable AO erosion.

4. RTV 560 + 12% graphite adhesive bonds failed in all cases.

5. The most significant changes in reflectance occurred in the leading edge polymer films.

LDEF MATERIALS WORKSHOP '91 AGENDA

NASA Langley Research Center
H. J. E. Reid Conference Center
14 Ames Road   Building 1222
Hampton, Virginia 23665-5225
November 19 - 22, 1991

Tuesday, November 19, 1991

8:30 a.m. **Introductions**

William H. Kinard, LDEF Chief Scientist
Bland A. Stein, Workshop Coordinator
Philip R. Young, Workshop Coordinator

9:00 a.m. **Technical Session**

- **LDEF Materials, Environmental Parameters, and Data Bases (Plenary Session)**

Cochairman: Bruce Banks, NASA - Lewis Research Center
Cochairman: Mike Meshishnek, The Aerospace Corporation
Recorder: Roger Bourassa, Boeing Defense & Space Group

LDEF Atomic Oxygen Fluence Update	Roger Bourassa Boeing Defense & Space Group
LDEF Yaw and Pitch Angle Estimates	Bruce Banks
LDEF Experiment M0003 Meteoroid and Debris Survey	Mike Meshishnek The Aerospace Corporation
Atomic Oxygen Erosion Yields of LDEF Materials	Bruce Banks, LeRC for John Gregory University of Alabama in Huntsville
The LDEF M0003 Experiment Deintegration Observation Data Base	Sandy Gyetvay The Aerospace Corporation
Overview of Flight Data from LDEF M0003 Experiment Power and Data System	John Coggi The Aerospace Corporation

12:00 Noon **Lunch**

Tuesday, November 19, 1991 continued

1:00 p.m. **Technical Session**

- **LDEF Contamination (Plenary Session)**

Cochairman: Steve Koontz, NASA Johnson Space Center
Cochairman: Wayne Stuckey, The Aerospace Corporation
Recorder: Russell Crutcher, Boeing Defense & Space Group

Introduction	Wayne Stuckey The Aerospace Corporation
Materials SIG Quantification and Characterization of Surface Contaminants	Russell Crutcher Boeing Defense & Space Group
Z-306 Molecular Contamination Ad-Hoc Committee Results	John Golden Boeing Defense & Space Group
LDEF Contamination Modelling	Tim Gordon Applied Science Technology and Ray Rantanen ROR Enterprises
M0003 Contamination Results	Wayne Stuckey and Carol Hemminger The Aerospace Corporation
Organic Contamination on LDEF	Gale Harvey NASA Langley Research Center

5:00 p.m. **End Session**

Wednesday, November 20, 1991

8:00 a.m. **Technical Session**

- **Thermal Control Coatings, Protective Coatings and Surface Treatments (Plenary Session**

Cochairman: Ann Whitaker, NASA Marshall Space Flight Center
Cochairman: Wayne Slemp, NASA Langley Research Center
Recorder: John Golden, Boeing Defense & Space Group

Thermal Control Materials on Thermal Control Surfaces (TCSE) Experiment	James Zwiener, NASA MSFC for Don Wilkes AZ Technology
Vacuum Deposited Coatings	Wayne Slemp NASA Langley Research Center
Anodized Aluminum on LDEF	John Golden Boeing Defense & Space Group
Thermal Control Tape	Rachel Kamenetsky NASA Marshall Space Flight Center
Fluorescence in Thermal Control Coatings	James Zwiener NASA Marshall Space Flight Center
Thermal Control Coatings on DoD Flight Experiment	William Lehn, Nichols Research Corp. for Charles Hurley Univ. of Dayton Research Institute and Michele Jones U.S.A.F Wright Laboratories
Next Generation LDEF: Retrieval Payload Carrier	Arthur Perry American Space Technologies, Inc.

Element Material Exposure Experiment
Experiment by EFFU — Yoshihiro Hashimoto, Ishikawajima- Harima Heavy Industries Co., Ltd. (IHI)

Skylab DO24 Thermal Control Coatings and
Polymer Films Experiment — William Lehn, Nichols Research Corporation

12:00 Noon **Lunch**

__Wednesday, November 20, 1991__ **continued**

1:00 p.m. **Technical Session**

- **Polymers and Films (including Ag/FEP) (Concurrent Session)**

Cochairman: Phil Young, NASA Langley Research Center
Cochairman: David Brinza, Jet Propulsion Laboratory
Recorder: Gary Pippin, Boeing Defense & Space Group

Ag/FEP Teflon — François Levadou, European Space Research & Technology Centre

Ag/FEP: Recent MSIG Results — Gary Pippin, Boeing Defense & Space Group

Polymer Films and Resins — Philip Young, NASA Langley Research Center

Texas A & M S1006 Balloon Materials Experiment — Alan Letton and Thomas Strganac, Texas A & M University

Depth Profiling of Orbital Exposure Damage to
Halar (A0171 Solar Array Materials Experiment) — William Brower, Marquette University

M0003: Recent Results on Polymer Films — Michele Jones, U.S.A.F Wright Laboratories

5:00 p.m. **End Session**

__Wednesday, November 20, 1991__ **continued**

1:00 p.m. **Technical Session**

- **Metals, Ceramics, and Optical Materials (Concurrent Session)**

Cochairman: Roger Linton, NASA Marshall Space Flight Center
Cochairman: John Gregory, University of Alabama
Recorder: Gail Bohnhoff-Hlavacek, Boeing Defense & Space Group

Selected Results from Metals on LDEF
Experiment A0171 — Ann Whitaker, NASA MSFC

Oxidation of Copper and Silver on LDEF — Ton de Rooij, European Space Research & Technology Centre

Optical Transmission and Reflection Measurements of Thin Metal Films Exposed on LDEF — Roger Linton, NASA MSFC for John Gregory University of Alabama in Huntsville and

Oxidation of Black Chromium Coatings on LDEF — John Golden, Boeing Defense & Space Group

LANL Results from Space-and Ground-based Atomic Oxygen Exposures of Metals and Inorganic Materials — Jon Cross, Los Alamos National Laboratory (LANL)

AXAF Optical Materials and Issues — James Bilbro, NASA MSFC for Alan Shapiro, NASA Marshall Space Flight Center

Effects of Space Exposure on Pyroelectric Infrared Detectors — James Robertson, NASA Langley Research Center

Status and Results of LDEF Optical Systems SSIG Data Base — Gail Bohnhoff-Hlavacek, Boeing Defense & Space Group

5:00 p.m. **End Session**

Thursday, November 21, 1991

8:00 a.m. **Technical Session**

- **Polymer-Matrix Composites (Concurrent Session)**

Cochairman: Rod Tennyson, University of Toronto
Cochairman: Gary Steckel, The Aerospace Corporation
Recorder: Pete George, Boeing Defense & Space Group

M0003 and Other Polymer-Matrix Composites — Gary Steckel, The Aerospace Corporation

A0134: Polymer Matrix Composites — Wayne Slemp, NASA Langley Research Center

Space Environmental Effects on LDEF Low-Earth Orbit (LEO) Exposed Graphite-Reinforced Polymer- Matrix Composites — Pete George, Boeing Defense & Space Group

Long-Term Environmental Effects on Carbon-and Glass-Fiber Composites — Ann Whitaker, NASA Marshall Space Flight Center

Evaluation of Long-Duration Exposure to the Natural Space Environment on Graphite-Polyimide and Graphite-Epoxy Mechanical Properties — Richard Vyhnal, Rockwell International

Proposed Test Program and Data Base for LDEF Polymer-Matrix Composites — Pete George, Boeing Defense & Space Group and Rod Tennyson, University of Toronto

12:00 Noon **Lunch**

Thursday, November 21, 1991

8:00 a.m. **Technical Session**

- **Lubricants, Adhesives, Seals, Fasteners, Solar Cells, and Batteries (Concurrent Session)**

Cochairman: James Mason, NASA Goddard Space Flight Center
Cochairman: Joel Edelman, LDEF Consultant
Recorder: Harry Dursch, Boeing Defense & Space Group

Identification and Evaluation of Lubricants, Adhesives, and Seals Used on LDEF	Bruce Keough Boeing Defense & Space Group
Results from the Testing and Analysis of LDEF Batteries	Steve Spear Boeing Defense & Space Group
Effects of Long-Term Exposure on Fastener Assemblies	Steve Spear Boeing Defense & Space Group
Results from the Testing and Analysis of Solar Cells Flown on LDEF	Harry Dursch Boeing Defense & Space Group
System Related Testing and Analysis of FRECOPA	Christian Durin Centre National D'etudes Spatiales

12:00 Noon **Lunch**

1:00 p.m.

- Working meetings of **Theme Panels** to prepare charts for Workshop Summary Session and begin draft of panel report. **(Concurrent Session)**

5:00 p.m. **End Session**

Friday, November 22, 1991

8:00 a.m. **Technical Session**

- **LDEF Materials Workshop '91 - Summary (Plenary Session)**

  - 20-minute presentations by panel chairmen followed by question/answer periods
  - Final general discussion period moderated by workshop coordinators

12:00 Noon **End Workshop**

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The LDEF Materials Workshop '91 was a follow-on to the Materials Sessions at the First LDEF Post-Retrieval Symposium held in Kissimmee, Florida, June 1991. The workshop comprised a series of technical sessions on materials themes, followed by theme panel meetings. Themes included Materials, Environmental Parameters, and Data Bases; Contamination; Thermal Control and Protective Coatings and Surface Treatments; Polymers and Films; Polymer Matrix Composites; Metals, Ceramics, and Optical Materials; Lubricants Adhesives, Seals, Fasteners, Solar Cells, and Batteries. This report contains most of the papers presented at the Technical sessions. It also contains theme panel reports and visual aids. This document continues the LDEF Space Environmental Effects on Materials Special Investigation Group (MSIG) pursuit of its charter to investigate the effects of LEO exposure on materials which were not originally planned to be test specimens and to integrate this information with data generated by Principal Investigators into an LDEF Materials Data Base.

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