NASA Conference Publication 10046

LDEF Materials Data Analysis Workshop

N90-26075

(NASA-CP-10046) PROCEEDINGS OF THE LDEF MATERIALS DATA ANALYSIS WORKSHOP (NASA) 289 p CSCL 07A

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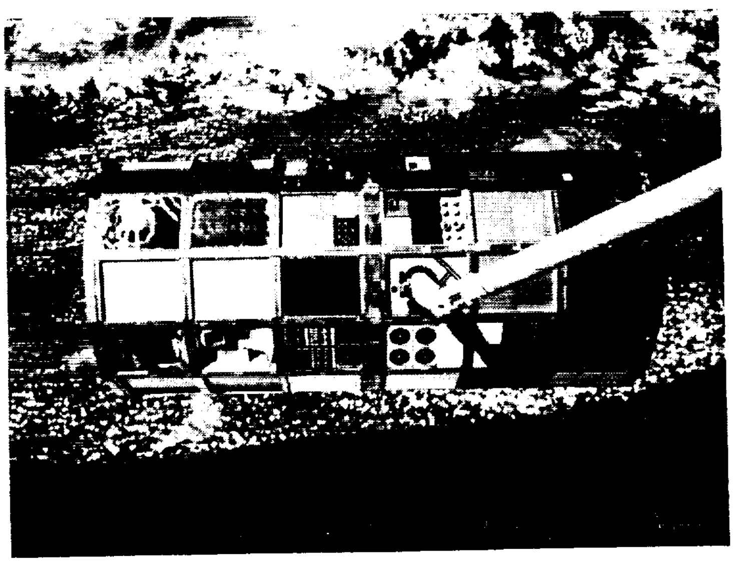

Compiled by
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Langley Research Center
Hampton, Virginia

Proceedings of a workshop sponsored by Langley Research Center and held at John F. Kennedy Space Center
Kennedy Space Center, Florida
February 13–14, 1990

July 1990

NASA
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665-5225

NASA
LONG DURATION EXPOSURE FACILITY

LDEF
MATERIALS DATA ANALYSIS WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

FOREWORD

The National Aeronautics and Space Administration Long Duration Exposure Facility (LDEF) was launched into low-Earth orbit (LEO) from the payload bay of the Space Shuttle Orbiter Challenger in April 1984. It was retrieved from orbit by the Columbia in January 1990. The original flight plan called for a 1-year mission. The extended time in orbit, some 4 years and 10 months longer than originally planned, generally enhanced the value of the 57 LDEF experiments which covered the disciplines of materials, coatings, and thermal systems; power and propulsion; space science; and electronics and optics. LDEF was designed to provide a large number of economical opportunities for science and technology experiments that require modest electrical power and data processing while in space and which benefit from post-flight laboratory investigations of the retrieved experiment hardware on Earth. Most of the materials experiments were completely passive; their data must be obtained in post-flight laboratory tests and analyses.*

The 5-year, 10-month flight of LDEF greatly enhanced the potential value of most LDEF materials, compared to that of the original 1-year flight plan. NASA recognized this potential by forming the LDEF Space Environmental Effects on Materials Special Investigation Group (MSIG) in early 1989 to address the expanded opportunities available in the LDEF structure and on experiment trays, so that the value of all LDEF materials data to current and future space missions would be assessed and documented. (Similar Special Investigation Groups were formed for the disciplines of Ionizing Radiation, Systems, and Meteoroids/Debris.) MSIG was chartered to investigate the effects of the long LEO exposure on structure and experiment materials which were not originally planned to be test specimens and to integrate the

*Clark, Lenwood G., Kinard, William H., Carter, David J. Jr., and Jones, James L. Jr. (Eds.): The Long Duration Exposure Facility (LDEF). NASA SP-473, 1984.

results of this investigation with data generated by the Principal Investigators of the LDEF experiments into the LDEF Materials Data Base. This LDEF Materials Data Analysis Workshop addressed the plans (and those of other LDEF groups) resulting from that charter (and similar charters for the other disciplines). The workshop ran concurrently with the activities surrounding the successful return of the LDEF spacecraft to the NASA Kennedy Space Center. This document is a compilation of the visual aids utilized by the speakers at the workshop.*

The LDEF Materials Data Analysis Workshop had several objectives. Session 1 summarized current information on analysis responsibilities and plans; this information was aimed at updating the workshop attendees: the LDEF Advisory Committee, Principal Investigators (PIs), Special Investigation Group Members, and others involved in LDEF analyses or management. Workshop Sessions 2 and 3 addressed materials data analysis methodology, specimen preservation/shipment/archival, and initial plans for the LDEF Materials Data Base. An equally important objective of this workshop was to stimulate interest and awareness of the opportunities to vastly expand the overall data base by considering the entire spacecraft as a materials experiment. To this end, the voluntary contribution and sharing of samples between PIs and MSIG were encouraged. These samples include both materials on experiment trays which were not intended to be test specimens and material test specimens which are available after the original test objectives have been achieved.

The synergistic effects of atomic oxygen, ultraviolet and particulate radiation, thermal cycling, and vacuum in the 5-year, 10-month LEO exposure of materials on LDEF will produce a data base unparalleled in the history of space environmental effects. Data of this type will not be available again until Space Station Freedom has deployed a materials exposure experiment for more than 6 years. Thus, the LDEF Principal Investigators and Materials Special Investigation Group now have the unique opportunity and responsibility to significantly contribute to spacecraft design, verification of analysis models based on previous in-space and Earth laboratory data on space materials, and planning of space research and development for the 1990s and into the 21st century. This workshop served as one step toward the realization of that opportunity.

Bland A. Stein   Philip R. Young

Bland A. Stein and Philip R. Young
Co-Chairmen, LDEF Materials Data Analysis Workshop

Notes: These charts reflect general understanding of space environmental effects on materials, prior to specific analyses of LDEF materials specimens. The LDEF materials analysis plans presented herein are subject to revision as the analyses proceed during the next several years.

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CONTENTS (CONCLUDED)

NASA
LONG DURATION EXPOSURE FACILITY

INTRODUCTION

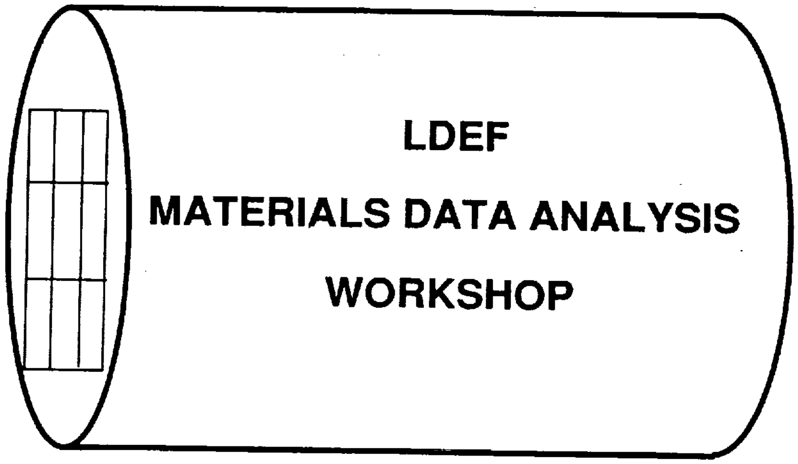
BLAND A. STEIN

NASA - LANGLEY RESEARCH CENTER
WORKSHOP CO-CHAIRMAN

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

LONG DURATION EXPOSURE FACILITY



NASA - KENNEDY SPACE CENTER
BUILDING M7-351, TRAINING AUDITORIUM

FEBRUARY 13 & 14, 1990

LONG DURATION EXPOSURE FACILITY

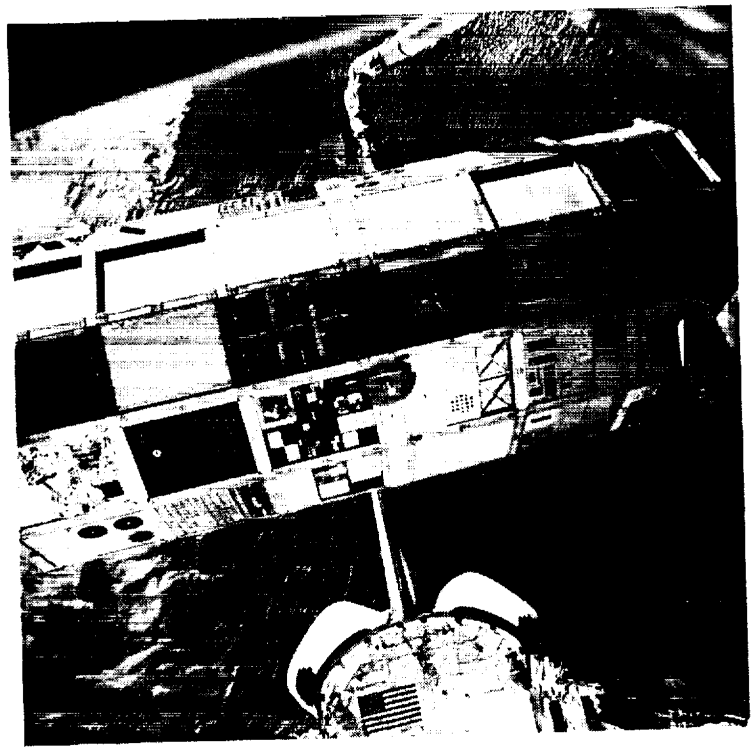
MATERIALS DATA ANALYSIS WORKSHOP

INTRODUCTION

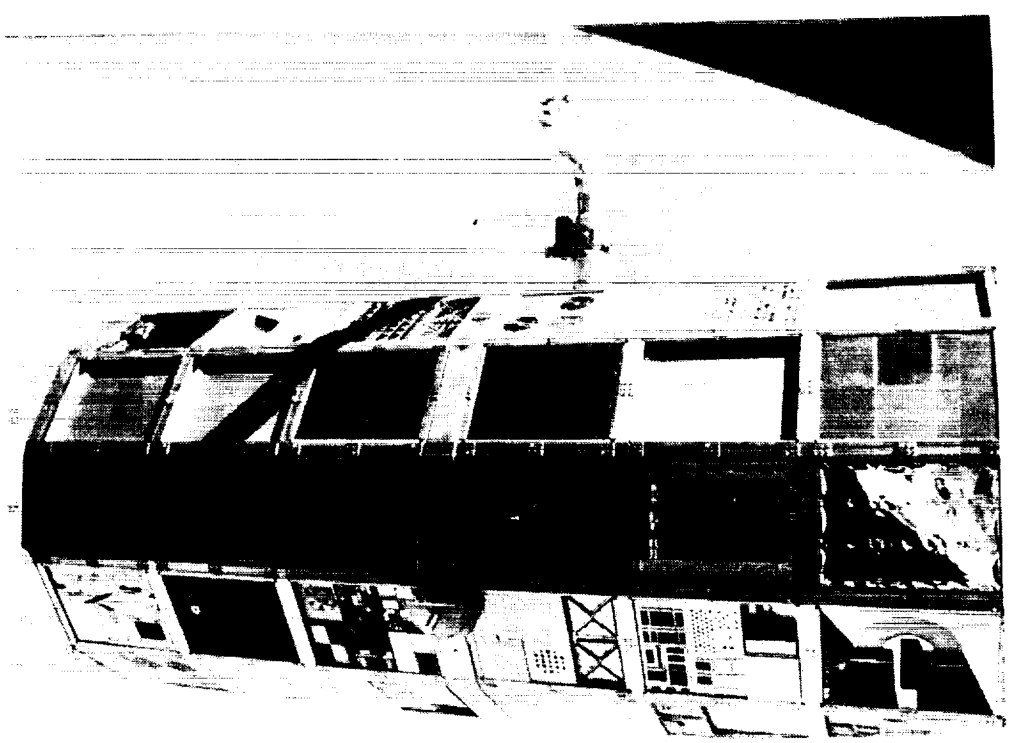
BLAND A. STEIN
NASA - LANGLEY RESEARCH CENTER,
WORKSHOP CHAIRMAN

LDEF MATERIALS DATA ANALYSIS WORKSHOP
NASA - KENNEDY SPACE CENTER
FEBRUARY, 1990

LDEF Retrieval.



LDEF Launch.



LDEF INSPECTION TEAM

LDEF RETRIEVAL OBSERVATIONS FROM DOWNLINK VIDEO, IN-SPACE PHOTOGRAPHS, AND INITIAL KSC OBSERVATIONS

GENERAL

- NO STRUCTURAL DAMAGE
- NO UNANTICIPATED PHENOMENA
- DAMAGE TO THIN FILMS, COATINGS, AND THERMAL BLANKET MATERIALS ON EXPERIMENT TRAYS, PREDOMINANTLY ON:
  - LEADING EDGE
  - SPACE END
- FLOATING DEBRIS VISIBLE NEAR LDEF, ESPECIALLY AFTER GRAPPLE
- MINIMAL DEBRIS IN CARGO BAY; SOLAR CELL MODULE ONLY LARGE PIECE OF DEBRIS FOUND
- LOCALIZED CONTAMINATION ON LDEF SURFACES IN SEVERAL AREAS

LDEF INSPECTION TEAM

LDEF RETRIEVAL OBSERVATIONS FROM DOWNLINK VIDEO, IN-SPACE PHOTOGRAPHS, AND INITIAL KSC OBSERVATIONS (CONTINUED)

MECHANISMS AND SYSTEMS

- ALL FIVE EXPERIMENT EXPOSURE CONTROL CANISTERS (EECCs) ON LDEF CLOSED, AS PLANNED
- A CLAMSHELL CANISTER IS OPEN (PROBABLY CLOSED AND REOPENED)
- MSFC THERMAL CONTROL SURFACES EXPERIMENT (A0069) MECHANISMS APPEAR TO HAVE FUNCTIONED CORRECTLY.

MICROMETEOROID AND DEBRIS EFFECTS

- SIGNIFICANT MICROMETEOROID AND DEBRIS IMPACTS OBSERVED ON EXPERIMENT TRAYS; IMPACTS GENERALLY CONSISTENT WITH EXPECTATIONS.
- NO LARGE, CATASTROPHIC IMPACT EVENTS DETECTED.
- MORE MICROMETEOROID/DEBRIS DAMAGE APPARENT ON LEADING EDGE THAN ON TRAILING EDGE.
- IMPACTS ALSO OBSERVED ON LDEF STRUCTURE.

LDEF INSPECTION TEAM

LDEF RETRIEVAL OBSERVATIONS FROM DOWNLINK VIDEO, IN-SPACE PHOTOGRAPHS, AND INITIAL KSC OBSERVATIONS (CONCLUDED)

<u>ATOMIC OXYGEN EFFECTS</u>

- SIGNIFICANT ATOMIC OXYGEN DEGRADATION OBSERVED ON MOST LEADING EDGE EXPERIMENTS.
- MORE THAN 0.005-INCH DEGRADATION OF KAPTON AND MYLAR FILMS ON LEADING EDGE EXPERIMENTS.
- SURFACES OF SILVER/TEFLON THERMAL BLANKETS ON LEADING EDGE TURNED "MILKY" WHITE.
- THERMAL CONTROL PAINT "TARGET SPOTS" REMAINED WHITE ON ENTIRE LEADING FACE OF LDEF.

<u>ULTRAVIOLET RADIATION EFFECTS</u>

- THERMAL CONTROL PAINT TARGET SPOTS DISCOLORED ON TRAILING FACE, EARTH END, AND SPACE END OF LDEF.

<u>INDUCED RADIATION EFFECTS</u>

- INDUCED RADIATION SURVEYS SHOW MEASUREABLE RADIOACTIVE ACTIVITY.
- NO THREATS TO HUMAN HEALTH.

LDEF MATERIALS DATA ANALYSIS WORKSHOP

SESSION 1: LDEF DATA ANALYSIS RESPONSIBILITIES AND PLANS

<u>OBJECTIVE</u>: Understanding of the breadth and potential of LDEF experimental and analytical data by LDEF Advisory Committee, Principal Investigators, Special Investigation Groups, and other Workshop Attendees

<u>APPROACH</u>: Presentations and Interactive discussions on

- LDEF
- LDEF Science Office and NASA HQ Management
- Supporting Data Group plans
- Special Investigation Group plans
- Principal Investigator Plans

LDEF MATERIALS DATA ANALYSIS WORKSHOP

SESSION 2: MATERIALS DATA ANALYSIS METHODOLOGY DISCUSSIONS
AND
SESSION 3: MATERIALS ANALYSIS, DATA BASE, AND PRESERVATION

OBJECTIVE: Stimulate interest and awareness of the opportunities to expand the LDEF data base through:

- Understanding the potential of data synergism
- Voluntary contribution of materials which:

  were not originally planned to be test specimens
  or
  were duplicate specimens in the experiment
  or
  are specimens whose initial experiment objectives have been satisfied

APPROACH: Interactive discussions on analysis methodology

- Characterization
- Surface science
- Atomic oxygen
- Contamination
- Other parameters which define (or obscure) the data
- Specimen preservation and shipment

NASA
LONG DURATION EXPOSURE FACILITY

NASA HEADQUARTERS PERSPECTIVE

ROBERT J. HAYDUK

NASA HEADQUARTERS
LDEF SCIENCE PROGRAM MANAGER

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

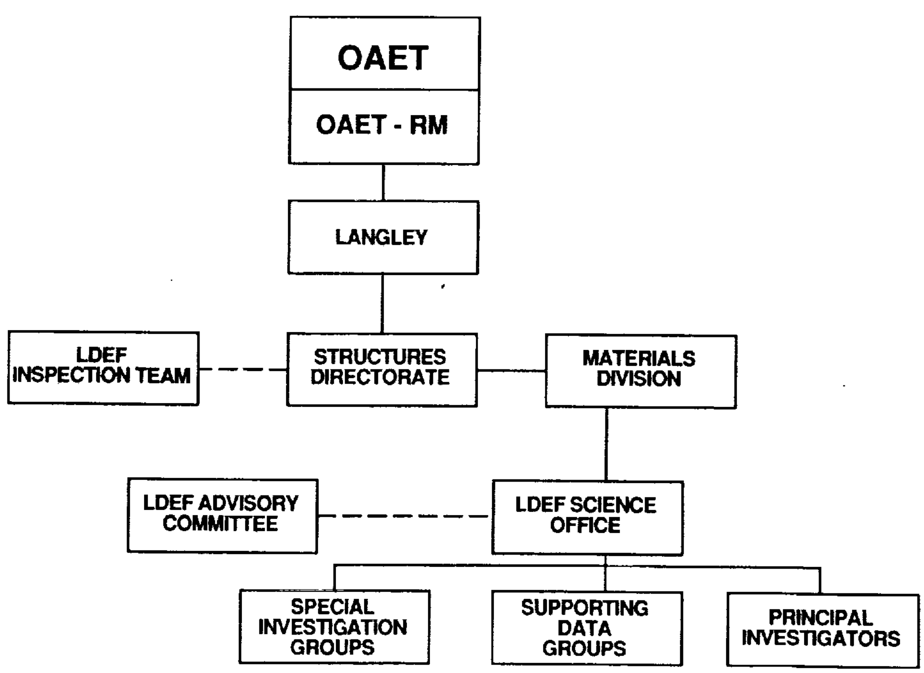
NASA HEADQUARTERS PERSPECTIVE OF LONG DURATION EXPOSURE FACILITY

BY

ROBERT J. HAYDUK
LDEF SCIENCE PROGRAM MANAGER
OAST, MATERIALS & STRUCTURES DIVISION

LDEF MATERIALS DATA ANALYSIS WORKSHOP
NASA KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

LDEF SCIENCE ORGANIZATION



LDEF HISTORY

- LDEF Announcement of Opportunity (OAET-76-1)
- "Solicited Research Experiments in Long Duration Testing in Space" in Areas of Interest to OAET, OSSA, & OSF
- Open to NASA, Universities, Industry, U.S. Government Agencies, & Foreign Participants
- AA OAET Selected Experiments

LDEF - EARLY 80's

- "Laboratory in the Sky"
- Many Flight Opportunities
- Sequential Plan of Experiments
  - Flights: A, B, C, etc.
  - Experiments: Based on Experiments of Prior Flights
  - Develop Large Data Base

LDEF - LATE 80's

- One Flight Opportunity
- LDEF Spacecraft & Experiments
  - Have Higher Interest & Potential-Payoff
- Significant Changes in Science Plan

  200 Principal Investigators

  Plus

  Special Investigation Groups
  - Materials
  - Environmental Stability
  - etc.

LDEF SCIENCE PROGRAM

OBJECTIVE

o Maximize Science Return From LDEF Mission

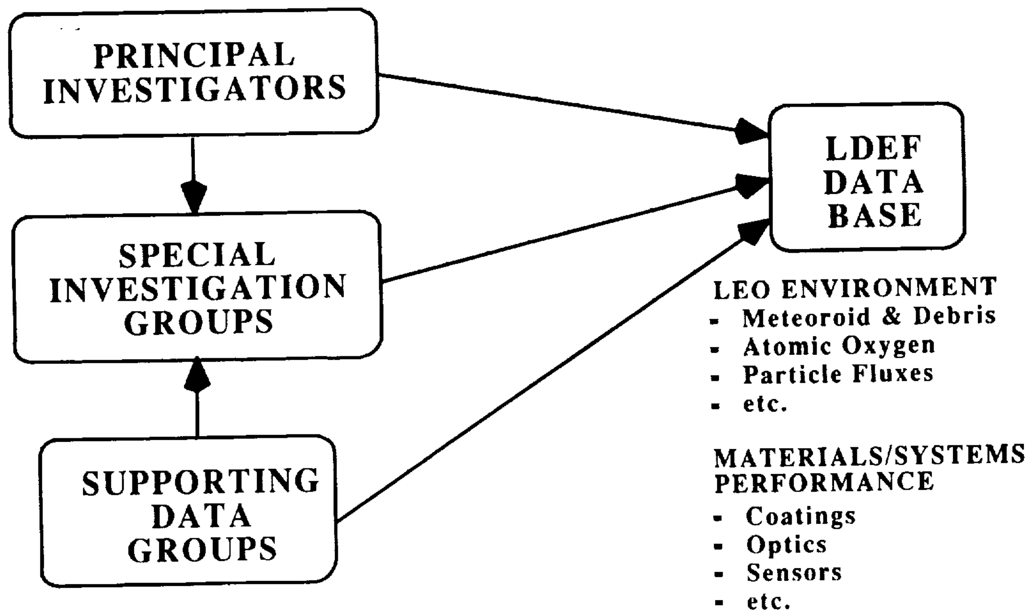
APPROACH

o Integrated Plan for Data Analysis

o Documentation and Timely Dissemination of Data

o Science Team of International Stature

LDEF SCIENCE



SUMMARY

- LDEF IS A UNIQUE OPPORTUNITY TO OBTAIN SCIENTIFIC AND TECHNOLOGICAL INFORMATION IN COLLABORATION WITH PRINCIPAL INVESTIGATORS FROM THE UNITED STATES AND NINE OTHER COUNTRIES, FOUR SPECIAL INVESTIGATION GROUPS, AND THREE SUPPORTING DATA GROUPS.

- AN LDEF DATA BASE WILL BE ASSEMBLED AND MANAGED TO COLLECT ALL SCIENTIFIC AND TECHNOLOGICAL RESULTS. THIS DATA BASE WILL BE ACCESSIBLE TO THE INTERNATIONAL SCIENTIFIC COMMUNITY.

- LDEF RESULTS WILL BE OF SIGNIFICANT BENEFIT TO FUTURE SPACE SYSTEMS.

LDEF DATA ANALYSIS PROJECT OFFICE OVERVIEW

DARREL R. TENNEY

NASA - LANGLEY RESEARCH CENTER
CHIEF, MATERIALS DIVISION

LDEF MATERIALS DATA ANALYSIS WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

LDEF DATA ANALYSIS

Darrel R. Tenney
Materials Division
NASA Langley Research Center

LDEF Materials Data Analysis Planning Workshop
NASA Kennedy Space Center
February 13, 1990

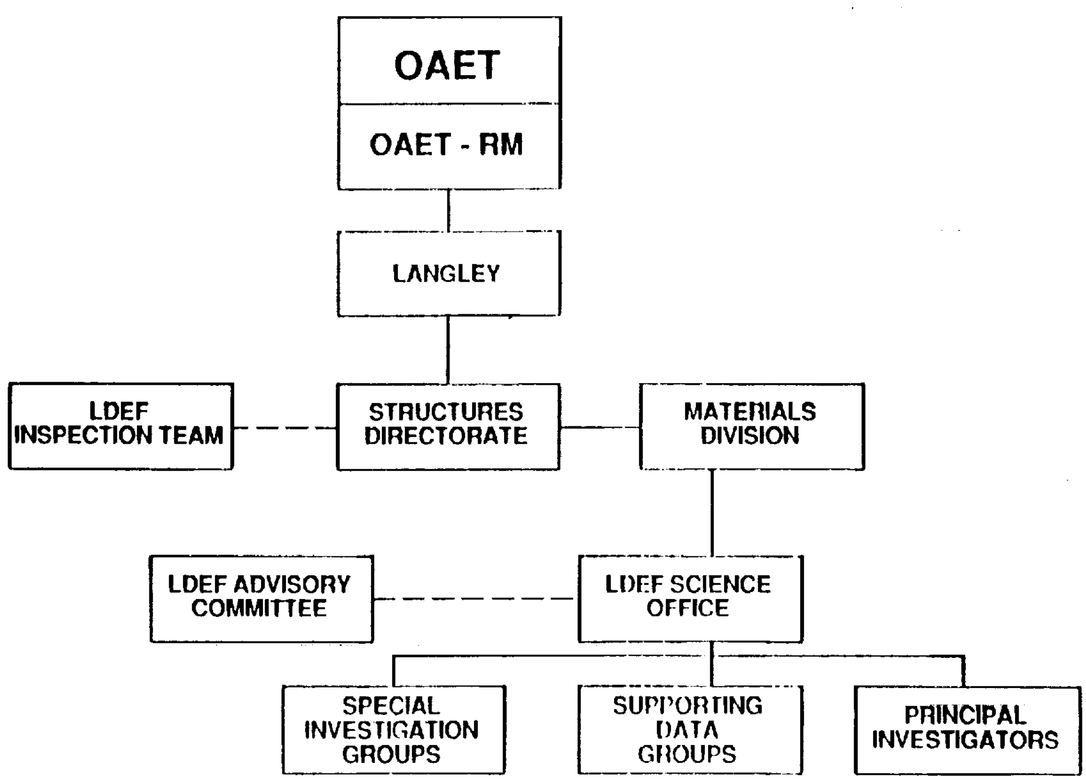
LONG DURATION EXPOSURE FACILITY

- Launched - April 1984 Retrieval - January 1990
- 57 Technology, Science, and Applications Experiments
  (More than 10,000 test specimens)
- Participants
  - P.I.'s: >200
  - Countries: 9
  - Industry: 33
  - Universities: 21
  - NASA Centers: 7
  - DOD Labs: 9
  - Special Investigation Groups (Approx. 60 participants)
    (Materials, Systems, Meteoroid/Debris, & Radiation)

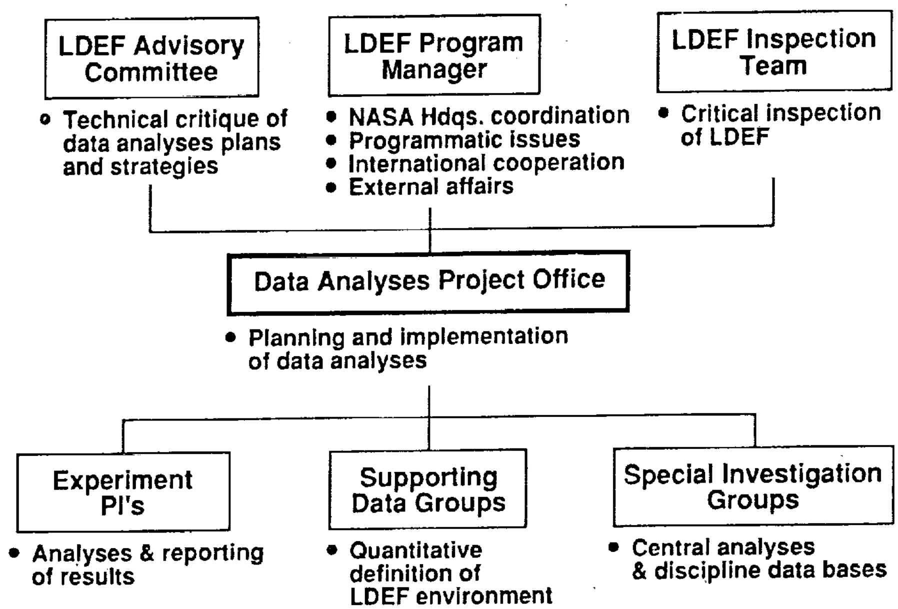
LDEF EXPERIMENTS (57 TOTAL)

- MATERIALS AND COATINGS (20 TOTAL)
  - NASA, 11
  - INDUSTRY, 2
  - DOD, 1
  - FRANCE, 4
  - CANADA, 1
  - TEXAS A&M, 1
- PROPULSION, POWER, AND ENERGY (8 TOTAL)
  - NASA, 5
  - WEST GERMANY, 1
  - MORTON THIOKOL, 1
  - McDONNELL DOUGLAS, 1
- INFORMATION SCIENCES AND HUMAN FACTORS (14 TOTAL)
  - NASA, 7
  - UK, 1
  - DOD, 2
  - FRANCE, 4
- SCIENCE (15 TOTAL)
  - NASA, 6
  - DOD, 2
  - UK, 1
  - GERMANY, 2
  - NETHERLANDS, 1
  - FRANCE, 2
  - PARK SEED, 1

LDEF SCIENCE ORGANIZATION



LDEF DATA ANALYSIS GROUPS AND FUNCTIONAL RESPONSIBILITIES



LDEF ADVISORY COMMITTEE

Membership, February, 1990

- Chairman: J. Garibotti, Ketema
- Executive Secretary: R. Hayduk, NASA Hq.

- U.S. Spacecraft Industry
  - J. Blumenthal, TRW
  - E. Littauer, Lockheed
  - S. Greenberg, Aerojet
  - H. S. Greenberg, Rockwell
  - M. Misra, Martin-Marietta
  - G. Wadsworth, Boeing
  - H. Babel, McDonnell Douglas
  - J. Schiewe, Aerospace Corp.

- NASA - User Community
  - J. Moacanin, JPL
  - K. Faymon, LeRC
  - D. Wade, JSC
  - H. Price, GSFC
  - A. Edwards, Space Station Freedom

- Science Community
  - J.Wightman, Va. Tech
  - J. Lewis, U. Arizona
  - R. Naumann, MSFC

- Department of Defense
  - A. Young, SDIO
  - M. Minges, USAF-WRDC

LDEF INSPECTION TEAM

Assess "Normality" of LDEF Spacecraft & Science Experiments

Membership

Chairman - Darrel R. Tenney - LaRC

Bland A. Stein - LaRC
Bill Kinard - LaRC
Lubert Leger - JSC
Ann Whitaker - MSFC
Tom Parnell - MSFC

Dr. William Lehn - WRDC
Lt. Dale Atkinson - AF Weapons Lab.
Bob Hayduk - NASA Headquarters
Jim Mason - GSFC

LONG DURATION EXPOSURE FACILITY

INSPECTION TEAM

REPORT TO OAET MANAGEMENT

DARREL R. TENNEY

NASA - KENNEDY SPACE CENTER
FEBRUARY 8, 1990

PI RELATIONS

- MOU/MOA's - (1) Trays Returned to PI's

  (2) PI's provide data to NASA/Science Community

- Addendum's to MOU/MOA's (Planned)

  -- Identify specific samples/data SIG's require

SUPPORTING DATA GROUPS

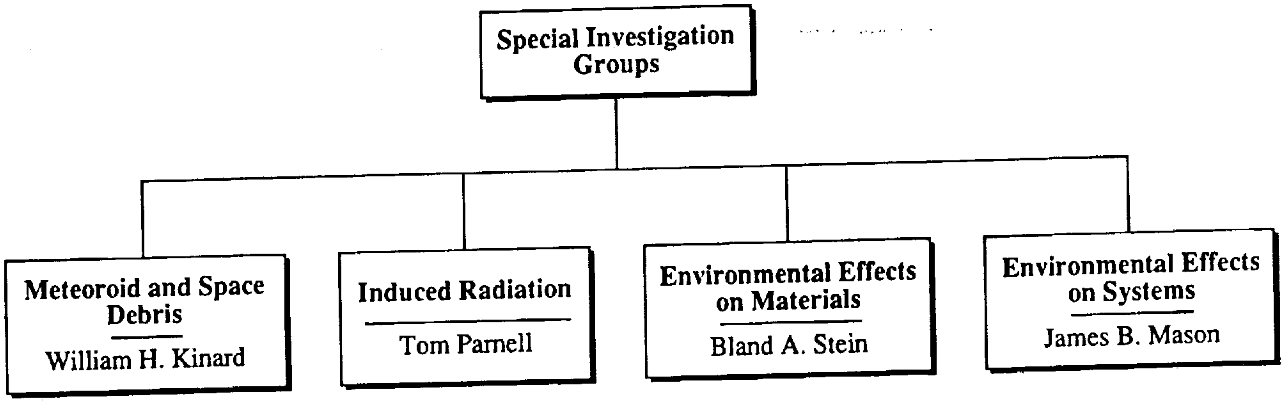
Environments: William Kinard, LaRC

1. Solar and Planetary Fluxes - William Berrios, LaRC
2. Particle Fluxes - Gene Benton, San Francisco State Univ.
3. Atomic Oxygen Fluxes - Lubert Leger, JSC
4. Meteoroid and Space Debris Fluxes
   - Don Humes, LaRC; Don Kessler, JSC
5. Contamination - Lubert Leger, JSC
6. Time Line of Operational Events - Larry Brumfield, LaRC

Spacecraft Thermal: William M. Berrios, LaRC

Orbit and Orientation: Mel Kelly, Analytical Mechanical Associates

LDEF Special Investigation Groups



SPECIAL INVESTIGATION GROUPS
(SIG)

STRATEGY

- Four working groups established (Jan. 1989) to address key technology areas which are broader than individual experiments
- Technical expertise was the principal criteria for selection of participants
- LDEF facilities and experiments studied to identify samples and systems of key interest from a total LDEF perspective
- Contracts established to provide central analyses of samples with state-of-the-art analyses techniques and procedures
- SIG's providing key mechanism to implement cooperative activities between PI's, NASA, and DOD

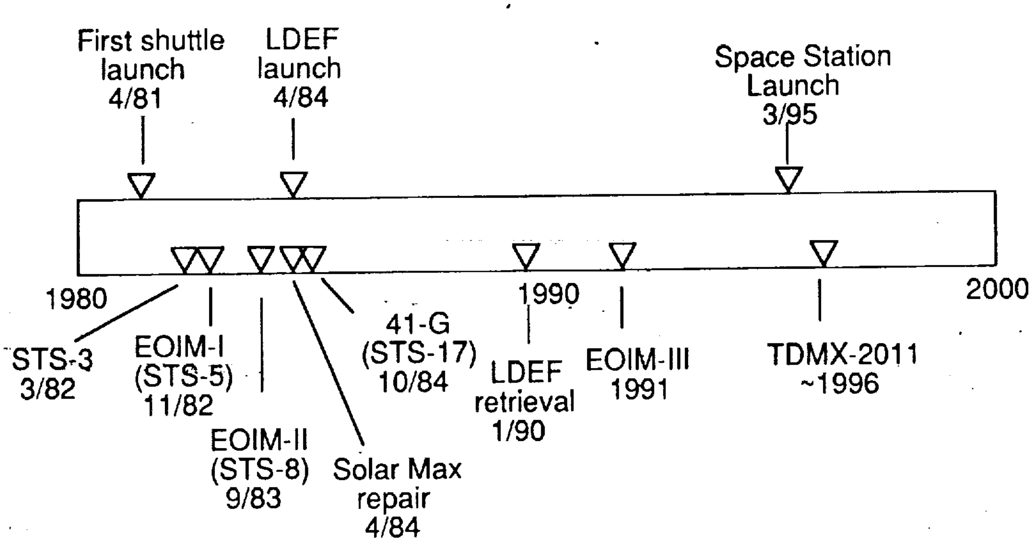
LDEF DATA ANALYSIS

Thrusts	FY-89	FY-90	FY-91	FY-92	FY-93	Expected results
LDEF retrieval	Retrieval & inspection	▽1 ▽1				• Early assessment of space environmental effects
Environment definition	LDEF supporting data	▽2 ▽2				• Definition of LDEF mission environment
LDEF experiment data analysis	Individual experiment analyses by Principal Investigators	▽3	▽4	▽5		• Effects of LDEF exposure on materials & systems • Enhanced models for space environmental effects
Special investigations & documentation	Materials/Systems/Debris impact/Radiation analyses by Special Investigation Groups	▽3	▽4	▽5	▽6	• Space environmental effects handbooks for low earth orbit exposures

Major milestones

- ▽1 LDEF retrieval & "quick-look-inspection" findings
- ▽2 Supporting data packages to PI's & SIG's
- ▽3 LDEF investigator workshop to compare preliminary data
- ▽4 LDEF data conference
- ▽5 LDEF data & space environmental effects models symposium
- ▽6 LDEF materials, systems, & debris effects data bases documented

SHUTTLE FLIGHTS WITH SAMPLE RETURNS



NASA
LONG DURATION EXPOSURE FACILITY

LDEF SUPPORTING DATA GROUP PLANS

- ENVIRONMENTS
- ORBIT AND ORIENTATION

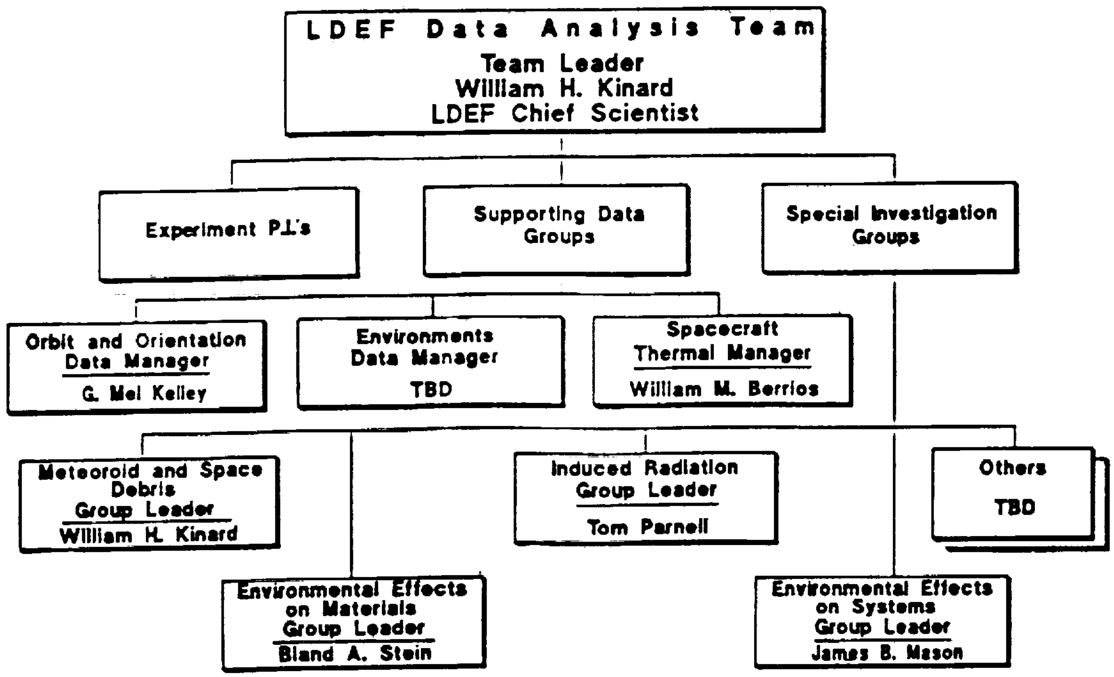
WILLIAM H. KINARD

NASA - LANGLEY RESEARCH CENTER
LDEF CHIEF SCIENTIST

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

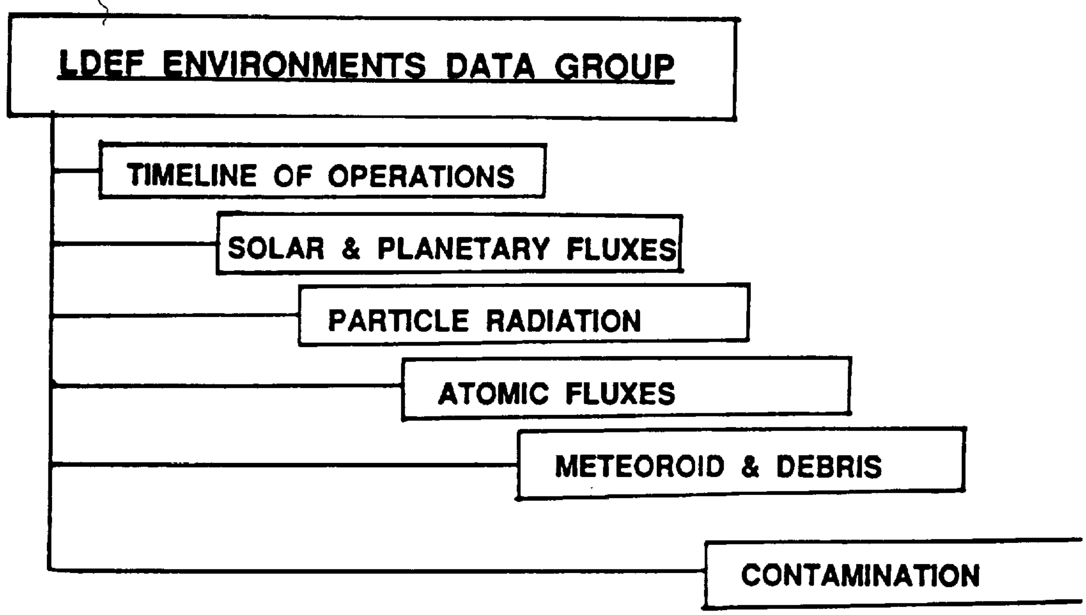
LDEF DATA ANALYSIS TEAM & SUPPORTING DATA GROUP



LDEF FIRST MISSION EXPERIMENTS

CRYSTAL GROWTH
ATOMIC OXYGEN OUTGASSING
ATOMIC OXYGEN INTERACTION
HIGH-TOUGHNESS GRAPHITE EPOXY
RADAR PHASED-ARRAY ANTENNA
COMPOSITE MATERIALS FOR SPACE STRUCTURES
EPOXY MATRIX COMPOSITES
COMPOSITE MATERIALS
METALLIC MATERIALS UNDER ULTRAVACUUM
GRAPHITE-POLYIMIDE AND GRAPHITE-EPOXY
POLYMER MATRIX COMPOSITE MATERIALS
SPACECRAFT MATERIALS
BALLOON MATERIALS DEGRADATION
THERMAL CONTROL COATINGS
SPACECRAFT COATINGS
THERMAL CONTROL SURFACES
TEXTURED AND COATED SURFACES
VARIABLE CONDUCTANCE HEAT PIPE
LOW-TEMPERATURE HEAT PIPE
TRANSVERSE FLAT-PLATE HEAT PIPE
THERMAL MEASUREMENTS
HIGH VOLTAGE DRAINAGE
SOLAR ARRAY MATERIALS
ADVANCED PHOTOVOLTAICS
COATINGS AND SOLAR CELLS
SOLID ROCKET MATERIALS
INTERSTELLAR GAS
ULTRA-HEAVY COSMIC RAY NUCLEI
HEAVY IONS
TRAPPED-PROTON ENERGY SPECTRUM
HEAVY COSMIC RAY NUCLEI
LINEAR ENERGY TRANSFER SPECTRUM
MICROABRASION PACKAGE
METEOROID IMPACT CRATERS
DUST DEBRIS COLLECTION
CHEMISTRY OF MICROMETEOROIDS
MEASUREMENTS OF MICROMETEOROIDS
INTERPLANETARY DUST
SPACE DEBRIS IMPACT
METEOROID DAMAGE
BIOSTACK
SEEDS IN SPACE
STUDENT SEEDS EXPERIMENT
HOLOGRAPHIC DATA STORAGE CRYSTALS
INFRARED MULTILAYER FILTERS
PYROELECTRIC INFRARED DETECTORS
METAL FILM AND MULTILAYERS
VACUUM-DEPOSITED OPTICAL COATINGS
RULED AND HOLOGRAPHIC GRATINGS
OPTICAL FIBERS AND COMPONENTS
ERB EXPERIMENT COMPONENTS
SOLAR RADIATION ON GLASSES
QUARTZ CRYSTAL OSCILLATORS
ACTIVE OPTICAL SYSTEM COMPONENTS
FIBER OPTIC DATA TRANSMISSION
FIBER OPTICS SYSTEMS
SPACE ENVIRONMENT EFFECTS

ENVIRONMENTS DATA



ORBIT AND ORIENTATION DATA

- Initial Orbit -
  - Inclination
  - Perigee Altitude
  - Apogee Altitude
  - Semi-major Axis Altitude
- Time History of Semi-major Axis Altitude Decay
- Orientation and Range of Oscillations About Each Axis

NASA
LONG DURATION EXPOSURE FACILITY

LDEF SUPPORTING DATA GROUP PLANS
- SPACECRAFT THERMAL

WILLIAM M. BERRIOS

NASA - LANGLEY RESEARCH CENTER
MEMBER, SUPPORTING DATA GROUP

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

LONG DURATION EXPOSURE FACILITY
LDEF

LDEF THERMAL DATA

LDEF THERMAL

TOPICS OF DISCUSSION

- OBJECTIVE
- APPROACH
- EFFECTS OF EXTENDED MISSION
- DATA REDUCTION PLAN
- STATUS

LDEF THERMAL

OBJECTIVE

- VALIDATE THE LDEF THERMAL MODEL
- ASSESS THE EFFECTS OF THE EXTENDED MISSION ON THE LDEF PREDICTED TEMPERATURES
- UPDATE THE LDEF END OF MISSION CALCULATED TEMPERATURES
- PROVIDE SCIENCE COMMUNITY WITH DATA DESCRIBING THE THERMAL ENVIRONMENT EXPERIENCED BY THE LDEF EXPERIMENTS

LDEF THERMAL

APPROACH

- UPDATE THERMAL MODEL ORBITAL PARAMETERS
- COMPARE AND VALIDATE BEGINNING OF MISSION THERMAL MODELS WITH RECORDED FLIGHT TEMPERATURE DATA
- SURVEY THE LDEF SURFACES END OF MISSION A/E PROPERTIES
- UPDATE THE LDEF THERMAL MODELS WITH END OF MISSION A/E PROPERTIES
- RUN END OF MISSION THERMAL MODELS
- PREPARE AND DISTRIBUTE THE LDEF THERMAL DATA PACKAGES

LDEF THERMAL

DATA PACKAGE

- BOUNDARY CONDITIONS

  BEGINNING/END OF MISSION

  ORBITAL PARAMETERS
  HEAT FLUXES
  SURVEY OF THERMAL COATINGS
  LDEF STRUCTURE TEMPERATURES

- CALCULATED LDEF TEMPERATURES

  BEGINNING OF MISSION

  DEPLOYMENT ALTITUDE
  NEW COATINGS
  HOT & COLD CASES
  1 YEAR BETA ANGLE TRACKING

  END OF MISSION

  RETRIEVAL ALTITUDE
  DEGRADED COATINGS
  HOT & COLD CASES
  1 YEAR BETA ANGLE TRACKING

LDEF THERMAL

EFFECTS OF EXTENDED MISSION

- Temperature data recorded for the first year of the LDEF mission. There are no active measurements of the LDEF temperatures for the remainder of the extended mission.
- Data mismatch. There are no recorded end of mission temperatures to correlate with the measured end of mission coatings.
- Uneven degradation of coatings will require increased sampling of thermal coatings in order to characterize their behavior.
- Role of coatings interaction effects on their thermal control performance needs to be characterized.
- On-board passive attitude detectors may be saturated at this time.

LDEF THERMAL

DATA REDUCTION PLAN

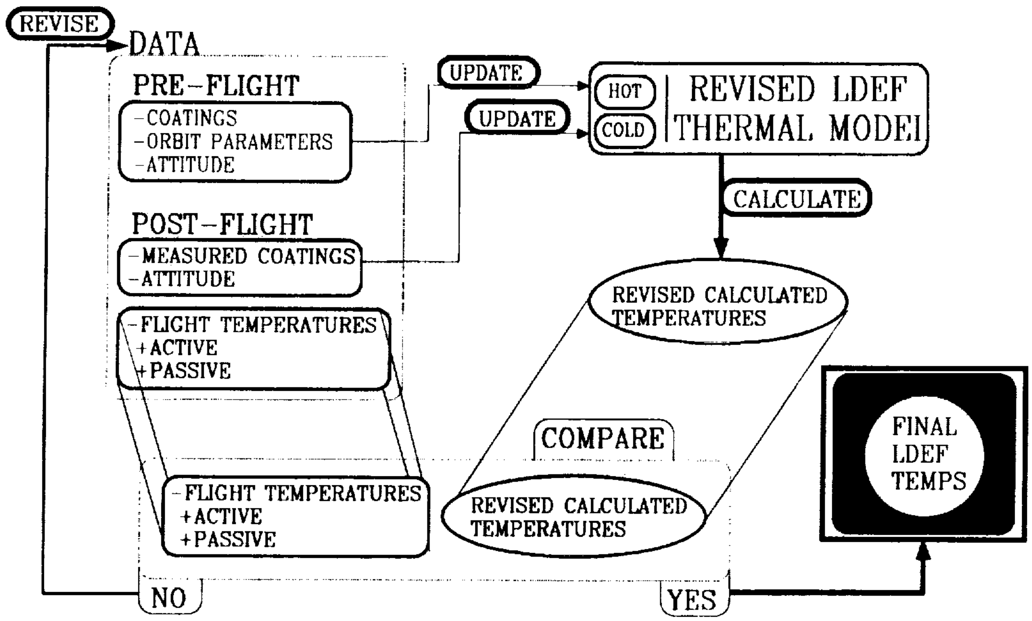
- BEGIN MEASUREMENT OF A/E PROPERTIES BY FEBRUARY 20, 1990
- BEGIN UPDATE OF THERMAL MODEL A/E VALUES BY FEBRUARY 23, 1990
- COMPLETE END OF MISSION SURVEY OF THERMAL SURFACES A/E PROPERTIES BY END OF MARCH 1990
- RECEIVE FLIGHT TEMPERATURE DATA BY END OF MARCH 1990
- PRELIMINARY REPORT BY SUMMER 1990
- FINAL REPORT BY WINTER 1990

LDEF THERMAL

DATA REDUCTION STATUS

- AQUIRED NEW INSTRUMENTATION FOR MEASUREMENT OF SOLAR ABSORPTANCE
- LOCATED INSTRUMENTATION IN THE SAEF II CLEAN ROOM AREA
- LOCATED OPERATIONS CENTER ON SUPPORT TRAILER 633
- OPENED DATA LINE TO LaRC COMPUTING FACILITIES
- PERFORMED INSTRUMENTATION CHECK-OUT
- PERFORMED A/E MEASUREMENTS OF THERMAL PANELS REMOVED FROM THE FACILITY
- PERFORMED A/E MEASUREMENTS OF SILVERED TEFLON SURFACES ON LOCATIONS A10 & B11
- READY FOR MEASUREMENT OF LDEF THERMAL COATINGS DURING DEINTEGRATION SCHEDULE

LDEF THERMAL DATA REDUCTION PLAN



NASA
LONG DURATION EXPOSURE FACILITY

SPECIAL INVESTIGATION GROUP PLANS

- METEOROID AND DEBRIS SIG

WILLIAM H. KINARD

NASA - LANGLEY RESEARCH CENTER
CHAIRMAN, M&DSIG

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

LDEF M&D SIG CHARTER

To exploit the wealth of M&D data recorded on the LDEF during the 5 1/2 year space exposure in space by:

- *Ensuring that natural meteoroid and man-made debris craters in retrieved LDEF and experiment hardware, which were not originally intended to be meteoroid & debris test specimens, are identified, investigated, and archived for future investigations.*

- *Coordinating the data obtained by the LDEF meteoroid & debris experiment P.I.'s with the data obtained by this SIG into a single LDEF METEOROID & DEBRIS DATA BASE for use by engineers and scientists in future studies.*

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NASA
LONG DURATION EXPOSURE FACILITY

SPECIAL INVESTIGATION GROUP PLANS
- SYSTEMS SIG

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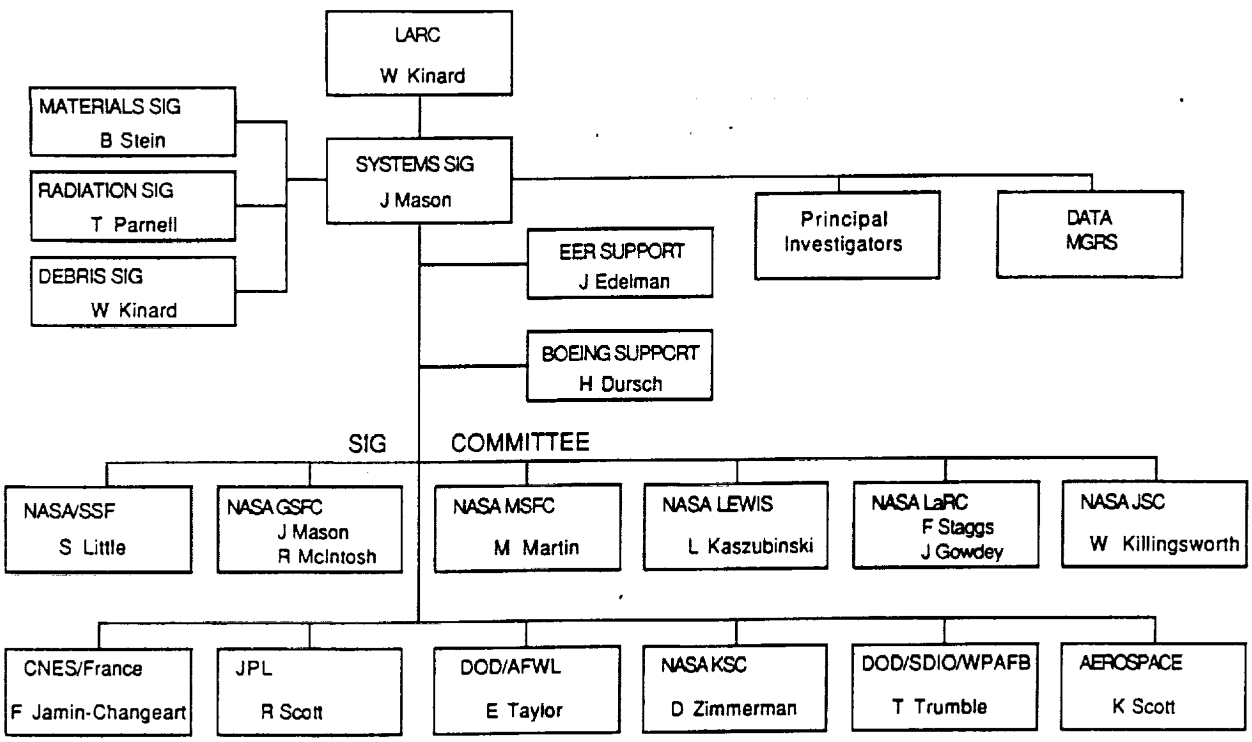
SSIG SUPPORT

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

LDEF SPACE ENVIRONMENTAL EFFECTS ON SYSTEMS

SPECIAL INVESTIGATION GROUP



LDEF SYSTEMS SIG

CHARTER

INVESTIGATE THE EFFECTS OF THE NEARLY SIX YEAR EXPOSURE IN SPACE ON LDEF AND EXPERIMENT SYSTEMS.

COORDINATE THE DATA FROM THE ANALYSIS OF THE LDEF AND EXPERIMENT SYSTEMS INTO A SINGLE LDEF SYSTEMS DATA BASE.

LDEF SYSTEMS SIG

OBJECTIVE

- DEVELOPMENT OF THE LDEF SYSTEMS DATA BASE

SYSTEMS SIG

<u>ROLE OF LDEF SYSTEMS SIG:</u>

- DEFINE LDEF DATA BASE REQUIREMENTS
- DEFINE LDEF SYSTEMS FOR ANALYSIS AND MEASUREMENT
- DEFINE MEASUREMENT PROGRAM FOR SELECTED SYSTEMS
  - LDEF STRUCTURE AND SUBSYSTEMS
  - EXPERIMENT TRAYS
  - MATERIAL USED IN BUILDING OF LDEF AND EXPERIMENTS (e.g., SPARES)
- DEVELOP INSPECTION, HANDLING, TESTING AND REPORTING PLANS AND PROCEDURES
- COORDINATE WITH AND SUPPORT PROJECT, SIGs, AND EXPERIMENTER ACTIVITIES
- COLLECT AND DOCUMENT SYSTEMS DATA BASE

THREE INVESTIGATION PHASES

I. PLANNING EFFORT

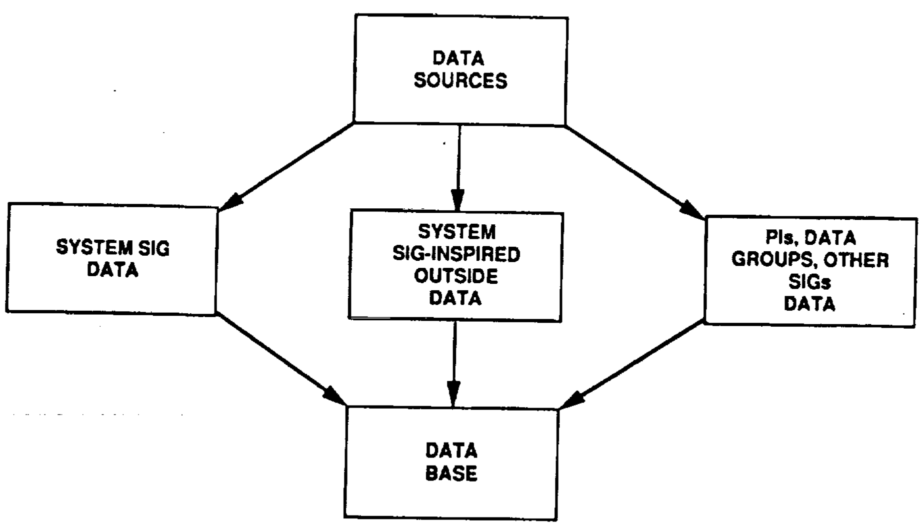
II. KSC OPERATIONS

III. POST-KSC TESTING AND DATABASE DEVELOPMENT

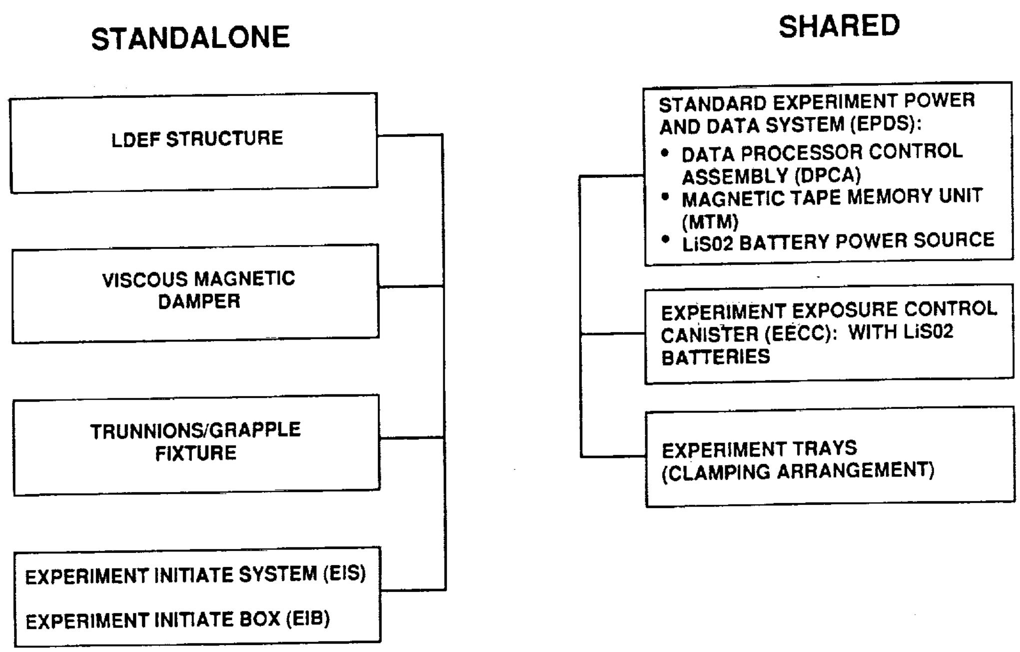
LDEF SYSTEMS SIG INVESTIGATION PLAN

SYSTEMS SIG

DATA BASE CONTRIBUTORS



LDEF SYSTEMS FLIGHT HARDWARE



LDEF EXPERIMENT SYSTEMS

EXPER ID NO.	KSC ACTVTY	LiSO2 BATT	OTHR BATT	EPDS DPCA	MTM	EECC	ELEC	OPT	MECH	THER	COMMENTS
A 0038	MANUAL	•					•		•		PYRO CABLE CUTTER, FLIP UP MECH
A 0054		•					•				HIGH VOLTAGE EQUIP, COULOMBMETER
A 0076	PWR	•					•		•	•	VARIABLE CONDUCTANCE HT PIPES
A 0133		•					•		•		RADAR ANTENNA, SOLID STATE MEMORY
A 0138-8		•					•		•		FRECOPA
A 0139-A	MANUAL	•					•		•	•	SEALED CRYSTAL DEWERS
A 0180		•					•		•		SEALED CASSETTE RECORDER
A 0187-1	MANUAL	•					•		•		CLAM SHELL AND ELECTROMECHANISMS
A 0201		•		•	•		•				SUN SENSOR
M 0003	MANUAL	•		• •	• •	• •	•	•	•	•	ALL SYSTEMS TYPES
M 0004	PWR	•		•	•		•	•		•	FIBER OPTICS ELECTRONICS
M 0006	PWR	•				•		•			OPTICAL SURFACES
P 0003	PWR	•					•			•	THERMOCOUPLES, EXTENSIVE HARNESS
S 0010		•				•					EECC ACCESSIBLE AT LaRC
S 0014	MANUAL	•		•	•		•	•			PV CELLS, SUN SENSOR, RADIOMETER
S 0069	MANUAL	•	LiCF		•		•	•	•	•	CAROUSEL, OPT SYSTEM, THERMAL SYSTEM
S 1001	PWR	•	NiCd	•	•		•	•		•	SOLAR ARRAY, POWER SYSTEM, HT PIPES
S 1002	MANUAL	•				•	•				SOLAR CELLS, QCM
S 1005		•	LiCF	•	•		•			•	HEAT PIPES
7 PASSIVE											MANUAL VALVES, SEALS

STANDARD TEST PLAN OUTLINE

I. GENERAL
- A. Review and Inspection
  1. Preliminary Review
  2. Visual Inspection
  3. Initial Data Review
- B. Calibration
  1. General
  2. Calibration Certification
  3. Accumulative Errors
  4. Statement of Accuracy
- C. Contamination

II. ELECTRICAL
- A. Electrical Systems
  1. Component examination and failure analysis
  2. Systems and subsystems functional testing
  3. Circuit board evaluation
- B. Power
  1. Batteries
  2. Solar Cells
  3. Power management and control components
  4. High voltage insulators/dielectrics
- C. Wire Harnesses

III. OPTICAL
- A. Glasses/Substrates/Filters
- B. Sources/Detectors/Radiometers
- C. Fiber Optics

IV. MECHANICAL
- A. Structures
- B. Mechanisms
- C. Electro-Mechanical/Servo
- D. Instrumentation

V. THERMAL
- A. Insulation
  1. Non-metallic insulators
  2. Thermal blankets
- B. Surfaces
- C. Instrumentation

LDEF SYSTEMS SIG
DATA BASE COMPOSITION

- Vendor and OEM specifications for systems, assemblies, parts and materials
- As-built drawings, schematics, and parts lists
- Pre-flight procedures
- Pre-flight parts screening and failure analysis data
- Pre-flight acceptance, qualification and performance test data
- Pre-flight control sample test data and storage history data
- Environmental data from supporting data groups
- Flight operational history
- Support equipment calibration data
- Post-flight test plans, procedures, and supporting data
- Post-flight failure/degradation analysis reports
- Post-flight measured data

LDEF DATA ANALYSIS REPORT
OUTLINE

1 Introduction and Background

- LDEF
- Systems SIG
- Investigation Plan
- Data Package Format

2 Investigation Results

- General Systems
  - Summary of the Investigation
  - Abstracts of Specific Studies
    - LDEF Systems
    - Experimenter Samples
- Electrical Systems
  - Summary of the Investigation
  - Abstracts of Specific Studies
    - LDEF Systems
    - Experimenter Samples
- Mechanical Systems
  - Summary of the Investigation
  - Abstracts of Specific Studies
    - LDEF Systems
    - Experimenter Samples
- Optical Systems
  - Summary of the Investigation
  - Abstracts of Specific Studies
    - LDEF Systems
    - Experimenter Samples
- Thermal Systems
  - Summary of the Investigation
  - Abstracts of Specific Studies
    - LDEF Systems
    - Experimenter Samples

3 Cross Reference Tables and Indices

4 Assessment of the Investigation Plan

MONTHLY REPORT

OBJECTIVES

- DISSEMINATION

- SOLICITATION

MONTHLY REPORT

CONTENTS

- DATABASE STATUS
- RECENT EVENTS AND OBSERVATIONS
- PROGRAM/PROJECT COMMENTARY AND NEWS
- SIG(s) STATUS REPORT(s)
- SDIO COMMENTARY AND NEWS
- EXPERIMENTER PUBLICATION NOTICES/ABSTRACTS/NEWS
- SCHEDULE/EVENTS/MEETINGS
- PEOPLE/TRANSITIONS

LDEF SYSTEMS

PRIMARY STRUCTURE:

INTEGRATE SSIG-DEVELOPED PLANS INTO PROJECT OFFICE PROCEDURES

- VISUAL INSPECTION, WELD INSPECTION, BOLT REMOVAL
- LDEF COMPONENTS FOR STRUCTURAL ANALYSIS AT BOEING
- NO POST-FLIGHT MODAL, WEIGHT AND ALIGNMENT MEASUREMENTS

EXPERIMENT INITIATE SYSTEM (EIS)

SSIG PROPOSED VERIFICATION OF EIS RELAY STATUS PRIOR TO TRAY REMOVAL

- DISCONNECT OUTPUT CABLE AT EIS, PERFORM CONTINUITY TESTS
- MULTIMETER WILL NOT ACTIVIATE RELAYS
- ALL TEST RESULTS RELEASED TO P.O.
- FOUR EXPERIMENTS PER CONNECTOR
- NEED PI CONSENT

LDEF SYSTEMS

ENVIRONMENTAL EXPOSURE CONTROL CANISTER (EECC)
- PI'S WITH CANNISTERS HAVE BEEN CONTACTED AND COMMENTS INCORPORATED
- CANNISTER INTERNAL PRESSURE, SURGE CURRENT, SEAL, MECHANISM, HARNESS AND CONNECTORS

EXPERIMENT POWER AND DATA SYSTEM (EPDS)
- START-UP, FUNCTIONAL TESTING

VISCOUS DAMPER
- LDEF PROCEDURE FOR REMOVAL
- JSC AND/OR OEM (GE) WILL PERFORM POST-FLIGHT TESTING

GRAPPLE (ACTIVE & PASSIVE)
- JSC AND/OR OEM (SPAR) WILL PERFORM POST-FLIGHT TESTING

BATTERIES
- PROJECT OFFICE PROCEDURES GOVERN REMOVAL
- DISCHARGE EVALUATION ADDED TO NO-LOAD TESTING

INDIVIDUAL EXPERIMENT AND IMPLEMENTATION PLANS

- EXPERIMENT NO. AND TITLE
- NAME & PHONE NO. OF PI CONTACTED
- LOCATION OF EXPERIMENT ON LDEF
- DESCRIPTION OF HARDWARE OF SYSTEM SIG INTEREST
- RESULTS OF DISCUSSIONS WITH PI
- PROPOSED TEST PLAN FOR EVALUATION OF SYSTEM HARDWARE AT KSC
- POST KSC TEST PLAN AND SCHEDULE
- IDENTIFICATION OF PREFLIGHT AND CONTROL HARDWARE
- NECESSARY ACTION ITEMS PRIOR TO THE GENERAL INSPECTION AT KSC
- EDITORIAL COMMENTS

NASA
LONG DURATION EXPOSURE FACILITY

SPECIAL INVESTIGATION GROUP PLANS
- MATERIALS SIG

BLAND A. STEIN

NASA - LANGLEY RESEARCH CENTER
CHAIRMAN, MSIG

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

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LONG DURATION EXPOSURE FACILITY

MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)

MATERIALS DATA ANALYSIS PLAN

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CHAIRMAN, LDEF MSIG

LDEF MATERIALS DATA ANALYSIS WORKSHOP
NASA - KENNEDY SPACE CENTER
FEBRUARY, 1990

LONG DURATION EXPOSURE FACILITY

MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)

CHARTER

- INVESTIGATE THE EFFECTS OF THE 5.5-YEAR EXPOSURE IN LEO ON LDEF STRUCTURAL AND EXPERIMENT MATERIALS WHICH WERE NOT ORIGINALLY PLANNED TO BE TEST SPECIMENS

- INTEGRATE THE DATA/ANALYSES FROM THE MATERIALS EXPERIMENT TEST SPECIMENS (GENERATED BY THE PIs) WITH THE MATERIALS DATA GENERATED BY MSIG INTO AN <u>LDEF MATERIALS DATA BASE</u>

MEMBERSHIP OF LDEF MSIG
February, 1990

NAME	AFFILIATION	ROLE/EXPERTISE
Bland Stein	NASA - LaRC	Chairman
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Ann Whitaker	NASA - MSFC	Atomic Oxygen
Wayne Stuckey	Aerospace Corp.	Contamination and Radiation
Bruce Banks	NASA - LeRC	Atomic Oxygen
Wayne Slemp	NASA - LaRC	Radiation, Coatings
Jack Berengoltz	NASA - JPL	Contamination
Jack Triolo	NASA - GSFC	Space Materials and Coatings
Lou McCreight	Aerospace Corp	Space Materials
Charles Bersch	IDA/SDIO	Space Materials
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Paul Sagalyn	Army MTL	Radiation
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John Davis	NASA-MSFC.	MAPTIS Data Base
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Francois Levadou	ESTEC	Space Materials, Environmental Effects
Alain Paillous	CERT	Space Materials
Lou Teichman	NASA-LaRC	Executive Secretary
Jim Mason	NASA - GSFC	Liaison with Systems SIG
Bill Kinard	NASA - LaRC	Liaison with Meteoroid and Space Debris SIG
Tom Parnell	NASA - MSFC	Liaison with Induced Radiation SIG

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP

ANALYSIS AND DOCUMENTATION PLAN

- SYSTEMATICALLY EXAMINE IDENTICAL MATERIALS IN MULTIPLE LOCATIONS AROUND LDEF TO ESTABLISH DIRECTIONALITY OF ATOMIC OXYGEN EROSION, THERMAL EFFECTS, AND ULTRAVIOLET RADIATION DEGRADATION
- ANALYZE SELECTED SAMPLES FROM LDEF "NON-MATERIALS" EXPERIMENTS
- ESTABLISH CENTRAL MATERIALS ANALYSIS CAPABILITY
  - STANDARDIZED, NON-CONTAMINATING PROCEDURES FOR SAMPLING/SHIPPING/ARCHIVING
  - UNIFORM TEST/ANALYSIS PROCEDURES
  - BASIS FOR ASSESSMENT OF LABORATORY-TO-LABORATORY VARIATIONS IN MATERIALS DATA
- FOCAL POINT FOR COORDINATION OF ALL LDEF MATERIALS ANALYSES
  - SPONSOR LDEF MATERIALS WORKSHOPS/SYMPOSIA
  - GENERATE UNIFIED LDEF MATERIALS DATA BASE, INCLUDING DATA FROM PRINCIPAL INVESTIGATORS, SUPPORTING DATA GROUPS, AND SPECIAL INVESTIGATION GROUPS

LDEF DATA ANALYSIS

THRUSTS	FY-89 · FY-90 · FY-91 · FY-92 · FY-93	EXPECTED RESULTS
LDEF RETRIEVAL	PLANNING, RETRIEVAL AND INSPECTION ▽1	• EARLY ASSESSMENT OF SPACE ENVIRONMENTAL EFFECTS
ENVIRONMENT DEFINITION	LDEF SUPPORTING DATA ▽2 ▽2	• DEFINITION OF LDEF MISSION ENVIRONMENT
LDEF EXPERIMENT DATA ANALYSIS	INDIVIDUAL EXPERIMENT ANALYSES BY PRINCIPAL INVESTIGATORS ▽3 ▽4 ▽5	• EFFECTS OF LDEF EXPOSURE ON MATERIALS AND SYSTEMS • ENHANCED MODELS FOR SPACE ENVIRONMENTAL EFFECTS
SPECIAL INVESTIGATIONS AND DOCUMENTATION	MATERIALS/SYSTEMS/ DEBRIS IMPACT/RADIATION ANALYSES BY SPECIAL INVESTIGATION GROUPS ▽3 ▽4 ▽5 ▽6	• SPACE ENVIRONMENTAL EFFECTS HANDBOOKS FOR LOW EARTH ORBIT EXPOSURES

MAJOR MILESTONES

- ▽1 LDEF RETRIEVAL AND "QUICK-LOOK INSPECTION" FINDINGS
- ▽2 SUPPORTING DATA PACKAGES TO PIs AND SIGs
- ▽3 LDEF INVESTIGATOR WORKSHOP TO COMPARE PRELIMINARY DATA
- ▽4 LDEF DATA CONFERENCE
- ▽5 LDEF DATA AND SPACE ENVIRONMENTAL EFFECTS MODELS SYMPOSIUM
- ▽6 LDEF MATERIALS, SYSTEMS, AND DEBRIS EFFECTS DATA BASES DOCUMENTED

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)

- KEY MILESTONES -

- SELECT MSIG PARTICIPANTS, JANUARY 1989; HOLD 4 MEETINGS IN 1989
- ADOPT MSIG PHILOSOPHY, MARCH 1989
- RECOMMEND SECURITY POLICY REGARDING MATERIALS INFORMATION TO LDEF PROGRAM OFFICE, APRIL 1989
- SELECT CONTRACTOR, INITIATE TASK CONTRACT FOR MATERIALS TESTS AND ANALYSES, MAY, 1989:
  - IDENTIFY ANALYSIS TECHNIQUES, JULY 1989
  - DEVELOP SPECIMEN SELECTION PLANS, AUGUST 1989
  - DEVELOP INITIAL SPECIMEN PRESERVATION PLANS, OCTOBER 1989
  - PRE-/POST-RETRIEVAL LIAISON WITH PIs, MAY 1989 - MARCH 1990
- SUGGEST CONTAMINATION MONITORING METHODOLOGY TO LDEF PO, SEPTEMBER 1989
- PROVIDE ATOMIC OXYGEN FLUX ESTIMATES AND PHOTOGRAPHIC SURVEY RECOMMENDATIONS TO LDEF PO, OCTOBER 1989
- DEVELOP MSIG DETAILED TEST PLAN, OCTOBER - DECEMBER 1990

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)

- KEY MILESTONES (Continued) -

- PLAN LDEF MATERIALS DATA ANALYSIS WORKSHOP, NOVEMBER - DECEMBER 1989
- DETERMINE UTILITY OF NASA-MSFC MAPTIS DATA BASE CAPABILITY FOR LDEF MATERIALS DATA BASE, JANUARY 1990
- RETRIEVE LDEF; FERRY TO KSC; INITIAL INSPECTIONS, JANUARY - FEBRUARY 1990
- CHAIR LDEF MATERIALS DATA ANALYSIS WORKSHOP AT KSC, FEBRUARY 1990
- OBTAIN MSIG SPECIMENS, FEBRUARY - MARCH 1990
- DATA GENERATION, DATA ANALYSIS, AND DATA BASING, 1990 - 1992
- MSIG REPORTS AT LDEF AND OTHER CONFERENCES, 1990 - 1993
- DEFINE, WITH PIs AND OTHER SIGs, MATERIALS DATA BASE, 1991 - 1992
- COLLATE AND DOCUMENT LDEF MATERIALS DATA BASE, 1992 - 1993

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)

- TEST PLAN OUTLINE* -

- GOALS AND PROCEDURES
- PRE-RECOVERY PREPARATIONS
- NASA - KSC OPERATION REQUIREMENTS
- ON LINE/OFF LINE EXAMINATION PROCEDURES
- IDENTIFICATION OF PRIORITY MATERIALS
- ANALYSIS/TEST PLAN FOR EACH MATERIAL TYPE
- SAMPLE HANDLING/PACKAGING/SHIPPING
- CONTAMINATION CONTROL
- LDEF MATERIALS DATA BASE
- KEY PERSONNEL
- SCHEDULE

*** SEE TEST PLAN DOCUMENT FOR DETAILS**

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- GOALS AND PROCEDURES* -

GOALS

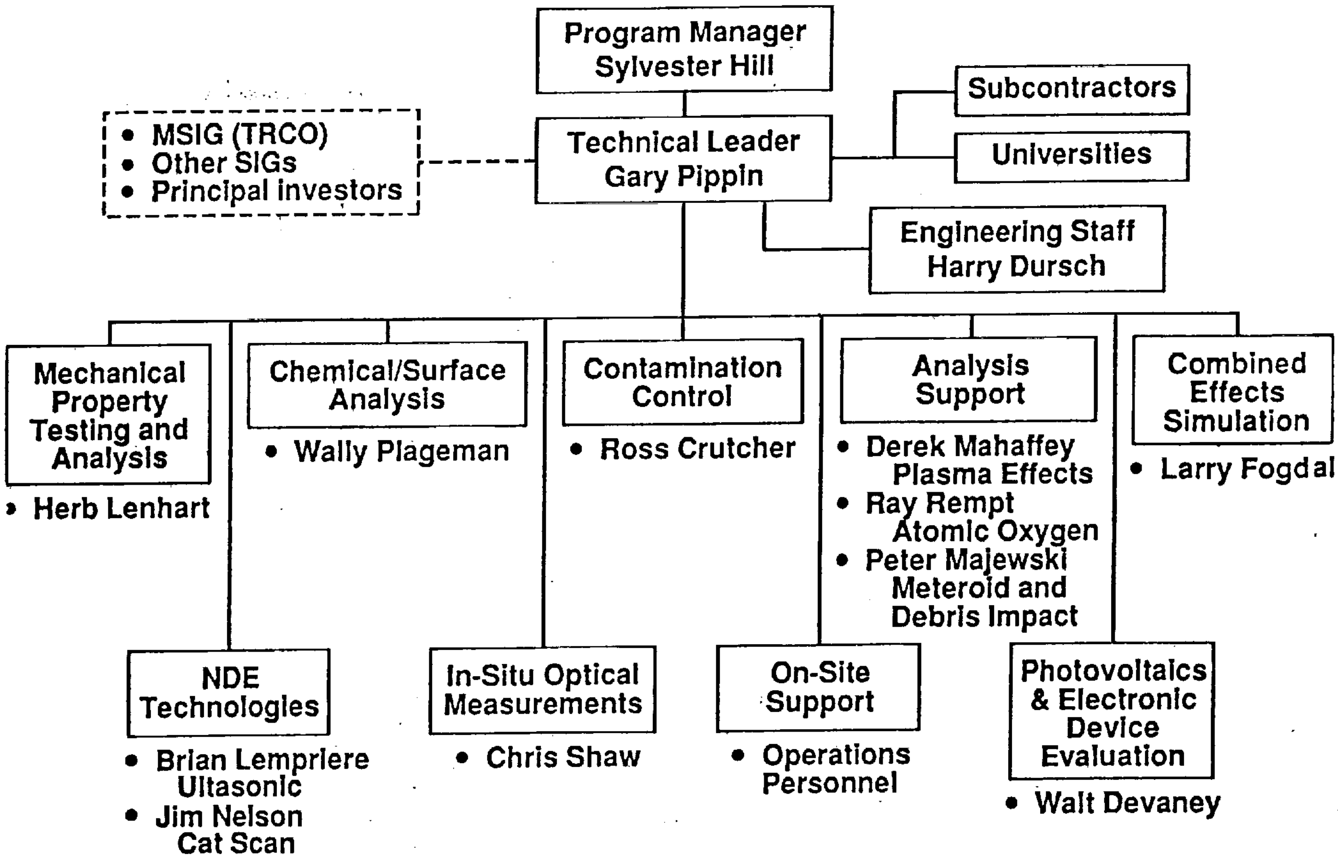
- INVESTIGATE THE EFFECTS OF LDEF EXPOSURES ON SPACECRAFT MATERIALS, ESPECIALLY THOSE NOT ORIGINALLY INTENDED TO BE MATERIAL SPECIMENS
  - DEVELOP ENGINEERING DATA FOR SPACECRAFT DESIGN
  - DEFINE MECHANISMS OF MATERIAL DEGRADATION
- COORDINATE DATA FROM PIs, MSIG, AND OTHER SIGs INTO LDEF MATERIALS DATA BASE
  - EFFECTS OF POSITION ON LDEF, ORIENTATION OF LDEF, POSITION ON EXPERIMENT TRAY
  - COMPARISONS WITH CONTROL SPECIMEN DATA
  - LABORATORY-TO-LABORATORY DATA VARIABILITY

PROCEDURES

- ESSENTIAL TASKS AT KSC DE-INTEGRATION
  - DETAILED PHOTGRAPHIC AND HIGH-RESOLUTION VIDEO SURVEYS OF SURFACES
  - DEFINE CONTAMINATION
  - WORK CLOSELY WITH OTHER SIGs AND PIs
  - COLLECTION AND PRESERVATION OF SOME SPECIMENS
  - DEFINITION OF ADDITIONAL MSIG SPECIMENS
- EXTENSIVE TESTING AND ANALYSES AT BOEING AEROSPACE UNDER CONTRACT NAS1-18224, TASK 12
- COMPUTERIZED DATA BASES PLUS HANDBOOK(S)

*** SEE TEST PLAN DOCUMENT FOR DETAILS**

BOEING AEROSPACE MANAGEMENT PLAN



LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- PRE-RECOVERY PREPARATIONS* -

- PREPARATION OF CONTAMINATION TAPELIFT KITS, DOCUMENTATION, AND INDEXING PROCEDURES
- ARRANGE FOR PHOTO AND VIDEO DOCUMENTATION EQUIPMENT
- OBTAIN PHOTOGRAPHS AND VIDEO FROM ON-ORBIT RETRIEVAL ACTIVITIES
- DEFINE SPECIMEN LABELING KEY; ARRANGE FOR LABELED PACKAGING MATERIALS AND DOCUMENTATION FORMS
- DEFINE STORAGE AND SHIPPING ARRANGEMENTS FOR MSIG SPECIMENS
- DEFINE KSC-PROVIDED EQUIPMENT AND FACILITIES
- DEFINE MSIG/BOEING-PROVIDED EQUIPMENT AND FACILITIES
- ESTABLISH KSC COORDINATION TEAM AND BOEING ANALYSIS TEAMS
- PLAN LDEF MATERIALS DATA ANALYSIS WORKSHOP DURING "LDEF INSPECTION WEEK" AT KSC

* SEE TEST PLAN DOCUMENT FOR DETAILS

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- LDEF EXAMINATION PROCEDURES* -

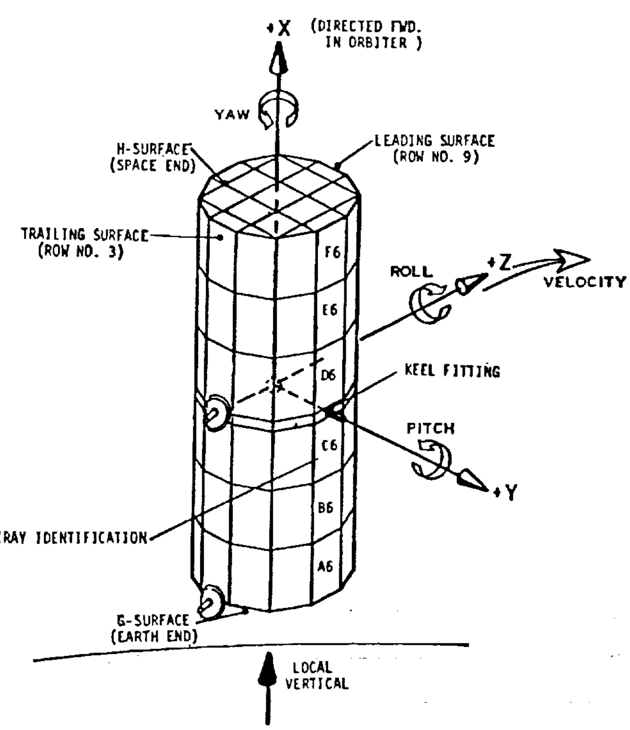
ON-LINE EXAMINATIONS

- DON'T GO IN WITH PRECONCEIVED CONCLUSIONS; OBSERVE FROM A MODERATE DISTANCE, OBSERVE FROM CLOSE DISTANCE, STEP BACK AND OBSERVE AGAIN. TRY TO "LISTEN TO LDEF'S STORY".
- ASSURE PHOTGRAPHIC/VIDEO DOCUMENTATION OF ENTIRE LDEF AND CLOSEUPS OF ALL REGIONS OF PARTICULAR INTEREST
- COLLECT TAPELIFTS FROM STRUCTURAL SURFACES; INDEX AND DOCUMENT
- ASSURE ACCESS TO CONTAMINATION WITNESS PLATE DATA
- DOCUMENT ALL REMOVED PARTS

OFF-LINE ACTIVITIES

- COORDINATE AND PARTICIPATE IN LDEF MATERIALS DATA ANALYSIS WORKSHOP
- COORDINATE PHOTO/VIDEO SURVEYS WITH JSC/M&D SIG TEAM
- NEGOTIATE WITH PIs AND OTHER SIGs FOR HARDWARE OF INTEREST TO MSIG
- MONITOR DE-INTEGRATION; PACKAGE AND SHIP INITIAL MSIG SPECIMENS

* SEE TEST PLAN DOCUMENT FOR DETAILS



LDEF Orbital Orientation Model.

LDEF ENVIRONMENTS

LDEF SPACE ENVIRONMENT

- ATOMIC OXYGEN
- METEOROIDS, MICROMETEOROIDS, AND SPACE DEBRIS
- COSMIC DUST AND HEAVY COSMIC-RAY NUCLEI
- HEAVY IONS
- SOLAR ELECTROMAGNETIC ENERGY AND ENERGY VARIATIONS
- PROTON AND ELECTRON RADIATION

LDEF EARTH, LAUNCH, RETRIEVAL, AND FERRY ENVIRONMENTS

- ATMOSPHERIC GASES (DRY AIR)
- HUMIDITY (BUT NOT CONDENSATION)
- CONTAMINANT GASES
- CONTAMINANT PARTICLES

PRELIMINARY APPROACH TO SPECIMEN SELECTION FOR MATERIALS ANALYSIS AND DATA BASE CREATION

MSIG SPECIMENS

- Materials not of primary interest to PIs
- Availability of extra exposed specimens
- Availability of extra control specimens

PI SPECIMENS

- Experiments with desirable locations
- Experiments with diverse materials

ANALYSIS ASSESSMENT

- Assessment of lab-to-lab variations

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- EXAMPLES OF "NON-MATERIALS EXPERIMENT" MATERIALS SOURCES* -

- TRUNNIONS AND SCUFF PLATES
- SHUTTLE PAYLOAD BAY DEBRIS
- REFLECTORS
- TRAY FASTENERS, BOLTS, WASHERS, NUTS, PLATES, ETC.
- MATERIALS AND COATINGS IN SYSTEMS EXPERIMENTS
- MATERIALS AND COATINGS IN SCIENCE EXPERIMENTS
- THERMAL BLANKET AND OTHER PROTECTION MATERIALS
- ELECTRONIC COMPONENT MATERIALS

* SEE TEST PLAN DOCUMENT FOR DETAILS

LDEF MATERIALS FOR ANALYSIS

Materials

- Polymeric films and composites
- Metal-matrix composites
- Polished metals
- Glasses, optical filters and fibers
- Ceramics
- Solar cell materials
- Solid rocket materials

Coatings

- Black and white paints
- Anodized aluminum
- Sputter deposited coatings
- Metallic coatings
- Second-surface mirrors
- Optical solar reflectors

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- PRIORITY MATERIALS FOR MSIG ANALYSIS* -

MATERIAL TYPES

- KAPTON
- COATED AND UNCOATED TEFLON
- THERMOSETS
- THERMOPLASTICS
- ANODIZED ALUMINUM
- STAINLESS STEEL
- BLACK AND WHITE THERMAL CONTROL PAINTS

TRAY LOCATIONS

- LEADING EDGE/TRAILING EDGE
- SPACE END/EARTH END
- 90° TO LEADING EDGE

*** SEE TEST PLAN DOCUMENT FOR DETAILS**

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- MATERIALS OF INTEREST FOR MSIG ANALYSIS* -

MATERIAL TYPES

- POLYMERS
- METALS
- COMPOSITES
- CERAMICS
- COATINGS
- INSULATION
- LUBRICANTS
- ELASTOMERS/ADHESIVES/POTTING COMPOUNDS

LDEF LOCATIONS/ENVIRONMENTS OF INTEREST

- RAM EDGE/AO, UV, SOLAR WIND, THERMAL CYCLING, M&D IMPACTS
- 30°, 60°, AND 90° TO RAM EDGE/LESS AO, UV, SOLAR WIND, TC, M&D
- TRAILING EDGE/UV, SOLAR WIND, TC, M&D IMPACTS
- 30° AND 60° FROM TRAILING EDGE/UV, SOLAR WIND, M&D IMPACTS
- SPACE END/UV, SOLAR WIND, TC, M&D IMPACTS
- EARTH END/UV, SOLAR WIND, TC, M&D IMPACTS, EARTH RADIATION
- INTERNAL AND PROTECTED AREAS/VACUUM, LESS TC, RELATIVE CONTAMINATION

*** SEE 18 PAGES OF TEST PLAN DOCUMENT FOR DETAILS**

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES* -

ULTRASONIC

- PULSE ECHO
- HIGH FREQUENCY
- SURFACE WAVE

EDDY CURRENT

COMPUTED TOMOGRAPHY

- X-RAYS
- MULTIPLANE RECONSTRUCTION

*** SEE TEST PLAN DOCUMENT FOR DETAILS**

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- TESTS FOR MATERIAL CATEGORIES* -

COMMON PROCEDURES FOR MOST MATERIALS

- VISUAL INSPECTION
- DETERMINE WEIGHT AND DIMENSIONS
- OPTICAL PHOTOMICROGRAPHY
- SURFACE ROUGHNESS (PROFILOMETER OR NOMARSKI MICROSCOPE)
- SOLAR ABSORBTANCE (UV-VIS/NIR SPECTROMETER, ASTM E-424 A)
- INFRARED EMITTANCE (DB-100 IR REFLECTOMETER, ASTM E-408 A)
- TOTAL HEMISPHERICAL REFLECTANCE (UV-VIS/NIR AND FTIR SPECTROMETERS)
- OUTGASSING (STANDARD TESTS PLUS PYROLYSIS GAS CHROMATOGRAPHY)
- COATING ADHESION PEEL TESTS

ADDITIONAL TESTS FOR ORGANICS

- THERMAL CHARACTERIZATION (TGA, TMA, DMA, DSC)
- CREEP
- HARDNESS (SHORE A AND D)
- DIELECTRIC CONSTANT AND STRENGTH (MIL-STD-202)
- ELECTRICAL RESISTANCE (MIL-P-13949)
- CONFORMAL COATING ANALYSIS (MICRO-IR, DSC, TGA, ETC.)
- SOLUTION PROPERTIES (HPLC, GPC)

*** SEE TEST PLAN DOCUMENT FOR DETAILS**

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- TESTS FOR MATERIAL CATEGORIES* (CONTINUED) -

ADDITIONAL TESTS FOR METALS

- HARDNESS (ROCKWELL AND ROCKWELL SUPERFICIAL)
- SURFACE ANALYSIS (SEM, EDS, AUGER, ESCA, X-RAY DIFFRACTION)
- RESIDUAL STRESS (X-RAY DIFFRACTION)
- MECHANICAL PROPERTIES (TENSILE, IMPACT, FRACTURE TOUGHNESS)
- FRACTURE ANALYSIS (OPTICAL MICROSCOPY, SEM, EDS)
- BULK CHEMICAL ANALYSIS (SPECTROCHEMICAL, EDS)
- METALLOGRAPHY
- OPTICAL AND THERMAL PROPERTIES (REFLECTIVITY, EMMITANCE, HEAT TRANSFER)

ADDITIONAL TESTS FOR CERAMICS AND GLASSES

- ELEMENTAL ANALYSIS (AUGER, ESCA, SIMS)
- CRYSTALLINITY (X-RAY DIFFRACTION)
- TRANSMISSION ELECTRON MICROSCOPY
- IN-SITU TRANSMITTANCE AND REFLECTANCE (CETF)
- BIDIRECTIONAL REFLECTANCE DISTRIBUTION (CETF)

*** SEE TEST PLAN DOCUMENT FOR DETAILS**

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- TESTS FOR MATERIAL CATEGORIES* (CONTINUED) -

ADDITIONAL TESTS FOR COMPOSITES

- SURFACE EROSION AND MICROCRACKING (OPTICAL MICROGRAPHY AND SEM)
- SPECIFIC GRAVITY
- DELAMINATIONS (NDE TECHNIQUES, MICROSCOPY, AUGER, MICROPROBE)
- MECHANICAL PROPERTIES (FLEXURE, COMPRESSION, SHEAR, TOUGHNESS)
- OPTICAL PROPERTIES (EMITTANCE, ABSORPTANCE, REFLECTANCE)
- FIBER CONTENT, RESIN CONTENT, VOID CONTENT (RESIN BURNOUT, CALCULATION)
- THERMAL EXPANSION, THERMAL CONDUCTIVITY (TMA, DILATOMETRY, ASTM D1225)
- GLASS TRANSITION TEMPERATURE (DTA, ASTM D1225)
- SPECIFIC HEAT (DSC)
- OUTGASSING, VOLATILES, CONDENSIBILES (TGA, ASTM E595)
- CHEMICAL ANALYSIS (INFRARED SPECTROSCOPY)

ADDITIONAL TESTS FOR INSULATION MATERIALS

- THERMAL CONDUCTIVITY (DYNATECH, HEAT FLOW METER)
- SPECIFIC HEAT (DSC)
- COMPRESSIBILITY/RESILIENCY
- WETTABILITY/CONTACT ANGLE (GONIOMETER)
- ELECTROSTATIC CHARGING (SURFACE ELECTRICAL POTENTIAL, CONDUCTIVITY)

*** SEE TEST PLAN DOCUMENT FOR DETAILS**

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- TESTS FOR MATERIAL CATEGORIES* (CONTINUED) -

ADDITIONAL TESTS FOR LUBRICANTS

- CREEP (VISUAL/OPTICAL EXAMINATION, INFRARED ANALYSIS)
- WEAR AND LUBRICANT CONDITION (TRIBOMETER, CHROMATOGRAPHY, SPECTROMETRY)
- PEEL (FOR SOLID FILM LUBRICANTS)

ADDITIONAL TESTS FOR THERMAL CONTROL COATINGS

- SURFACE ANALYSIS/ROUGHNESS, CRACKING (SEM, NOMARSKI MICROSCOPY)
- SURFACE ANALYSIS/CHEMISTRY (FTIR, X-RAY PHOTOELECTRON SPECTROSCOPY)
- TOTAL INTEGRATED SCATTER AND BIDIRECTIONAL REFLECTANCE DISTRIBUTION (LASER ILLUMINATION, VARYING SOURCE AND DETECTOR ANGLES)
- IN-SITU SOLAR ABSORPTANCE (COMBINED RADIATION EFFECTS TEST CHAMBER, DOUBLE PASS REFLECTANCE)
- COATING THICKNESS (PROFILOMETRY)

* SEE TEST PLAN DOCUMENT FOR DETAILS

LDEF
MATERIALS SPECIAL INVESTIGATION GROUP (MSIG)
TEST PLAN

- TESTS FOR MATERIAL CATEGORIES* (CONCLUDED) -

ADDITIONAL TESTS FOR ELASTOMERS, ADHESIVES, AND POTTING COMPOUNDS

- VISUAL APPEARANCE (LOW MAGNIFICATION)
- CHEMICAL ANALYSIS (FTIR)
- SOLUTION PROPERTIES (HPLC, GPC)
- HARDNESS (SHORE A OR D, ASTM 2240)
- THERMAL CHARACTERIZATION (TGA, TMA, DMA, DSC)
- DIELECTRIC CONSTANT AND STRENGTH (MIL-STD-202)
- ELECTRICAL RESISTANCE (MIL-P-13949)

* SEE TEST PLAN DOCUMENT FOR DETAILS

LDEF
ENVIRONMENTAL EFFECTS ON MATERIALS
SPECIAL INVESTIGATION GROUP

- ACCOMPLISHMENTS THROUGH FEBRUARY, 1990 -

- MEETINGS HELD AT LaRC, WILLIAMSBURG, BOEING/KENT, AND KSC; MARCH, MAY, AUGUST, AND OCTOBER, 1989 (AND FEBRUARY, 1990)

- BRIEFINGS TO LDEF PRINCIPAL INVESTIGATORS, OTHER SPECIAL INVESTIGATION GROUPS, SPACE STATION M&P WORKING GROUP, SDIO/AEROSPACE CORP., AND NASA HQ

- MSIG PHILOSOPHY ADOPTED:
  - DEVELOP ENGINEERING DATA AS FIRST PRIORITY
  - DEVELOP MECHANISTIC DATA AS HIGH PRIORITY

- SECURITY POLICY REGARDING MATERIALS INFORMATION RECOMMENDED TO LDEF PROGRAM OFFICE; LDEF INSPECTION TEAM FORMED

- CONTRACTOR SELECTED, TASK CONTRACT INITIATED FOR MATERIALS TESTS AND ANALYSES
  - PRELIMINARY ANALYSIS TECHNIQUES IDENTIFIED
  - APPROACHES TO SPECIMEN SELECTION DEVELOPED
  - PLANNING, ANALYSIS, AND DOCUMENTATION TASKS INITIATED

LDEF
ENVIRONMENTAL EFFECTS ON MATERIALS
SPECIAL INVESTIGATION GROUP

- ACCOMPLISHMENTS THROUGH FEBRUARY, 1990 - (Continued)

- SPECIAL FY89 FUNDING REQUESTED FROM NASA ASSOCIATE ADMINISTRATOR FOR AERONAUTICS AND SPACE TECHNOLOGY; JULY 1989

- MSIG CHAIRMAN INSPECTED LDEF-RELATED FACILITIES AT KSC TO ASSESS CONTAMINATION POTENTIAL; JULY 1989

- MSIG CONTAMINATION MONITORING SUGGESTIONS SENT TO LDEF PO; SEPT. 1989

- ATOMIC OXYGEN/PHOTOGRAPHIC SURVEY SUGGESTIONS SENT TO LDEF PO; OCT. 1989

- LDEF MATERIALS DATA-BASING OPTIONS REVIEWED; NASA-MSFC MAPTIS DATA BASE SELECTED FOR INITIAL ASSESSMENT; AUGUST - OCTOBER 1989

- LDEF MATERIALS DATA ANLYSIS WORKSHOP PLANNED; NOVEMBER 1989 TO JANUARY 1990

- MSIG TEST PLAN DEVELOPED AND DOCUMENTED; TRANSMITTED TO LDEF PROJECT OFFICE; DECEMBER 1989

LDEF
ENVIRONMENTAL EFFECTS ON MATERIALS
SPECIAL INVESTIGATION GROUP

- ACCOMPLISHMENTS THROUGH FEBRUARY, 1990 -
(Concluded)

- SUPPORT OF LDEF INSPECTION TEAM DURING DOWNLINK VIDEO, IN-SPACE PHOTOGRAPHY, AND INITIAL KSC INSPECTIONS; JANUARY AND FEBRUARY 1990
- PRELIMINARY IDENTIFICATION OF LDEF LEADING EDGE POSITION, FEBRUARY 1990
- MSIG SPECIMEN IDENTIFICATION; FEBRUARY AND MARCH 1990
- ASSUMED RESPONSIBILITY FOR TOTAL LDEF CONTAMINATION IDENTIFICATION AND DOCUMENTATION; FEBRUARY 1990
    - PARTICULATE CONTAMINATION (PRE-DEINTEGRATION)
    - MOLECULAR CONTAMINATION (POST-DEINTEGRATION)

NASA
LONG DURATION EXPOSURE FACILITY

SPECIAL INVESTIGATION GROUP PLANS
- IONIZING RADIATION SIG

THOMAS A. PARNELL

NASA - MARSHALL SPACE FLIGHT CENTER
CHAIRMAN, IRSIG

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

LDEF IONIZING RADIATION
SPECIAL INVESTIGATION GROUP
KSC 2-13-90

- Objectives of IRSIG
- Review Team Members
- Radiation Measurements in LDEF Experiments
- Improvements in Radiation Environments Knowledge Anticipated from LDEF
- IRSIG Plans
  - Predictions Booklet
  - Calculations Plan
  - P0006 Measurements and Analysis
  - Induced Radiation Measurements and Analysis
  - Radiations Effects Coordination
  - Coordination with Experimenters and Other SIG's
- Status

LDEF IONIZING RADIATION SIG
REVIEW TEAM

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Marshall Space Flight Center

E.V. Benton
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Allan R. Smith
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Richard Scott (SSIG Rep)
Jet Propulsion Laboratory

Paul Sagalyn (MSIG Rep)
Army Materials Lab, Watertown, Mass.

W.H. Kinard (M&DSIG Rep)
Langley Research Center

LDEF IONIZING RADIATION SIG
CHARTER

1. Provide Radiation Environment Predictions (Booklet)
2. Analyze Supporting Radiation Data and Induced Radio-Activity and Compare to Calculations.
3. Provide Detailed Calculations of Radiation Dose, Linear Energy Transfer Spectra and Secondary Components (Including Neutrons) as a Function of Position Around LDEF and Shielding Depth. Provide Detailed Calculations of Induced Activity. Update Calculation Methods and Environment Models as Warranted by Data.
4. Compare Radiation Data , when Available, from Experiments with Calculations.
5. Disseminate Results of 2-4 as Available.
6. Coordinate Data Exchange Among LDEF Investigators with Radiation Measurements.
7. Provide Calculations/Estimates for Specific Locations in LDEF, or for Specific Components with Suspected Radiation Effects.
8. Advise Experiment Investigators and Other SIG's About Potential Radiation Effects and Methods of Post-Flight Radiation Testing.
9. Provide Final Report on LDEF Radiation Environment and Effects.

IMPROVEMENTS IN RADIATION ENVIRONMENT KNOWLEDGE/CALCULATION METHODS WITH LDEF

- Effects of Directional Properties of Trapped Protons
  - Measurements of Dose with TLD's and Activation Around Flight-Direction Stabilized Spacecraft.
  - Calculations witn Directional Proton Model as a Function of Position and Depth in LDEF. HETC Calculation of Activation Using Directional Proton Flux.
- Accurate Neutron Fluence and Spectrum
  - Measurements of Gamma Ray Lines Only Caused by Neutron Activation. Measurements of Neutrons with Fission Foils.
  - Calculations of Secondary Neutrons Created in Structure by Trapped Protons and Cosmic Rays Using HETC Calculations. Calculation of Flux of Atmospheric Albedo Neutrons from Cosmic Ray Bombardment.
- Measurement of Linear Energy Transfer Spectrum Beyond the "Iron Peak" in Cosmic Rays
  - Measurement (by Long Exposure and Large Area Detectors) the LET Spectra Caused by "Anomolous" Cosmic Rays and Ultra Heavy Cosmic Rays.
- Fluence, LET Spectra, and Dose of Low Energy Target Spallation Nuclides or "Star" Particles.
  - Some New Measurements
  - HETC Calculations
- More Accurate Levels of AP8 Proton Fluxes at Solar Minimum
  - Measurements of Dose with TLD's and Activation at Various Spacecraft Locations and Depth. Enhanced by Flight Direction Stability of LDEF.
  - Requires Application of Directional Proton Model (as AP8 Post Processor) and HETC Calculations. Also Requires Maximum Use of TLD's and Activation Materials in LDEF.

RADIATION DETECTORS ON LDEF

	TLD'S ABSORBED DOSE (RADS)	PNTD'S HEAVY ION FLUENCE & LET SPECTRA	ACTIVATED MATERIALS PROTON & NEUTRON FLUENCE	FISSION FOILS NEUTRONS & SPECTRA	OTHER DETECTORS
P0004-1	X	X			
P0004-2	X	X			
P0006	X	X	X	X	
M0001		X	X		
M0002-1	X	X	X		MICROSPHERE
M0002-2		X	X		
M0003-12	X				
M0003-17	X				
M0004	X	X			
M0006	X				
A0015	X	X		X	Agcl
A0138-7	X		X		
A0114-1			X		
A0114-2			X		
A0178		X			
LDEF STRUCTURE & EXPERIMENTS			X		

RADIATION MEASUREMENT PRINCIPAL CATEGORIES

ENVIRONMENT	DOSIMETRY/EFFECTS	ASTROPHYSICS	SPONSOR
P0004 - 1	P0004 - 1		NASA
P0004 - 2	P0004 - 2		NASA
P0006	P0006		NASA
M0001	M0001	M0001	DOD
M0002 - 1	M0002-1		DOD
M0002 - 2		M0002 - 2	FRG
M0003 - 12 & 17	M0003 - 12 & 17		DOD
A0015	A0015		FRG
A0138 - 7	A0138 - 7		FRANCE
A0114	A0114		NASA
A0178		A0178	IRELAND
ACTIVATION SUB-EXPERIMENT	ACTIVATION SUB-EXPERIMENT		NASA
FULL-LDEF ACTIVATION	FULL-LDEF ACTIVATION		DOD
M0004	M0004		DOD

IONIZING RADIATION

L D E F

PREDICTION BOOKLET —— OUTLINE

THE LONG DURATION EXPOSURE FACILITY
IONIZING RADIATION PREDICTIONS (BOOKLET)

I. • INTRODUCTION -- VALUE OF LDEF MEASUREMENT -- LIST OF LDEF RADIATION MEASUREMENTS

II. • DESCRIPTION OF TRAPPED PARTICLES AND COSMIC RAYS IN LDEF ORBIT (REFERENCES)

III. • RADIATION ABSORBED DOSE -- DEPTH DOSE AND GENERAL DESCRIPTION OF DIRECTIONAL EFFECTS
- MEASUREMENTS ON SHUTTLE COMPARED TO PREDICTIONS

IV. • LET SPECTRA AND GENERAL DESCRIPTION OF "SINGLE HIT" ASPECT OF PARTICLES -- DISCUSSION OF SOURCE OF PARTICLES IN VARIOUS PARTS OF LET SPECTRUM
- MEASUREMENTS ON SHUTTLE AND COMPARISON WITH PREDICTIONS

V. • NEUTRONS AND DISCUSSION OF OTHER SECONDARIES

VI. • EQUIVALENT DOSE (APPROXIMATE)

VII. • ACTIVATION OF MATERIALS

VIII. • RADIATION EFFECTS (GENERAL)
- BULK PROPERTIES -- MECHANICAL, OPTICAL (COLOR CENTERS)
- HIGH LET ELECTRONIC PHENOMENA/SEU's AND CATASTROPHIC FAILURE
- BIOLOGICAL EFFECTS
- POSSIBILITY OF SYNERGISTIC EFFECTS WITH TEMPERATURE, UV, VACUUM

IX. • RADIATION MEASUREMENT AND ANALYSIS PLAN FOR LDEF
- MEASUREMENTS IN EXPERIMENTS
- OTHERS ON S/C
- CALCULATIONS TO BE PERFORMED

X. • REFERENCES

External Environment Calculations

- Geomagnetically trapped protons and electrons differential fluxes (Vette AP8MIN proton and AE8MIN electron environment)
- Directional proton flux (AP8 post-processor (Watts-MSFC))
- Galactic cosmic radiation (GCR) differential flux (CREME GCR environment)
- Albedo neutrons flux from atmosphere (T. Armstrong)
- Magnetic field Model

First Order Internal Environment Calculations

- Dose and dose equivalent versus shield thickness for trapped particles (Burrell "straight-ahead, continuous slowing down" proton dose program) (MSFC electron dose program based on fits to ETRAN)
- Dose and dose equivalent versus shield thicknesss for GCR (CREME)
- Let spectra for trapped protons versus shield thickness (CREME)
- Let spectra for GCR/anomolous component versus shield thickness (CREME)

Models of LDEF

- Vector mass model for dose and fluence calculations at shielding depths
- Radioactivity model from sample/mass model calculations

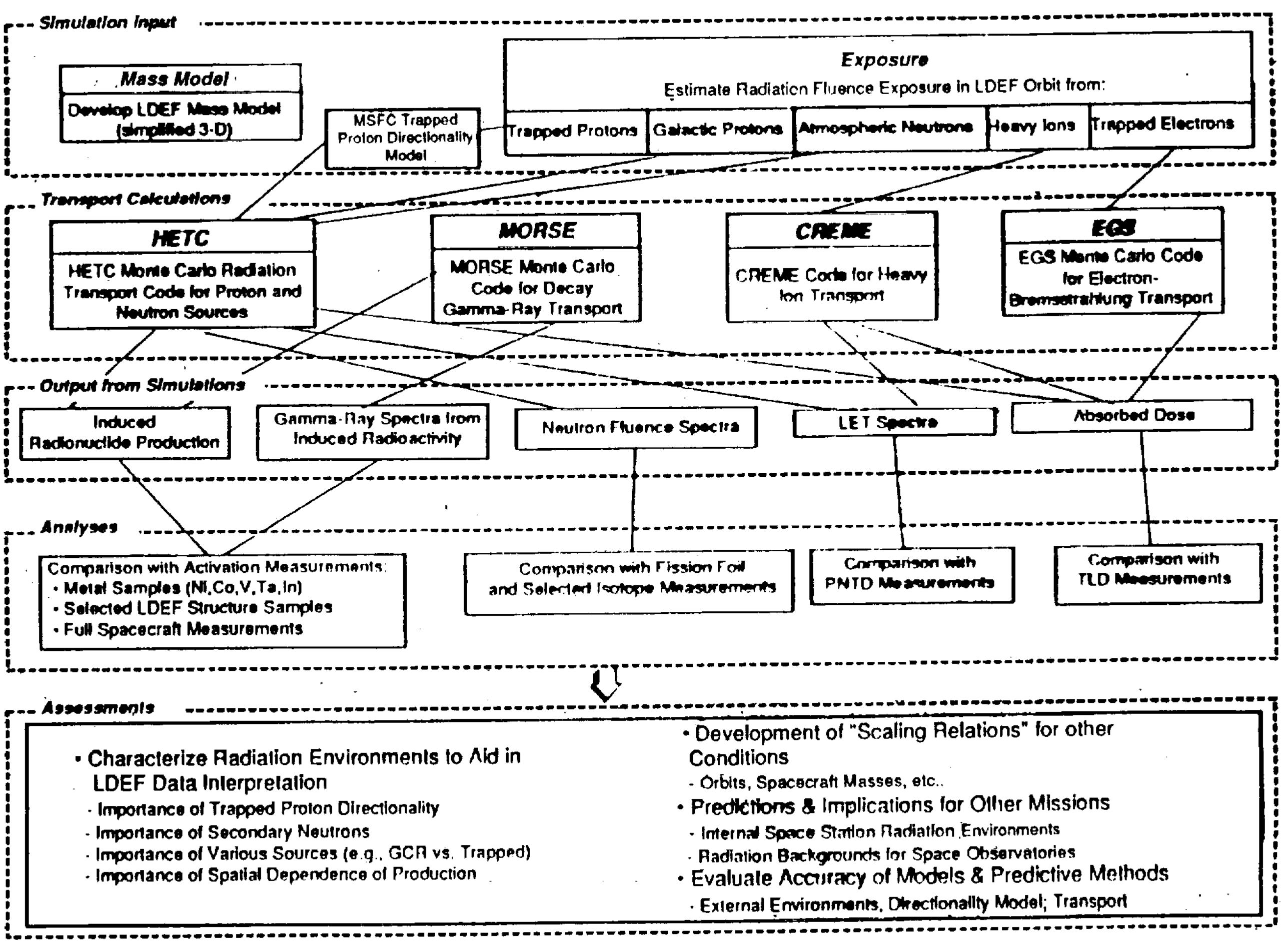
Activation Calculations using HETC

- Activation of experiment samples
- Activation of materials available in other experiments
- Activation of spacecraft structure samples
- Activation for a simple total spacecraft model

Secondaries Calculations using HETC

- Secondary proton spectra
- Secondary neutron spectra

Approach for LDEF Calculations



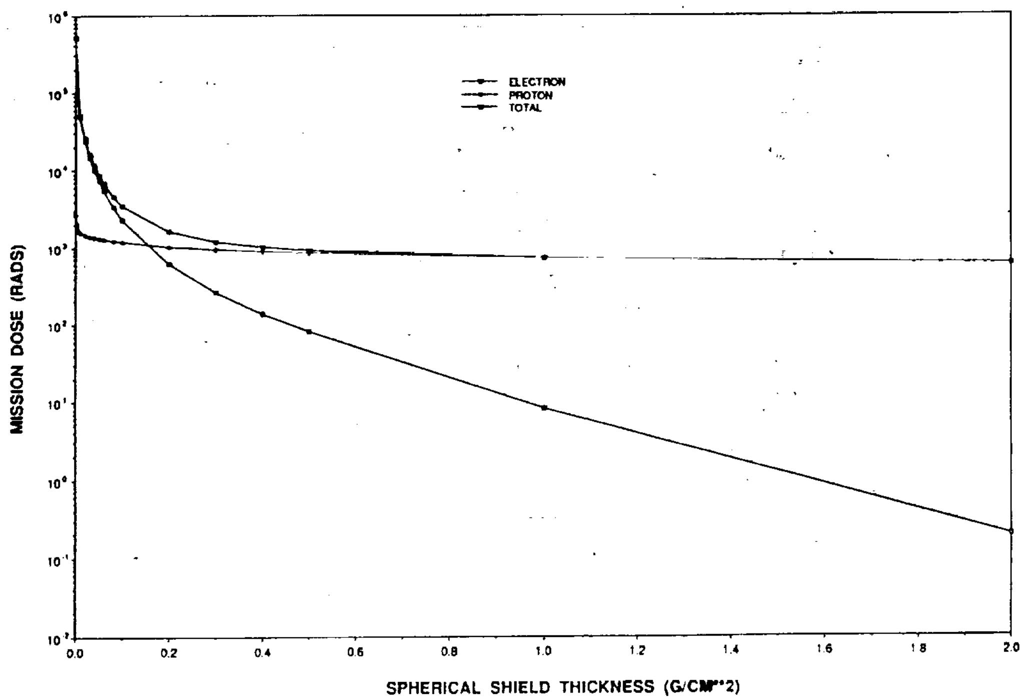
Dose LDEF Mission due to Trapped Protons and Electrons
Behind a Plane Aluminum Slab with Infinite Backing

Thickness (g/cm^2)	Electron (rads)	Proton (rads)	Total (rads)
0	2.53×10^5	1340.	2.54×10^5
0.01	25000.	712.	25700.
0.02	12100.	648.	12700.
0.03	7350.	610.	7960.
0.04	5080.	582.	5660.
0.05	3680.	560.	4240.
0.06	2760.	541.	3300.
0.08	1710.	511.	2220.
0.1	1150.	488.	1640.
0.2	310.	418.	728.
0.3	130.	381.	511.
0.4	69.0.	355..	424.
0.5	40.9	335.	376.
1.0	4.13	274.	278.
2.0	0.990	212.	212.
5.0	5.83×10^{-2}	130.	130.
10.0	2.96×10^{-2}	75.3.	75.3.
20.0		35.0.	35.0.
30.0		19.6	19.6
40.0		12.0	12.0

Dose LDEF Mission due to Trapped Protons and Electrons
Center of a Spherical Aluminum Shell

Thickness (g/cm^2)	Electron (rads)	Proton (rads)	Total (rads)
0	5.06×10^5	2680.	5.08×10^5
0.01	49900.	1600.	51500.
0.02	24200.	1480.	25700.
0.03	14700.	1410.	16100.
0.04	10200.	1360.	11500.
0.05	7350.	1320.	8670.
0.06	5530.	1290.	6810.
0.08	3420.	1230	4640.
0.1	2300.	1180.	3480.
0.2	620.	1020.	1640.
0.3	260.	937.	1200.
0.4	138.	885.	1020.
0.5	81.8	846.	928.
1.0	8.26	724.	732.
2.0	0.198	606.	606.
5.0	0.117	431.	431.
10.0	5.92×10^{-2}	292.	292.
20.0		161.	161.
30.0		101.	101.
40.0		67.8	67.8

LDEF MISSION DOSE FROM TRAPPED PARTICLES



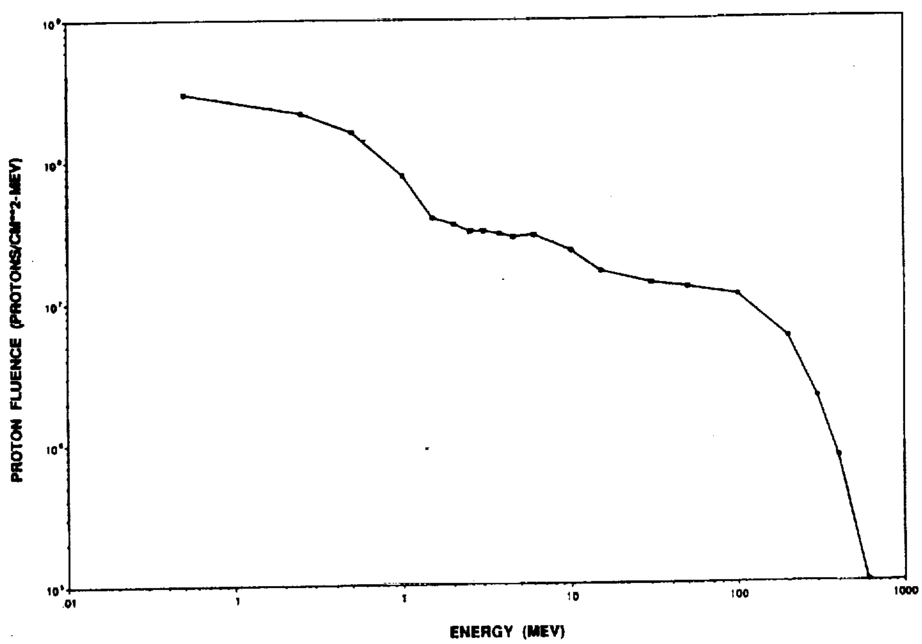
Trapped Proton Fluence for LDEF

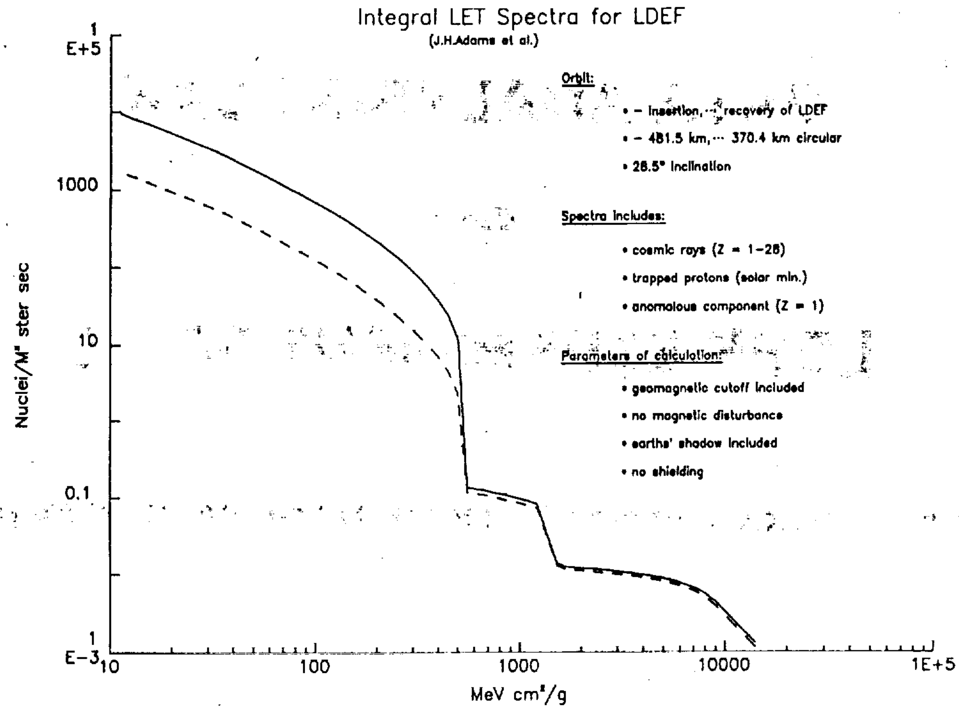
Energy (MeV)	Fluence (protons/cm²-MeV)
0.05	2.98×10^8
0.25	2.18×10^8
0.50	1.60×10^8
1.0	7.84×10^7
1.5	3.94×10^7
2.0	3.52×10^7
2.5	3.15×10^7
3.0	$3,13 \times 10^7$
3.75	3.01×10^7
4.5	2.86×10^7
6.0	2.94×10^7
10.0	2.29×10^7
15.0	1.64×10^7
30.0	1.35×10^7
50.0	1.24×10^7
100.0	1.09×10^7
200.0	5.40×10^6
300.0	2.07×10^6
400.0	7.72×10^5
600.0	1.01×10^5

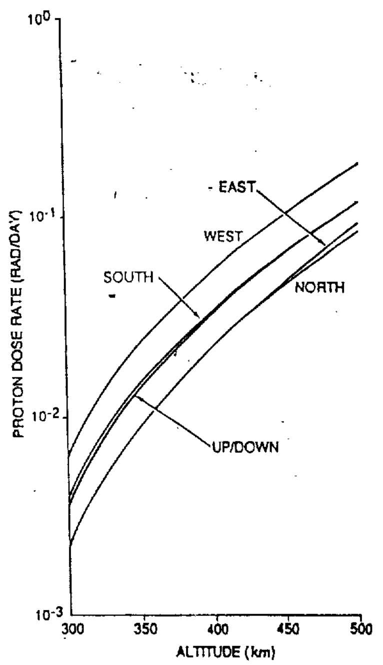
Trapped Electron Fluence for LDEF

Energy (MeV)	Fluence (electrons/cm^2-MeV)
0.05	$1.95x10^{13}$
0.25	$2.06x10^{12}$
0.50	$2.24x10^{11}$
1.0	$2.30x10^{10}$
1.5	$6.16x10^{9}$
2.0	$2.49x10^{9}$
2.5	$1.73x10^{9}$
3.0	$5.18x10^{8}$
3.75	$2.08x10^{7}$

TRAPPED PROTON FLUENCE FOR LDEF







Average proton dose rates for 28.5° orbit for a detector behind a 5 g/cm² aluminum shield with infinite backing with the plane facing in the specified directions relative to the geographic coordinates.

DATA ANALYSIS PLAN

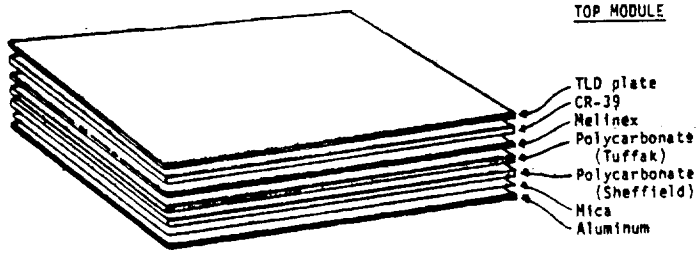
for

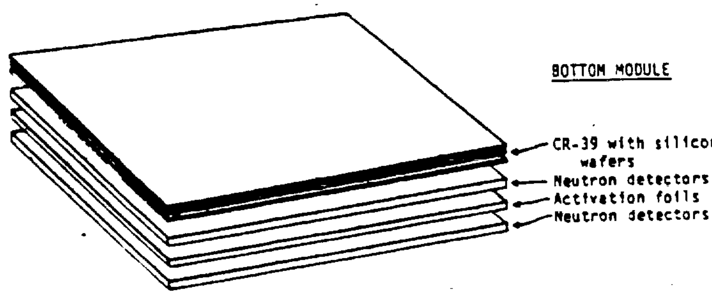
LDEF EXPERIMENT P0006

Linear Energy Transfer Spectrum Measurements Experiment

October 1989

E.V. Benton





Composition of the top and bottom modules of the P0006 experiment.

P0006:

LINEAR ENERGY TRANSFER SPECTRUM MEASUREMENT EXPERIMENT (LETSME)

OBJECTIVES

THE MAJOR SCIENTIFIC OBJECTIVES OF THE P0006 EXPERIMENT ARE AS FOLLOWS:

1. MEASURE LET SPECTRA DUE TO HZE PARTICLES AT DIFFERENT SHIELDING DEPTHS
2. OBTAIN HIGH LET (>100 keV/μm) PORTIONS OF LET SPECTRA WITH SUPERIOR STATISTICAL ACCURACY
3. MEASURE TOTAL MISSION RADIATION DOSE, NEUTRON FLUENCES AND ACTIVATION OF METAL SAMPLES
4. PERFORM VECTOR SHIELDING CALCULATIONS TO DETERMINE COMPLEX SHIELDING DISTRIBUTIONS OF LDEF EXPERIMENTS
5. CALCULATE LET SPECTRA, TOTAL RADIATION DOSES AND NEUTRON FLUENCES FOR COMPARISON WITH EXPERIMENTAL LDEF RESULTS
6. DEVELOP CALCULATIONAL METHODS TO EXTRAPOLATE THE DATA TO OTHER ORBITS
7. PERFORM CALCULATIONS OF RADIATION FIELD FOR THE SPACE STATION ORBIT
8. FROM LET SPECTRA, DETERMINE FLUENCE OF HIGH ENERGY DEPOSITION EVENTS (IN SILICON) THAT CAUSE SINGLE EVENT UPSETS (SEU) IN MICROCIRCUITS IN LDEF ORBIT
9. MEASURE FLUENCE OF RECOIL NUCLEI IN SILICON CAUSED BY PROTONS IN THE SOUTH ATLANTIC ANOMALY (NEW METHOD)
10. DETECT RADIATION EFFECTS ON BULK OR MECHANICAL PROPERTIES OF MATERIALS (LiF, POLYCARBONATE, POLYESTERS)

OTHER LDEF EXPERIMENTS HAVING UNIVERSITY OF SAN FRANCISCO RADIATION DETECTORS

I. P0006: LINEAR ENERGY TRANSFER SPECTRUM MEASUREMENT EXPERIMENT (UNIVERSITY OF SAN FRANCISCO)

A. PNTDs

1. CR-39 (PURE)
2. CR-39 (WITH DOP PLASTICIZER)
3. TUFFAK POLYCARBONATE
4. SHEFFIELD POLYCARBONATE
5. MELINEX POLYESTER

B. MUSCOVITE MICA

C. TLDs

D. FISSION FOIL DETECTORS

1. ^{238}U/MICA
2. ^{232}TH/MICA
3. ^{209}BI/MICA
4. ^{181}TA/MICA
5. ^{6}LiF/CR-39, with and without Gd

E. ACTIVATION FOILS

1. Ni
2. Ta
3. In
4. V

F. SILICON WAFERS WITH CR-39

II. P0004-1: SEEDS IN SPACE EXPERIMENT (G. PARK SEED CO.)

A. PNTDs

1. CR-39
2. TUFFAK POLYCARBONATE

B. TLDs

C. ^{6}LiF/CR-39, with and without Gd

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III. P0004-2: SPACE EXPOSED EXPERIMENT DEVELOPED FOR STUDENTS (NASA HEADQUARTERS)

A. PNTDs

1. CR-39
2. TUFFAK POLYCARBONATE

B. TLDs

C. ^{6}LiF/CR-39, with and without Gd

IV. A0015: FREE-FLYER BIOSTACK EXPERIMENT (DFVLR)

A. PNTDs

1. CR-39
2. SHEFFIELD POLYCARBONATE
3. TUFFAK POLYCARBONATE

B. MUSCOVITE MICA

C. TLDs

D. FISSION FOIL DETECTORS

1. ^{238}U/MICA
2. ^{232}TH/MICA
3. ^{209}BI/MICA
4. ^{181}TA/MICA
5. ^{6}LiF/CR-39, with and without Gd

V. M0004: SPACE ENVIRONMENT EFFECTS ON FIBER OPTICS SYSTEMS (AFWL)

A. PNTDs

1. CR-39
2. TUFFAK POLYCARBONATE
3. SHEFFIELD POLYCARBONATE
4. MELINEX POLYESTER

B. TLDs

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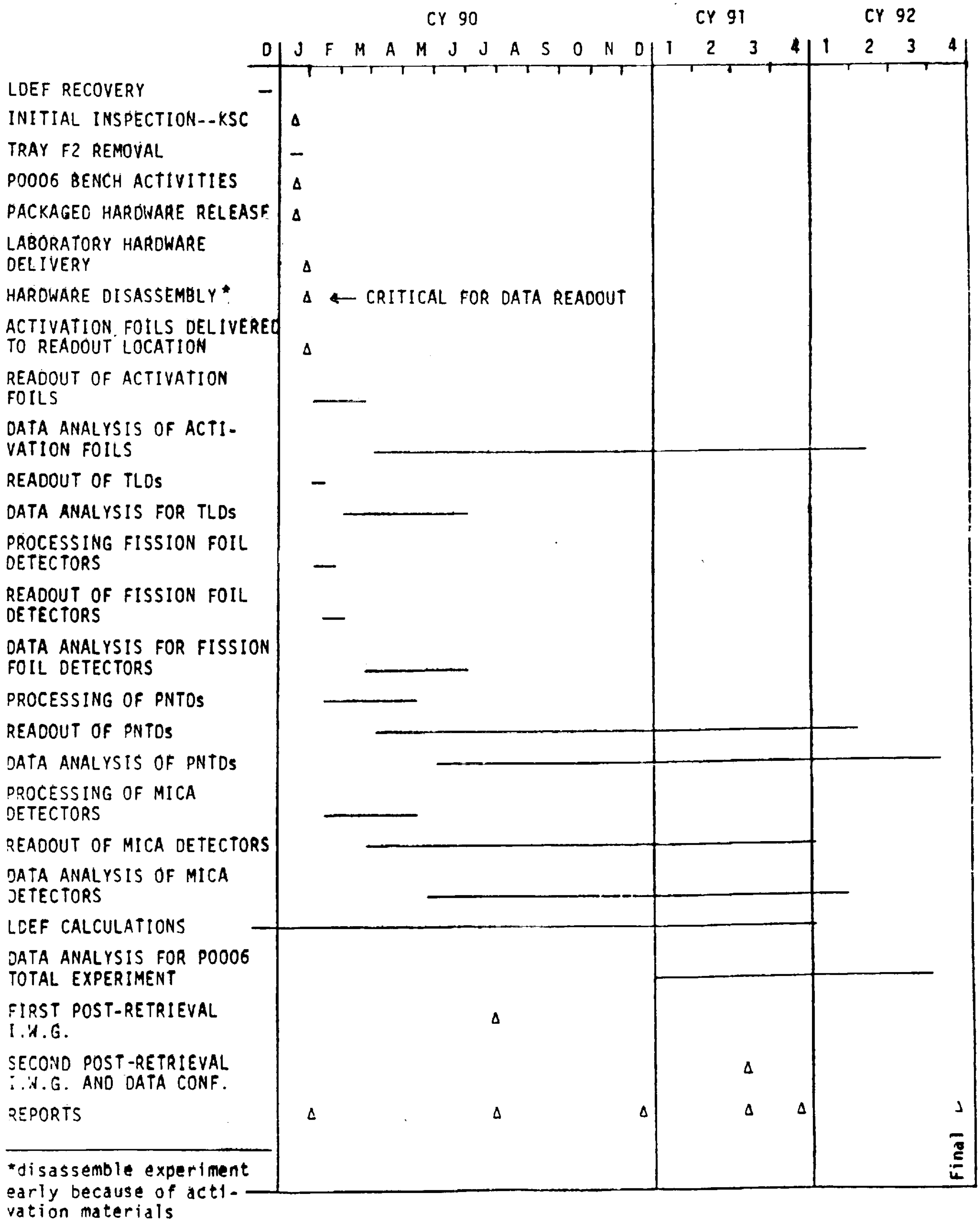
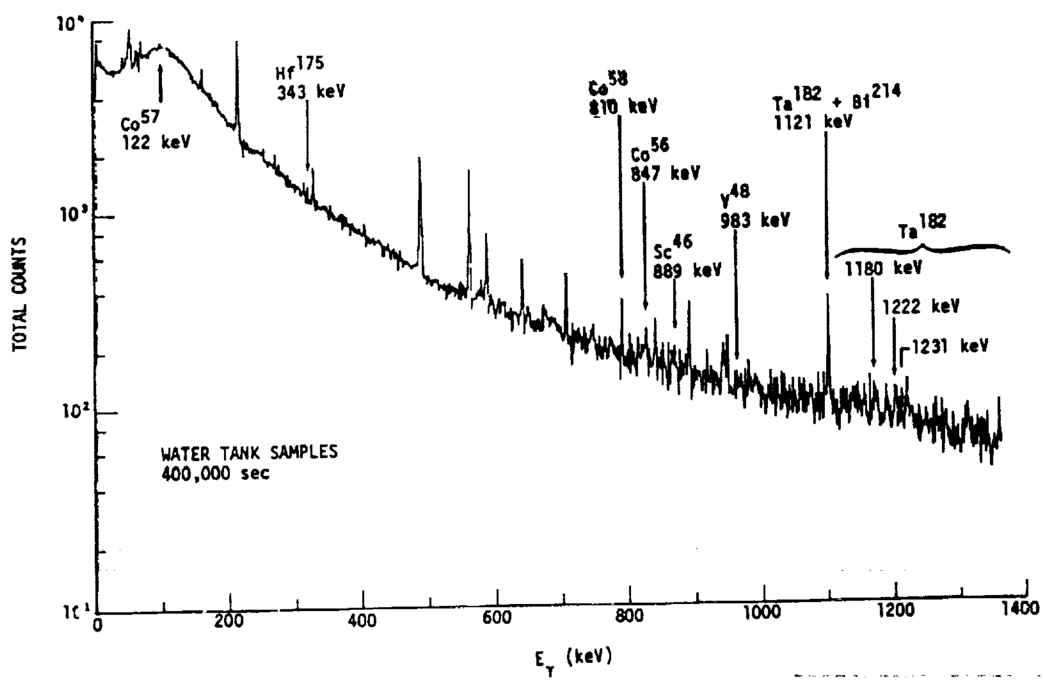
SCHEDULE -- P0006 ANALYSIS PLAN



LDEF
INDUCED RADIOACTIVITY ANALYSIS PLAN

- FULL SPACECRAFT MEASUREMENTS
- INDIVIDUAL SAMPLE MEASUREMENTS
- CALCULATIONS OF SAMPLE AND SPACECRAFT MATERIAL RADIOACTIVITY AND COMPARISONS WITH MEASUREMENTS
- MASS MODEL AND RADIOACTIVITY MODEL OF SPACECRAFT
- CALCULATION OF GAMMA FLUX AND SPECTRA AT DETECTOR POINTS OF FULL SPACECRAFT MEASUREMENTS
- EXTRAPOLATION OF CALCULATIONS TO OTHER ORBITS



GAMMA-RAY SPECTRUM - PACKET NO. 2. The activation gamma-ray peaks are identified; all other peaks are due to background gamma-ray lines. A strong background continuum is also apparent.

ESTIMATIONS FOR LDEF FROM SKYLAB DEBRIS MEASUREMENTS

TABLE 1. MEASURED INDUCED RADIOACTIVITY (SKYLAB DEBRIS)

MATERIAL	gm MASS	ISOTOPE	ENERGY (keV)	HALF-LIFE	NET COUNTS/ 1000 sec	RE-ENTRY PLUS
A ℓ (6)	~ 150	Na^{22}	1278	2.6 yr	0.50 ± .15	3 - 6 wks
SS (7)	367	Co^{58}	811	71d	0.49 ± .13	3 - 6 wks
		Mn^{54}	835	303d	4.32 ± .24	3 - 6 wks
		Co^{56}	847	77d	0.90 ± .16	3 - 6 wks
SS (11)	175	Co^{58}	811	71d	0.41 ± .15	3 - 6 wks
		Mn^{54}	835	303d	2.83 ± .28	3 - 6 wks
		Co^{56}	847	77d	0.91 ± .18	3 - 6 wks
SS ? (15)	117	Mn^{54}	835	303d	4.14 ± .30	3 - 6 wks
		Co^{56}	847	77d	0.50 ± .26	5 months
SS (16.	281	Mn^{54}	835	303d	2.41 ± .35	5 months

SS = STAINLESS STEEL ( ) SAMPLE NUMBER

TABLE 2. TYPICAL SPECIFIC ACTIVITIES OF SKYLAB DEBRIS SAMPLES

SAMPLE MATERIAL	ISOTOPE	SPECIFIC ACTIVITY* (AT RE-ENTRY)
ALUMINUM	Na^{22}	1.1 DISINTEGRATIONS/sec/kg
STAINLESS STEEL	Co^{58}	0.8 DISINTEGRATIONS/sec/kg
STAINLESS STEEL	Mn^{54}	3.0 DISINTEGRATIONS/sec/kg
STAINLESS STEEL	Co^{56}	1.5 DISINTEGRATIONS/sec/kg

*ESTIMATED ACCURACY: ±30 PERCENT

LDEF

Long Duration Exposure Facility

INDUCED RADIOACTIVITY EXPERIMENT

Target Types :

I. Intentional Samples

- Metal Targets, 2" x 2" : Ni, Co, Ta, V, In
- Contained in : A0114 Atomic Oxygen (Gregory/Peters)
  P0006 LET Spectra (Benton)
  M0001 Heavy Ions (Adams)
  M0002 Trapped Proton Spectra (AFCRL)

II. Spacecraft Structure/Components

- Stainless Steel Trunions
- Lead Ballast Plates
- Aluminum Structural Components

III.Components of Other Experiments Desired :

- Samples of Metals or Alloys of High Atomic No. (>30) with weights over 1/2 oz.

Long Duration Exposure Facility (LDEF)

RADIATION SIG

INDUCED RADIOACTIVITY STUDIES

OBJECTIVES

I. Measurements of Induced Radioactivity in Spacecraft and Experiment Materials in Low Earth Orbit

- A. Spacecraft Materials : Aluminum Alloys, Stainless Steels
- B. Experiment Materials : Copper, Germanium, Structural Alloys
- C. Activation vs. depth in a large spacecraft
- D. Activation vs. orientation in a gravity-gradient stabilized spacecraft

II. Characterization of the Nuclear-Active Particle Environment in Low Earth Orbit

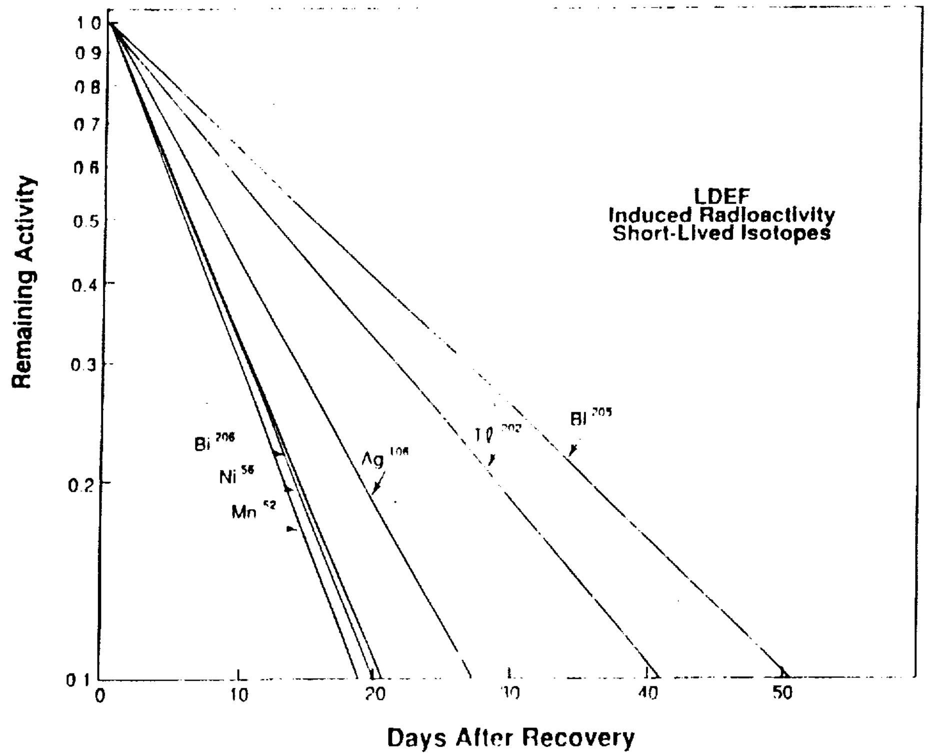
- A. Proton Flux and Spectra Above 20 MeV
- B. Neutron Flux and Coarse Spectral Measurements
- C. Separation of Trapped Proton and Cosmic Ray Proton Fluxes
- D. Proton Anisotropy Measurements

III. Experimental Verification of Spacecraft Activation Computer Codes Developed for Future Programs

- A. Space Station
- B. Lunar Base
- C. Manned Mars Mission

Targets/Reactions/Gamma Ray Energy/Half Lives

TARGET MATERIAL	MAJOR PRODUCTION MODE	RADIOACTIVE NUCLIDE	GAMMA ENERGY MeV	HALF LIFE
Aluminum	$Al^{27}(p,-)$	Na^{22}	1.28	2.6 y
		Be^{7}	.478	53 d
Stainless Steel	$Ni^{58}(n,p)$	Co^{58}	.810	71 d
	$Ni^{58}(p,2p)$	Co^{57}	.122	270 d
	$Ni^{58}(p,2pn)$	Co^{56}	.847	77 d
	$Fe^{56}(p,2pn)$	$M_n{}^{54}$	.835	313 d
Nickel	$Ni^{58}(n,p)$	Co^{58}	.810	71 d
	$Ni^{58}(p,2p)$	Co^{57}	.122	270 d
	$Ni^{58}(p,2pn)$	Co^{56}	.847	77 d
Cobalt	$Co^{59}(n,\gamma)$	Co^{60}	1.173, etc.	5.26 y
Tantulum	$Ta^{181}(n,\gamma)$	Ta^{182}	1.211	115 d
		W^{181}	.153, etc.	113 d
		Hf^{181}	.482	43 d
Titanium	$Ti^{46}(n,p)$	Sc^{46}	.899	84 d
	$Ti^{48}(p,n)$	V^{48}	.983	16 d
Indium		Cd^{115}	.940, etc.	43 d
		In^{114}	.72, etc.	50 d
		Cd^{113}		14 y
		Sn^{113}		118 d
		Ag^{110}		260 d
Copper				
Vanadium				
Germanium				
Gold				



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LDEF INDUCED RADIOACTIVITY
REQUEST FOR LOAN OF OTHER EXPERIMENT MATERIALS
FOR GAMMA RAY COUNTING

EXP. NO.	MATERIAL	DESCRIPTION	SIZE/WT
M0003*	Gallium Arsenide		2 X 2 X .09
M0003*	Molybdenum	Optical Mirrors (2)	114g
M0003*	Copper	Dia. Turned	100g
M0006	CdSe	Semiconductors (2)	1" Dia.
M0006	GaAs	Semiconductors (7)	1" Dia.
A0056	BaF_2	Substrate	25mm
A0056	Cd Telluride	Substrate	25mm dia. x 1.2mm
A0056	Thallium Bromoiodide	Substrate	1" Dia.
A0056	Germanium	Substrate	25mm
A0139A	Copper OFHC	Instrumentation	<100g
A0189	Copper OFHC	Instrumentation	<100g
S0014	Gallium Arsenide	APEX Sample	1.6cm x 1.3cm
S0014	Copper OFHC	Instrumentation	<100g
S0014	GaAlAs/Ga/As	APEX Samples (2)	
P0003	Copper	Plate, Radiometer	115g
A0114	Copper	Disc.	1" Dia.

EXP. NO.	MATERIAL	DESCRIPTION	SIZE/WT
A0114	Germanium	Disc.	1" Dia.
A0114	Silver	Single Crystal Disc.	1" Dia.
A0114	Silver	Solid Disc.	1" Dia.
A0114	Titanium Alloy	6A-4B Alloy Disc.	1" Dia.
A0114	Titanium	75 A Disc.	1" Dia.
A0187	Gold	Detector	?
A0178	Iridum	Foil	0.5mm thick
S1002	Titanium Alloy	Alloy 6V4 AMS 4911B AMS 4928D VFN 13307/20 LN 9247	
S1002	Copper	Electrolytic	?
S1001	Silver	Diode Heat Pipe	?

* NOTE 1: All samples on #M0003 have matching unexposed samples attached to the bottom of the tray. Also, since #M0003 is on four different trays, there may be more than one set of materials.

NOTE 2: These samples are desired for counting with low background gamma ray detectors as soon as feasible following de-integration of the experiments, since many nuclides of interest have short half lives. The samples can be shipped and analyzed in thin, low background radioactivity, hermetic enclosures (if required). A few materials will have some long lived radio-nuclides allowing useful analysis for several months or more following deintegration. The desired loan period for gamma ray counting is two weeks minimum. The availability of a ground control samples of the material would considerably enhance the analysis.

LDEF
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List of LDEF spacecraft structural and systems materials suitable for induced radioactivity studies.

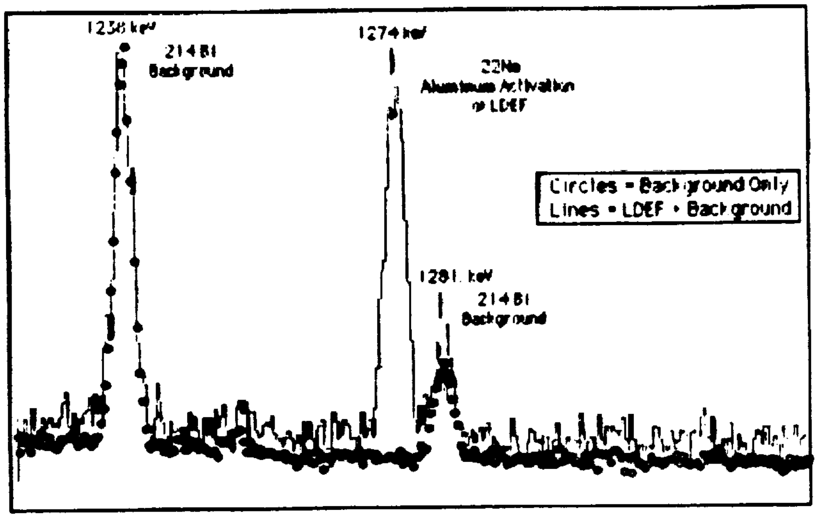
This table contains only major parts; numerous other minor components such as fasteners, and small structural parts would also be of value for the induced radioactivity studies

Description	Material	Wt.(lbs.)	Ref. No.
Trunnion pins:			
Main (middle) (2)	SS 17-4 PH	85.4	815934-E
End (2)	SS 17-4 PH	52.3	815835-B
Keel (1)	SS 17-4 PH	61.6	815950-C
Ballast plates (ap. 18 total)	Lead	7.5-30	819225
Ballast cover plates (18)	Alum., 6061	1.9, 2.8	819226
Keel plate	Alum., 6061	7.75	815947

Long Duration Exposure Facility (LDEF)

Nuclear Activation Measurements
Low Level Spectroscopy Facilities

LABORATORY/ADDRESS/PHONE	PRINCIPAL CONTACT
Battelle Memorial Institute Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352 509-376-3529, FTS 444-3529	Dr. R.L. Brodzinski
Lawrence Berkeley Laboratory Mail Stop 72-131 1 Cyclotron Road Berkeley, CA 94720 415-486-5679	Dr. Alan R. Smith
Los Alamos National Laboratory Mail Stop D-436 Los Alamos, NM 87545 (FTS 843-5066)	Dr. Calvin E. Moss
Lawrence Livermore National Laboratory Nuclear Chemistry Division, L-232 P.O. Box 808 Livermore, CA 94550 415-422-6680	Dr. David C. Camp
Oak Ridge National Laboratory Mail Stop 6204 Oak Ridge, TN 37831-6204 (FTS 624-4924)	Mr. Jim S. Eldridge



INDUCED RADIATION FROM THE LDEF

Results from 16 hours of counting with one detector on the SPACE end of LDEF compared to a background taken in the SAEF-11 high bay with no LDEF present. The line at 1274 keV comes from nuclear reactions between the aluminum on LDEF and the high-energy proton flux encountered in orbit.

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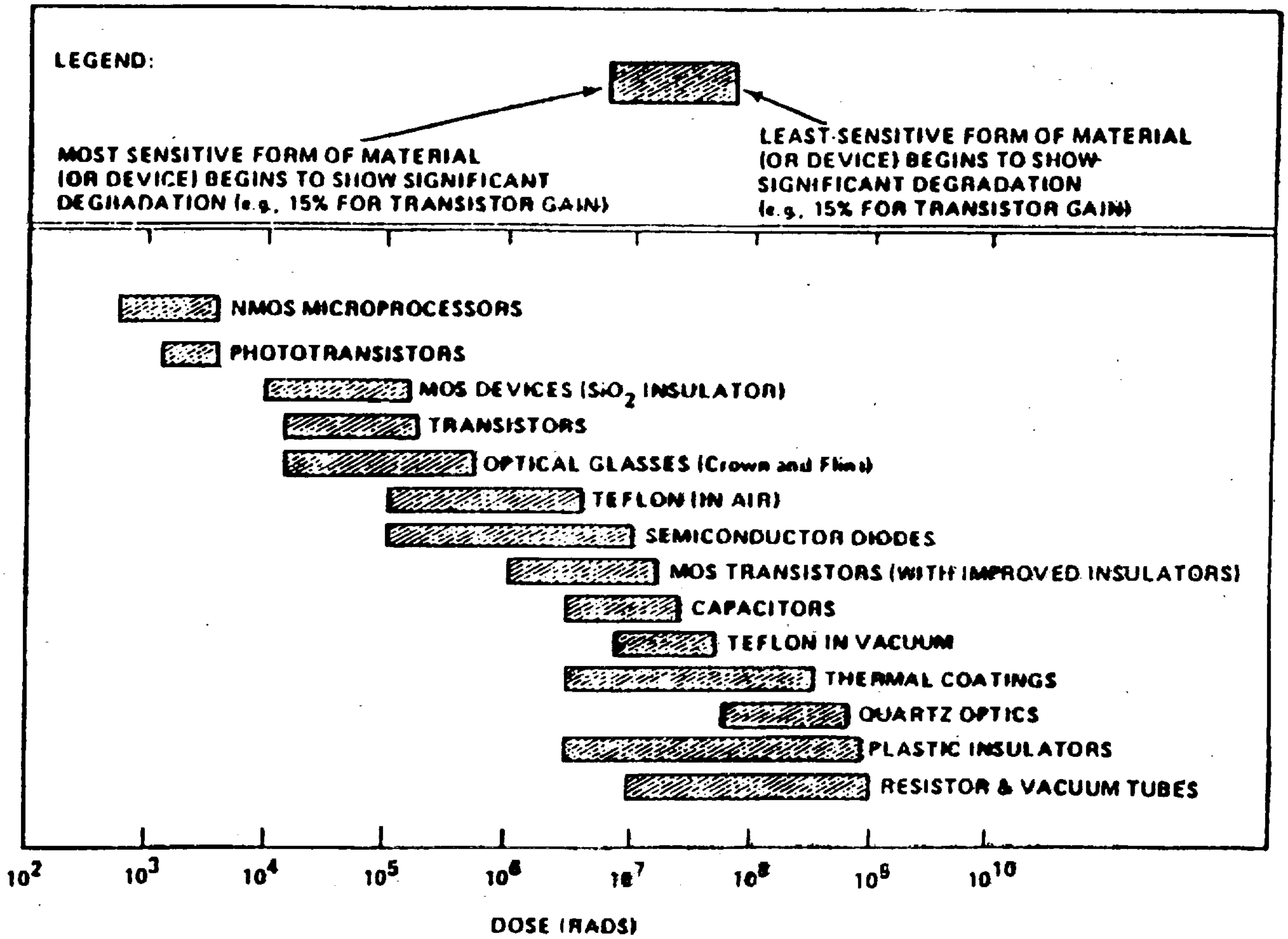
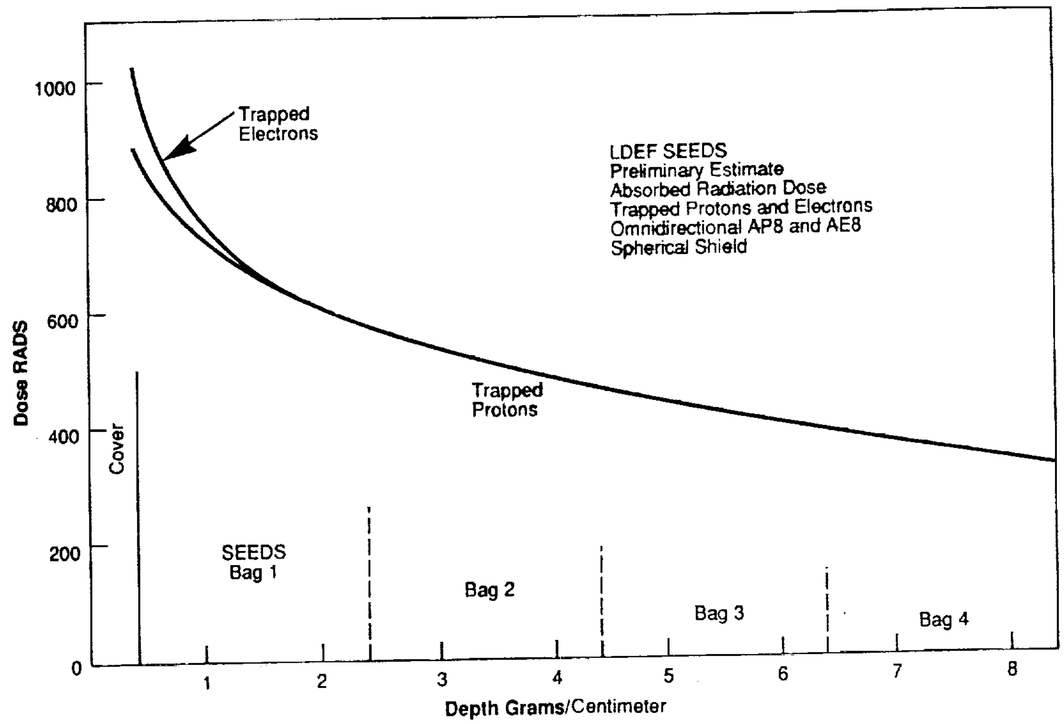


Sensitivity of Various Components to the Ionization Effects of Radiation

LDEF IRSIG TAP 2/13/90

LDEF - RADIATION EFFECTS

- DETAILED KNOWLEDGE OF RADIATION ENVIRONMENT IN LDEF WILL BE SUPPLIED BY IRSIG
- THE IRSIG WILL ARRANGE CONSULTANTS TO ADVISE CONCERNING POTENTIAL RADIATION EFFECTS IN SYSTEMS AND MATERIALS
- SPECIAL CALCULATIONS WILL BE MADE FOR COMPONENTS WITH SUSPECTED EFFECTS
- IF POST FLIGHT RADIATION TESTING IS DESIRED THE IRSIG WILL ADVISE ON PARTICLE BEAMS TO USE AND ARRANGE RADIATION EFFECTS CONSULTATION TO DESIGN THE TESTS
- IT IS RECOMMENDED THAT ANY REQUIRED RADIATION EFFECTS GROUND TESTS FOR SEU'S, OPTICAL PROPERTIES EFFECTS, DISPLACEMENT DAMAGE IN CRYSTALLINE MATERIALS ETC. BE PERFORMED BY THE RELEVANT EXPERIMENTER OR SIG


Trapped
Electrons
LDEF SEEDS
Preliminary Estimate
Absorbed Radiation Dose
Trapped Protons and Electrons
Omnidirectional AP8 and AE8
Spherical Shield
Trapped
Protons
Cover
SEEDS
Bag 1
Bag 2
Bag 3
Bag 4
Dose RADS
1000
800
600
400
200
0
1
2
3
4
5
6
7
8
Depth Grams/Centimeter

LDEF Ser. No.________

LDEF IONIZING RADIATION INFORMATION REQUEST

1. Originator:________________________ Phone:______________

2. Organization/Address:______________________________________
____

3. LDEF Experiment/System/Component/Material:_________________
____
____
____

4. Tray Number/Location:______________________________________
____

5. Anticipated/Observed Effect:_______________________________
____
____
____

6. Suspected Radiation Component (Total Dose, High LET Particles, Neutrons, etc.)______________________________
____
____

7. Other Justification for Radiation Analysis:________________
____
____

8. Desired action by Ionizing Radiation SIG (Radiation calculations at suspect site, recommendation for post-flight testing, radiation effects references, etc.)_____
____
____
____

9. Please supply detailed drawing showing component in tray and materials identification so that shielding model may be developed.

10. Requestor Signature:______________________________________

SIG Signature:____

Add continuation sheets as necessary, send copies to the following:

(1) LDEF Project Office, Code 356, NASA, LaRC, Hampton, VA 23665-5225
(2) T.A. Parnell, ES62, NASA, Marshall Space Flight Center, AL 35812

NOTE: The LDEF IRSIG does not plan to perform experimental radiation effect studies on materials/components. It does plan to supply accurate information on radiation dose, flux, secondary components at suspect sites. It will also supply references to relevant literature on radiation effects, and advice concerning post flight radiation testing.

LDEF IRSIG STATUS

- o IRSIG PLANS COMPLETE
- o PRELIMINARY DOSE, FLUENCE AND LET MEASUREMENTS COMPLETE AND CIRCULATED
- o PREDICTIONS BOOKLET IN PRESS - DISTRIBUTION 3/15/90
- o RADIATION CALCULATIONS PLAN COMPLETE*
- o P0006 ANALYSIS PLANS COMPLETE*
- o INDUCED ACTIVITY ANALYSIS PLANS COMPLETE*
- o MEASUREMENTS OF FULL SPACECRAFT INDUCED ACTIVITY IN PROGRESS
- o INDUCED ACTIVITY CALCULATIONS PLANS COMPLETE*
- o RADIATION EFFECTS CONSULTING PLAN IN PROGRESS

* AWAITING FUNDING

NASA
LONG DURATION EXPOSURE FACILITY

OVERVIEW OF PRINCIPAL INVESTIGATOR PLANS

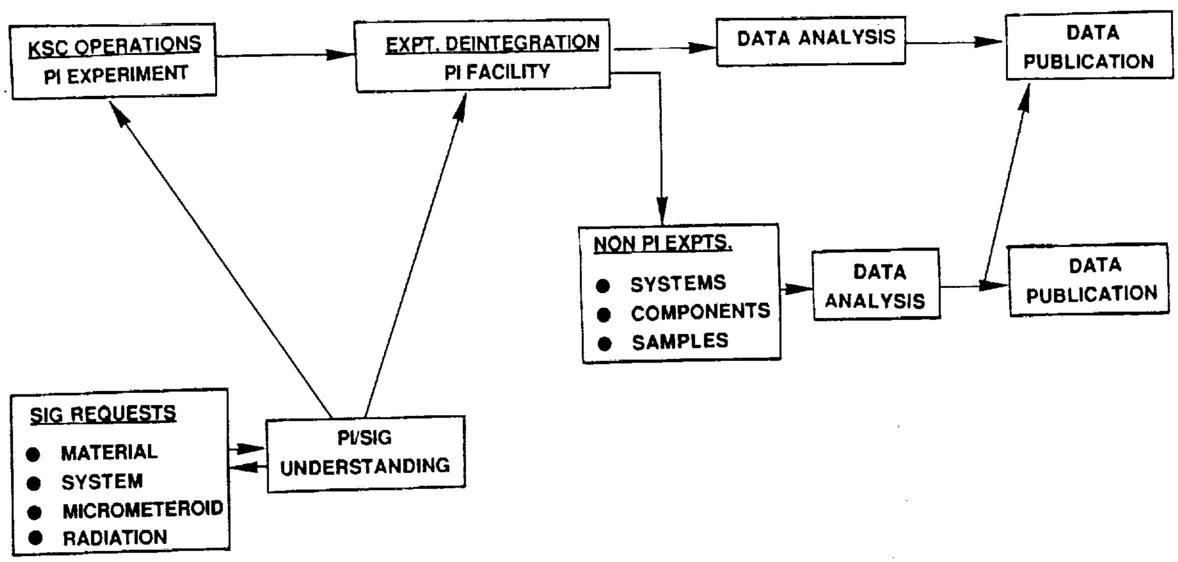
JAMES L. JONES, JR.

NASA - LANGLEY RESEARCH CENTER
LDEF SCIENCE MANAGER

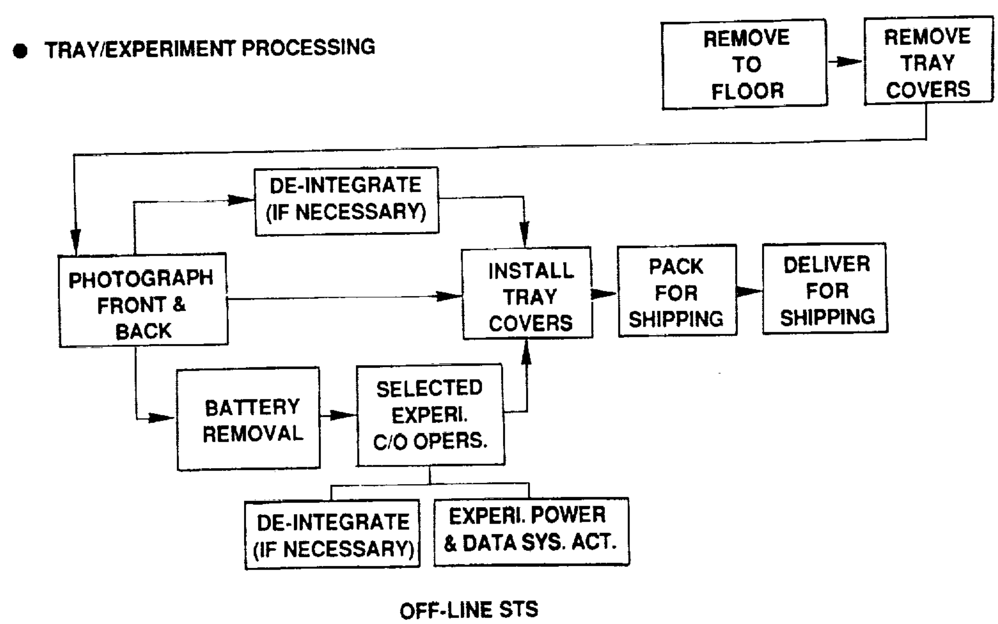
LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

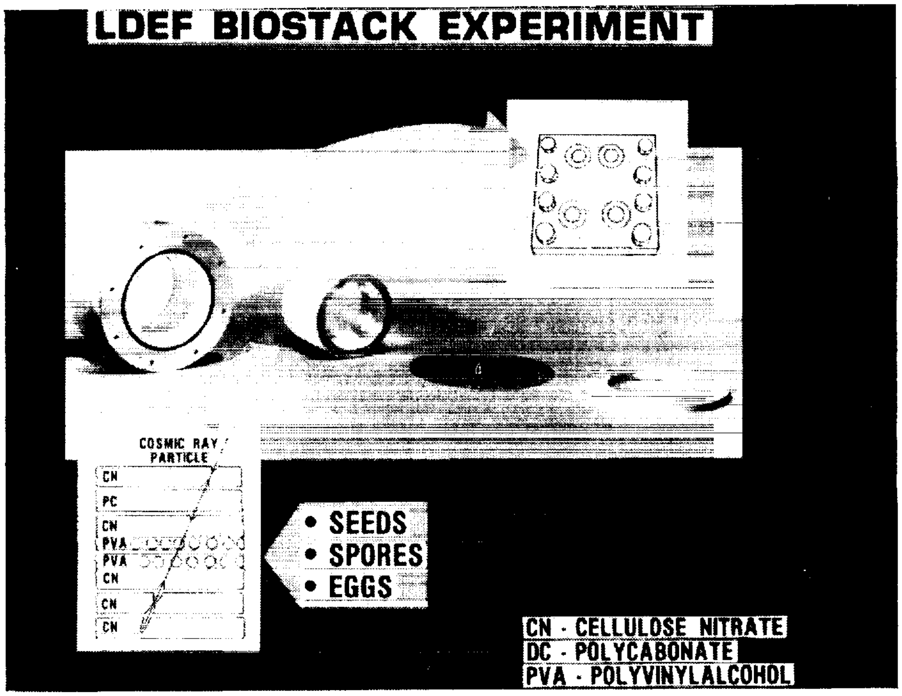
PI EXPERIMENT ACTIVITIES

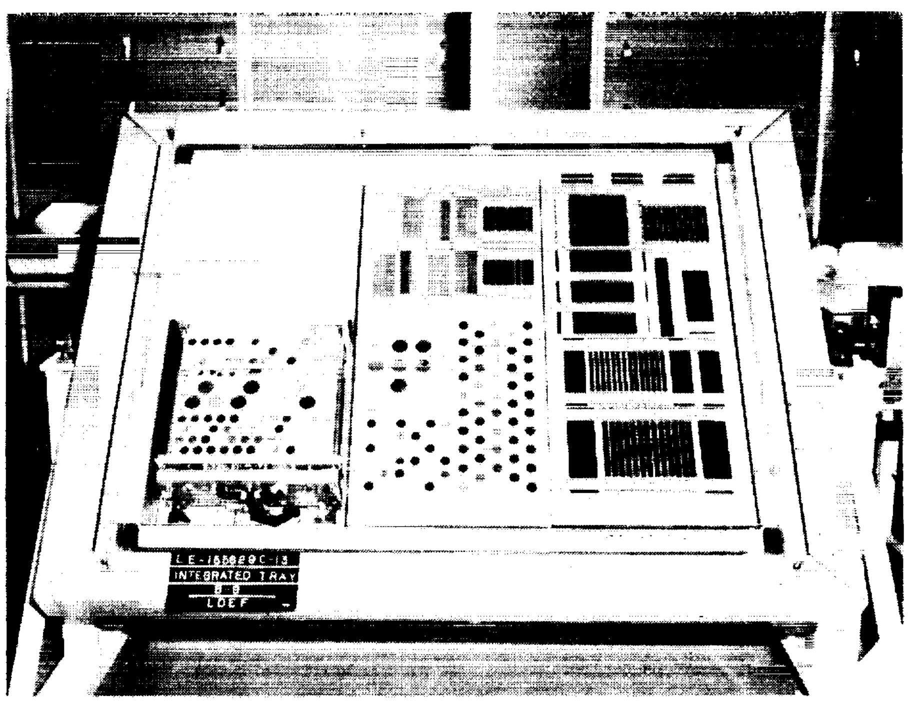


RETRIEVAL PLANS (COMPLETED)



C-2





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EXPERIMENTS A0134 AND S0010—BEFORE INTEGRATION ON LDEF STRUCTURE.

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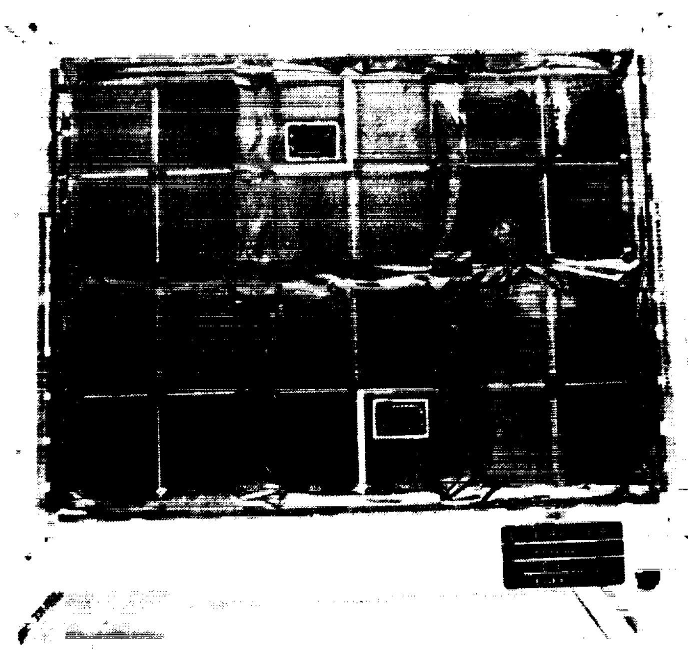
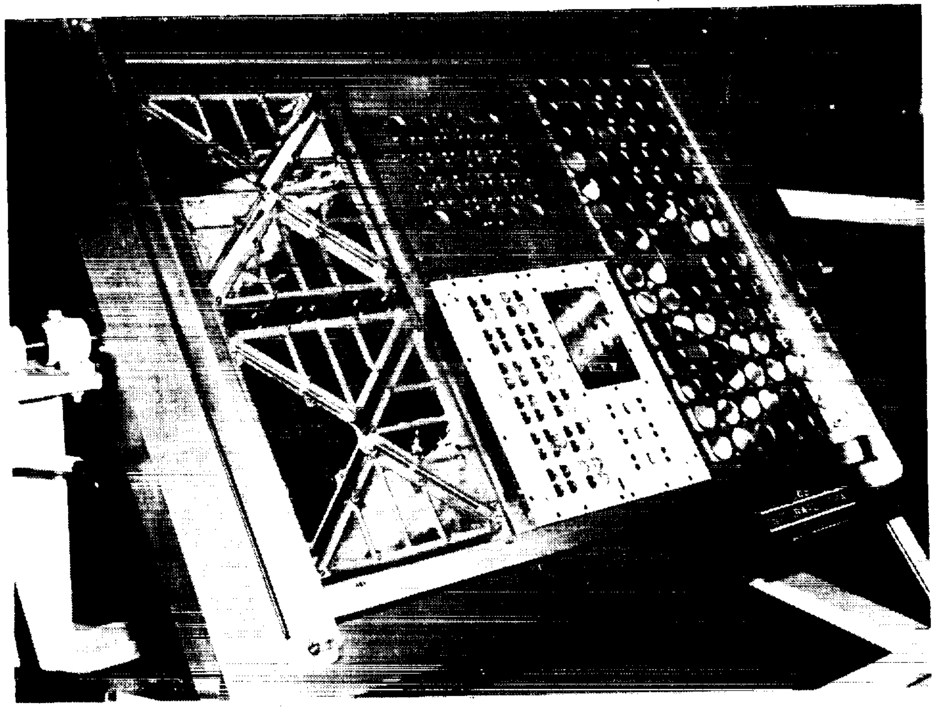
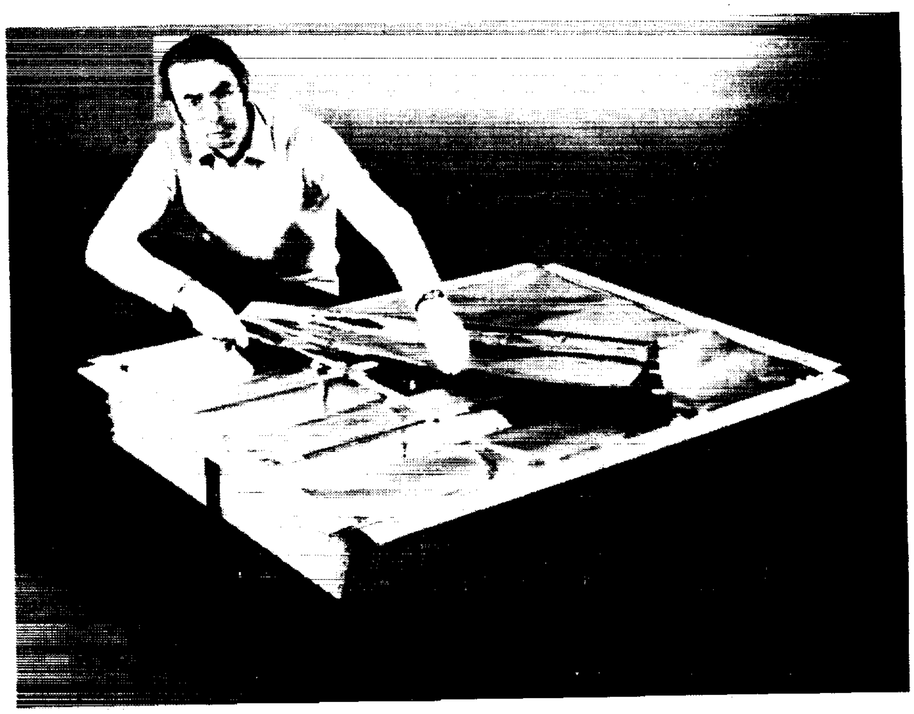
EXPERIMENT S1001—BEFORE INTEGRATION ON LDEF STRUCTURE.



EXPERIMENT A0054—BEFORE INTEGRATION ON LDEF STRUCTURE.



INTEGRATED TRAY C-3—BEFORE INTEGRATION ON LDEF STRUCTURE.



EXPERIMENT A0178—BEFORE INTEGRATION ON LDEF STRUCTURE.

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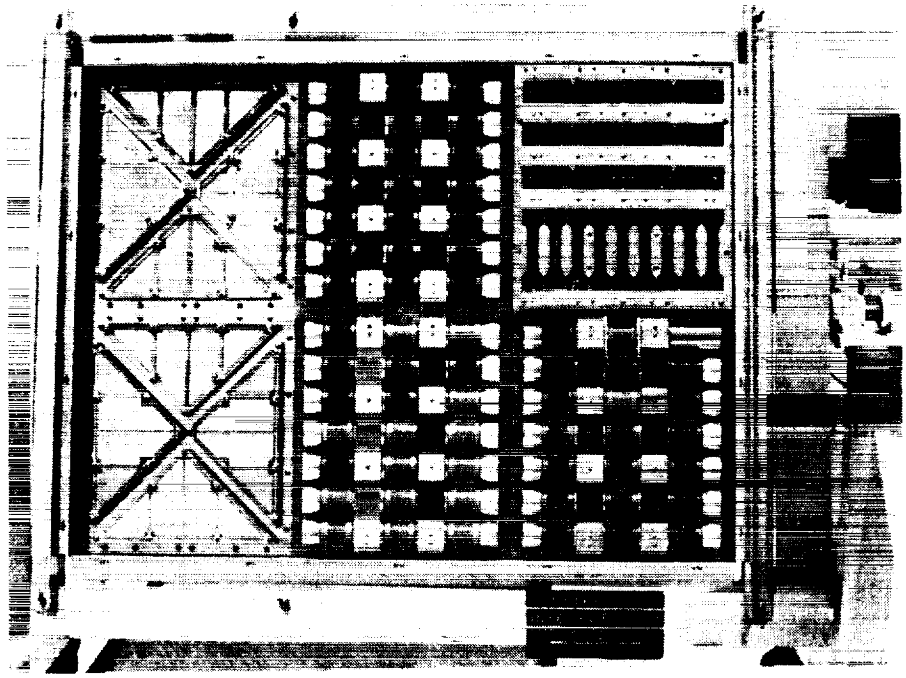
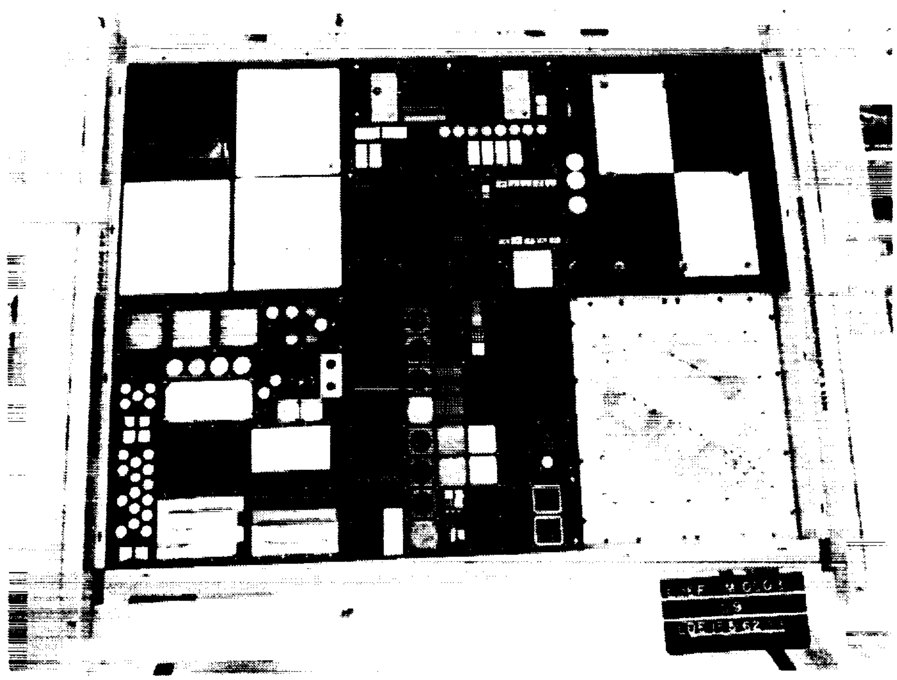
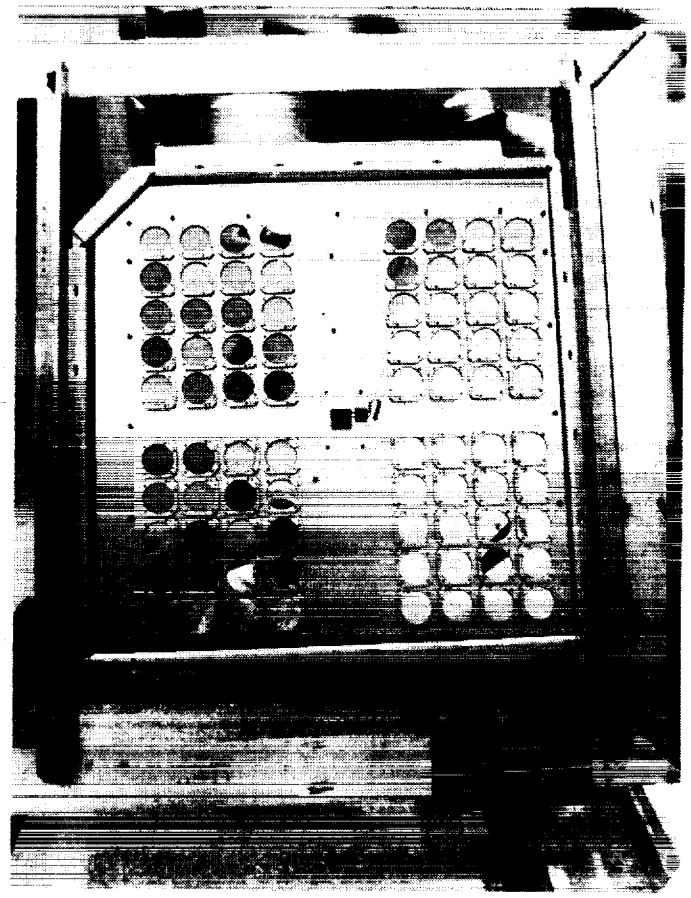


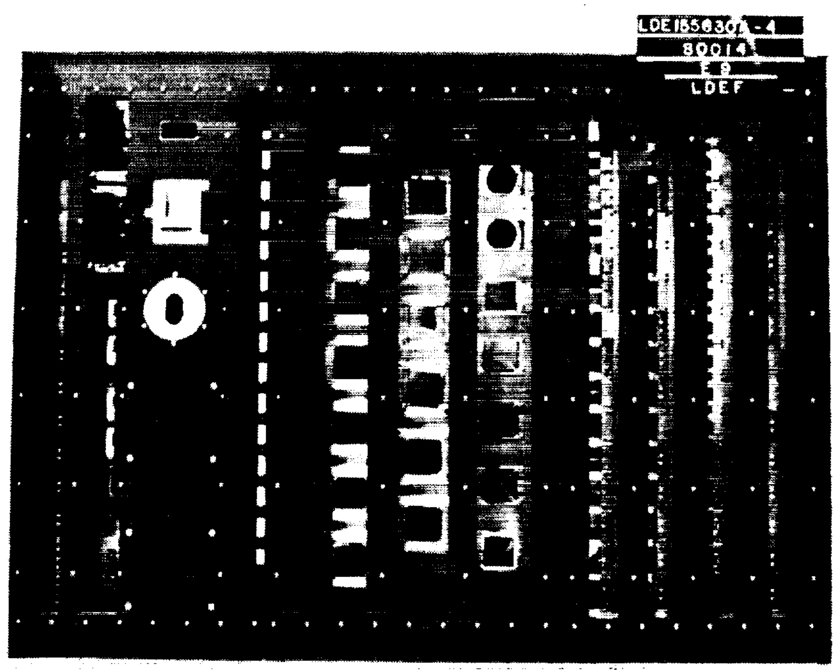
INTEGRATED TRAY D-12—BEFORE INTEGRATION ON LDEF STRUCTURE.



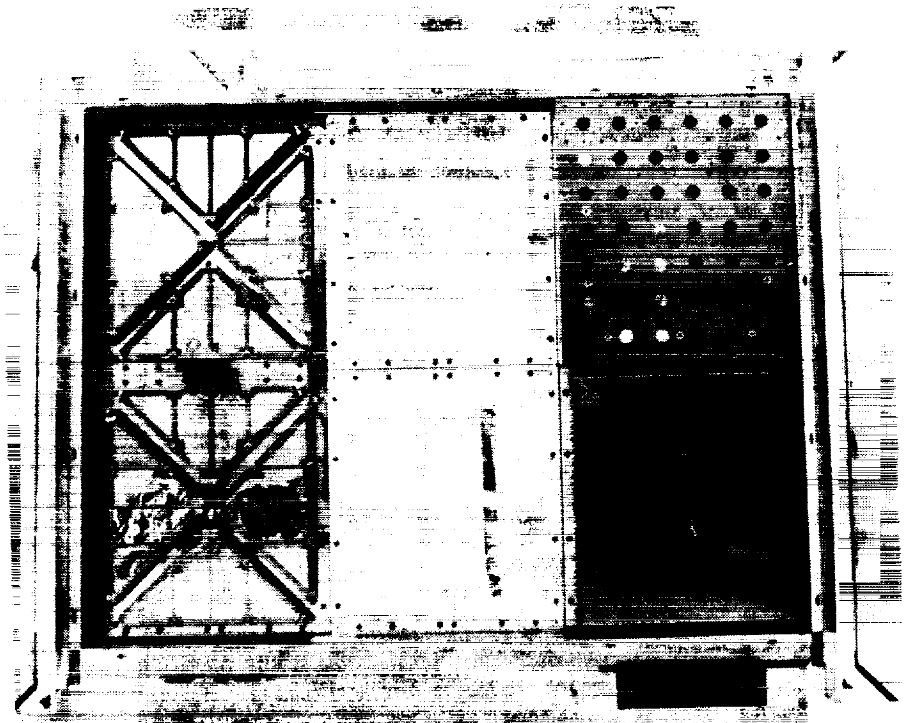
EXPERIMENTS M0002 AND M0003—BEFORE INTEGRATION ON LDEF STRUCTURE.



TRAY G10—BEFORE INTEGRATION ON LDEF STRUCTURE.

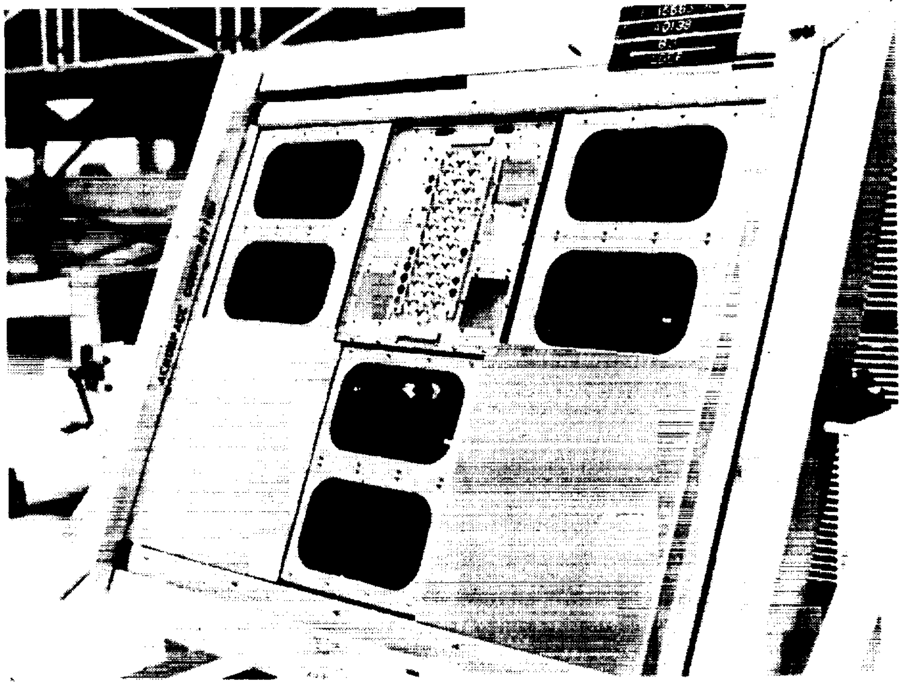


EXPERIMENT S0014—BEFORE INTEGRATION ON LDEF STRUCTURE.



INTEGRATED TRAY E-6—BEFORE INTEGRATION ON LDEF STRUCTURE.

EXPERIMENT M0004—BEFORE INTEGRATION ON LDEF STRUCTURE.



EXPERIMENT A0138—BEFORE INTEGRATION ON LDEF STRUCTURE.

NASA
LONG DURATION EXPOSURE FACILITY

SDIO OVERVIEW

WAYNE E. WARD

U.S.AIR FORCE SYSTEMS COMMAND
MEMBER, MSIG

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

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SDIO ASSESSMENT OF THE NASA LONG DURATION EXPOSURE FACILITY (LDEF)

IDENTIFICATION OF DATA/SAMPLES DESIRED

NASA/LDEF WORKSHOP
KSC
13 - 14 FEBRUARY 1990

WAYNE E. WARD

WRDC/MLBT
WRIGHT-PATTERSON AFB,
OHIO 45433-6533

SPACE ENVIRONMENTAL EFFECTS PROGRAM OBJECTIVES

PROVIDE SELECTED, CRITICAL SPACE ENVIRONMENTAL EFFECTS DATA ON MATERIALS IN THE FORM TO ASSIST MORE CONFIDENT DESIGN OF LONG LIFE SDS SPACECRAFT

TWO PHASE EFFORT

- UTILIZE EXISTING NATIONAL RESOURCES AND CURRENT OR CURRENTLY DEVELOPMENTAL MATERIALS TO ACQUIRE ESSENTIAL DATA FOR PHASE ONE SYSTEM DESIGNS (e.g. BSTS, SSTS)
- ENHANCE AND INTEGRATE NATIONAL TESTING CAPABILITIES FOR LONG LIFE IN ALL ENVIRONMENTAL CONDITIONS
- EXPAND TESTING TO INCLUDE MATERIALS NOW IN EARLY DEVELOPMENT
- COMPLY WITH LONG LEAD TIME REQUIREMENTS BY IMMEDIATELY INITIATING SPACE FLIGHT PLANNING TO ACQUIRE ESSENTIAL DATA

SPACE ENVIRONMENTAL EFFECTS SUMMARY

WRDC / ML: SERVE AS EXECUTING AGENT

* TO PLAN AND EXECUTE THE SPACE ENVIRONMENTAL EFFECTS PROGRAM

* TO MANAGE A COORDINATED NATIONAL EFFORT

* TO PROVIDE SELECTED SPACE ENVIRONMENTAL EFFECTS INFORMATION FOR MATERIALS SELECTION, PERFORMANCE AND END OF LIFE PREDICTIONS FOR NEAR TERM AND FUTURE SDS SPACECRAFT

* TO FILL CRITICAL VOIDS IN THE TRANSITION OF NEW MATERIALS AND STRUCTURES TECHNOLOGY TO SDS SPACECRAFT

SPACE ENVIRONMENTAL EFFECTS NEEDS

- SPACE ENVIRONMENTAL EFFECTS ON MATERIALS PROPERTIES / PERFORMANCE MUST BE QUANTIFIED
  - GROUND SIMULATION
    - COMBINED EFFECTS
    - ORBITAL DEPENDENCE
  - ORBITAL EXPERIMENTS / DATA
    - LDEF, DELTA STAR, OTHERS
  - MATHEMATICAL MODELING
    - COMBINED EFFECTS
    - ENHANCED DATA BASE
  - STANDARDIZED TEST METHODS AND PROCEDURES
  - ACCELERATED TESTING
- SPACE ENVIRONMENTAL EFFECTS ON HARDNESS MUST BE QUANTIFIED
  - COMBINED ENVIRONMENTAL / HARDNESS TESTING
- RESULTS MUST BE CORRELATED FOR EASY ACCESS BY SYSTEMS DESIGNERS
- GUIDE MATERIALS DEVELOPMENT

SPACE ENVIRONMENTAL EFFECTS

TECHNOLOGY INSERTION WORKING GROUP(TIWG)

MEMBERSHIP

AIR FORCE	- DR. WAYNE WARD	WRDC/ML, CHAIRMAN
	- DR. ED MURAD	AFGL/PHK
	- LT. DALE ATKINSON	AFWL/NTCAS
	- LT. BRIAN LILLIE	AFSTC/XLA
SDIO	- LTC RICHARD YESENSKY	SDIO/TNK
	- DR. AINSLIE YOUNG	SDIO/TNK
	- LTC CHIP HILL	SDIO/TNK
NAVY	- MR. AL BERTRAM	NSWC/WL
NASA	- DR. DARREL TENNEY	LANGLEY RESEARCH CENTER
	- DR. LUBERT LEGER	JOHNSON SPACE CENTER
W.J. SCHAFER	- MR. ROBERT TURNER	
AEROSPACE CORP.	- DR. GRAHAM ARNOLD	CPL
	- DR. MIKE MESHISHNEK	MSL
JET PROPULSION LAB	- DR. RANTY LIANG	SPACE MATERIALS S&T
	- DR. JOHN SCOTT-MONCK	SPACE MATERIALS S&T

LDEF: OBJECTIVES OF SDIO EFFORT

WRDC/MLBT WPAFB,OH 45433-6533

- IDENTIFY SDIO DATA ANALYSIS REQUIREMENTS AND SAMPLE NEEDS
- SET SDIO PRIORITIES
- DEVELOP INPUT FOR NASA - LDEF SIG CHAIRMEN
- SORT REQUIREMENTS BY BENEFITING PROGRAM OFFICES

PRIORITIES

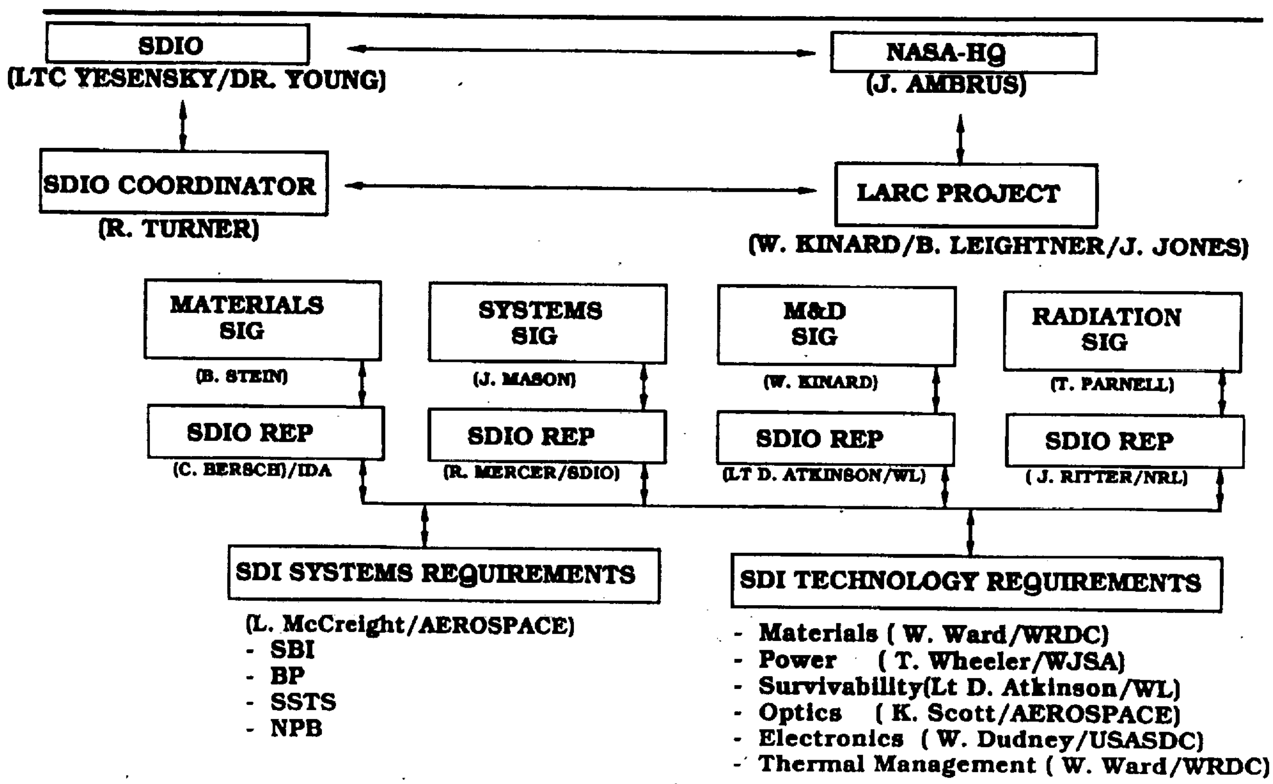
WRDC/MLBT WPAFB,OH 45433-6533

I CRITICAL TO SDIO SYSTEMS AND TECHNOLOGY PROGRAMS.

II ESSENTIAL TO SDIO DATA GENERATION AND GROUND-TO-SPACE CORRELATIONS.

III SUPPORTS GENERIC RESEARCH NEEDS.

SDIO PARTICIPATION IN NASA-LDEF ORGANIZATION CHART



SDIO PARTICIPATION IN NASA-LDEF RESPONSIBILITIES

SDIO SIG REPRESENTATIVES

- COORDINATES NASA-LDEF REQUIREMENTS/PREPARATION
- PROVIDES COORDINATED SDIO REQUIREMENTS TO NASA SIG's
- PROVIDES COST ESTIMATES
- PRIORITIZE REQUIREMENTS

SDIO SDI SYSTEMS AND TECHNOLOGY REPRESENTATIVES

- REVIEWS EXPERIMENTS/LDEF SPACECRAFT DATA OPPORTUNITIES
- PROVIDES SDIO SIG REPRESENTATIVES WITH REQUIREMENTS FOR ASSIGNED AREA
  - DATA NEEDS PER NASA FORMAT
  - SAMPLE NEEDS
  - ESTIMATE COSTS

SDIO - LDEF COORDINATOR

- POC FOR NASA LDEF PROJECT
- SHEPHERDS ACTION TIMELINE
- SUPPORTS COORDINATION OF SDIO ACTIVITIES, RESOLUTION OF ISSUES

STATUS OF SDIO PLANNING EFFORT

- SDIO REQUIREMENTS DEFINED
- MATERIALS OR SYSTEMS ANALYSES AND PRIORITIES ARE IDENTIFIED BY LDEF EXPERIMENT
- SAMPLE NEEDS AND TEST SEQUENCES ARE IDENTIFIED BY LDEF-EXP
- FURTHER COORDINATION NEEDS ARE IDENTIFIED BY LDEF EXPERIMENT
- NEED TO IDENTIFY IMPLEMENTATION APPROACHES
  - DATA ANALYSES
  - SAMPLE COLLECTION

EXPERIMENT # M0006 (PI: TSGT MICHAEL STESKAL (407) 494-2531)

LEVEL III SUMMARY OF TYPE OF MATERIALS OR SYSTEMS REQUESTED AND TESTS REQUIRED					
SIG: COMBINED				PRIORITIZED 1 THRU n	
SDIO CODE	TRAY #	TYPE OF MAT/SYS NAME/COMPANY	PRIORITY	TEST/SAMPLE REQUIREMENT	ADDITIONAL INFORMATION NEEDED
SYS 04	M0006	Vacuum canister	I	Stiction, lube condit, migration	Dry lubricant specifications
SYS 05	M0006	Detectors & shielding matl.	II	Performance (13)	Preflight data, control samples
SYS 06	M0006	Mechanisms	I	Contamination degradation (16)	
SYS 07	M0006	Clocks, opt. filters, substrs		Neutral particle beam surv.	Preflight, post-flight test data
SYS 07	M0006	Thermal paints, thermocpls		AGT and laser survivability	Preflight, post-flight test data
DEB01	M0006	Mirrors-fused Si & Be	I	Evaluate Impacts (1)	Orig. Specs., Chars. (1)
MAT 02	M0006	Mirrors-Be	I	Optical Properties / Samples	Collaboration with M0003
MAT 06	M0006	Electro Optics	I	Optical and T/C Tests (1)	Control Sample Info (1)
MAT 07	M0006	Electronics (9)		Materials degradation data	

LEVEL III NOTES FOR SUMMARY OF TYPE OF MATERIALS OR SYSTEMS REQUESTED AND TESTS REQUIRED					
SIG: MATERIALS				PRIORITIZED 1 THRU n	
SDIO CODE	TRAY #	TYPE OF MAT/SYS NAME/COMPANY	PRIORITY	TEST/SAMPLE REQUIREMENT	ADDITIONAL INFORMATION NEEDED
MAT 06 Note (1)				If not performed by PI, perform the following tests. For more complex tests obtain samples from PI when his prior testing is complete: - Visual examination under varying lighting conditions - Contamination collection, analysis, and identification - Total integrated scatter measurements before and after contamination removal - *Reflectance/transmittance measurements - *Analysis of defects of and causes for: --separations --flaking --peeling --other surface anomalies *Nomarski tests of selected surfaces.	If available, obtain control samples corresponding to exposed samples provided by the PI. Where critical tests are performed by PI, review his data and if values or calibrations uncertain, request flight and control samples be submitted to SIG for retest.

LEVEL III	NOTES TO SUMMARY OF TYPE OF MATERIALS OR SYSTEMS REQUESTED AND TESTS REQUIRED				
SIG:	DEBRIS				
SDIO CODE	TRAY #	TYPE OF MATERIAL OR SYSTEM	PRIORITY	TEST/SAMPLE REQUIREMENT	ADDITIONAL INFORMATION NEEDED
Note (1)				Evaluate: Number of impacts Crater depths and diameters Impact effects (spalling, cracking, delamination, etc.) Impactor material/compositions (especially on Be mirror) Degradation of optical characteristics due to impacts	Original specifications and optical characteristics (TIS, BRDF,TMR, etc.), post retrieval optical measurements on control samples
Note (2)				Evaluate: Secondary eject impacts Contamination Impactor and contaminaton materials/compositions Degradation of optical characteristics due to contamination	

LIMITATIONS TO THE DEFINITION OF SDIO NEEDS

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- DEPTH OF REQUIREMENTS DEFINITION -- ID LIMITED BY AVAILABLE INFORMATION.
- TYPES OF MATERIALS ARE IDENTIFIED, NOT SPECIFIC SPECIMENS IN MOST CASES
- "ASSUMES" ALL TRAYS WILL BE ANALYZED
- REQUIREMENTS ARE NOT SEPARATED RELATIVE TO WHAT IS BEING DONE BY SIGs AND PIs VERSUS SDIO SPECIFIC NEEDS
- CONFLICTS / OVERLAPS BETWEEN SIGs NOT RESOLVED
- TIMELINESS OF AVAILABLILITY OF DATA TO IMPACT SDI SYSTEMS
- INTERESTED IN "LEADING EDGE" SAMPLES OR BEST ALTERNATIVE

EXPERIMENTS OF INTEREST TO SDIO

A0019	A0023	P0003	S0001
A0034	A0038	P0005	S0010
A0044	A0054		S0014
A0056	A0076		S0050
A0114	A0133	M0001	S0069
A0134	A0135	M0003-4,-5	S0109
A0138	A0139	M0004	S1001
A0147	A0171	M0006	S1002
A0172	A0175		S1003
A0178	A0180		S1005
A0187	A0189		
A0201			

EXPERIMENTS OF INTEREST TO SDIO

EXPERIMENT (LOCATION)

A0019 (D12)	A0023 (various)	M0001 (H3,H12)	S0001 (various)
A0034 (C3,C9)	A0038 (various)	M0003-4,-5 (D3,4,8,9)	S0010 (B9)
A0044 (E5)	A0054 (B4,D10)	M0004 (F8)	S0014 (E9)
A0056 (B8,G12)	A0076 (F9)	M0006 (C2)	S0050 (E5)
A0114 (C3,C9)	A0133 (H7)		S0069 (A9)
A0134 (B9)	A0135 (E5)		S0109 (C12)
A0138 (B3)	A0139 (G6)	P0003 (CR)	S1001 (F12,H1)
A0147 (B8,G12)	A0171 (A8)	P0005 (CR)	S1002 (E3)
A0172 (D2,G12)	A0175 (A1,A7)		S1003 (E6)
A0178 (various)	A0180 (D12)		S1005 (B10)
A0187 (various)	A0189 (D2)		
A0201 (various)			

FUTURE DIRECTION AND COORDINATION

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- NEED TO INTERACT FURTHER WITH SIGs AND PIs
  - IDENTIFY PLANNED PI TESTS AND ANALYSES
  - IDENTIFY PLANNED SIG TESTS AND ANALYSES
  - IDENTIFY ANY MISMATCHES BETWEEN SDIO AND NASA PLANS
- NEED TO LAYOUT A MUTUALLY AGREEABLE PROCESS FOR INTERACTION
- SOME DETAIL MISSING FOR SOME REQUIREMENTS

IMPLEMENTATION PLAN

WRDC/MLBT WPAFB,OH 45433-6533

- SDI SPACE ENVIRONMENTAL EFFECTS (SEE) PROGRAM MANAGER RESPONSIBLE FOR COORDINATION OF SDI/LDEF ACTIVITIES
  - ESTABLISH SDI/LDEF ADVISORY PANEL (SEE TIWG & SDIO SIG REPS)
- IMPROVE COORDINATION WITH NASA
  - INCREASED PARTICIPATION IN SIG ACTIVITIES
  - HELP IDENTIFY/RESOLVE DATA/SAMPLE QUESTIONS AMONG PIs/SIGs/SDI
    - DUPLICATIONS, CONFLICTS, TEST SEQUENCING, etc.
- COMMUNICATE WITH PIs
  - PI INTERESTS/DATA GENERATION PLANS
  - SDI INTERESTS/DATAAND/OR SAMPLES DESIRED
- ENSURE COOPERATIVE APPROACH
  - MAXIMIZES BENEFITS FROM RESOURCE EXPENDITURES
  - BEST WAY TO PROTECT EVERYONE'S RIGHTS AND INTERESTS

HOW CAN SDI ACQUIRE DESIRED DATA/SAMPLES?

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- EXPERIMENTS/ SAMPLES BELONG TO PIs
  - TWO KINDS OF DATA: "GENERAL INTEREST" AND "SDI UNIQUE"

•"GENERAL INTEREST"
- IS PI PLANNING TO GET IT?

IF YES
- ASSURE COMPATIBILITY OF PIs PLANS WITH "GLOBAL"PLANS
- KEEP IN TOUCH (THROUGH SIGS)

IF NO
CAN/WOULD PI GET IT IF ASKED?

IF YES
- KEEP IN TOUCH

IF NO
WOULD PI AGREE TO LOAN/GIVE A SAMPLE FOR DATA GENERATION
- BY SIG/BOEING
- BY SOMEONE ELSE (TBD)
- PI GETS PUBLICATION RIGHTS

IF YES
- KEEP IN TOUCH

IF NO
"????"

HOW CAN SDI ACQUIRE DESIRED DATA/SAMPLES?

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- "SDI UNIQUE" DATA (e.g. SURVIVABILITY)
  - REQUEST SAMPLES FROM PIs
    - SUITABLE FOR TESTING
    - MAY NOT BE RETURNED (DEPENDS ON TESTS TO BE PERFORMED)
    - CONTROL SAMPLES MAY BE NEEDED FOR CORRELATION
  - DATA GENERATED MAY NOT BE RELEASED (MAY BE CLASSIFIED)
- <u>COOPERATIVE EFFORT</u> TO MAXIMIZE DATA WHICH CAN BE OBTAINED FROM UNIQUE LDEF OPPORTUNITY

NASA
LONG DURATION EXPOSURE FACILITY

MATERIALS DATA ANALYSIS METHODOLOGY OVERVIEW

BLAND A. STEIN

NASA - LANGLEY RESEARCH CENTER
WORKSHOP CO-CHAIRMAN

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

LONG DURATION EXPOSURE FACILITY

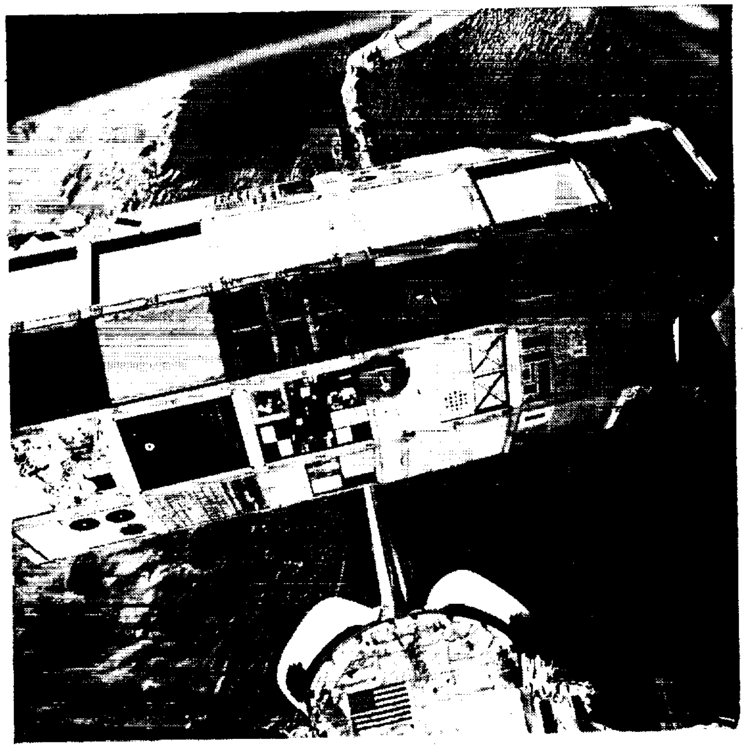
MATERIALS DATA ANALYSIS METHODOLOGY OVERVIEW

BLAND A. STEIN
NASA - LANGLEY RESEARCH CENTER,
CHAIRMAN, LDEF MSIG

LDEF MATERIALS DATA ANALYSIS WORKSHOP
NASA - KENNEDY SPACE CENTER
FEBRUARY, 1990

LDEF launch

LDEF retrieval



LDEF MATERIALS CHARACTERIZATION OPPORTUNITIES

UNIQUE MATERIALS DATA

- 5.5-year exposure in low Earth orbit
- Well-defined environmental parameters
  - Natural environment
  - Induced environments (e.g.-contamination, debris)
- Large variety of materials in materials experiments, systems experiments, and science experiments

BENEFICIAL MATERIALS DATA

- Design data base for NASA, DoD, and Commercial missions
  - Space Station Freedom
  - In-Space Experiments
  - Global Change Technology Platforms/Experiments
  - SDI systems
  - Communications satellites
  - Concept studies for advanced missions
- Design data for space-based operations
- Verification of space materials environmental degradation models
- Fundamental understanding of space environmental effects

COORDINATION OF LDEF MATERIALS DATA

<u>MATERIALS SPECIAL INVESTIGATION GROUP TASK</u>:

>>> CONSIDER ENTIRE SPACECRAFT AS AN EXPERIMENT<<<
(Synergism: The whole is greater than the sum of its parts)

<u>MSIG APPROACH</u>:

- Provide central data analysis laboratory
- Encourage voluntary contribution of P.I. experiment materials for documentation, mapping, analysis, archival, and/or determination of laboratory-to-laboratory variability
- Specimen requirements
  - 75% of objective can be accomplished with 10mg of sample
  - 95% of objective can be accomplished with 100 - 500mg
- All experimental and analytical data will be shared with contributor

LDEF MATERIALS DATA ANALYSIS WORKSHOP

SESSION 2: MATERIALS DATA ANALYSIS METHODOLOGY DISCUSSIONS AND SESSION 3: MATERIALS ANALYSIS, DATA BASE, AND PRESERVATION

<u>OBJECTIVE</u>: Stimulate interest and awareness of the opportunities to expand the LDEF data base through:

- Understanding the potential of data synergism
- Voluntary contribution of materials which:
  - were not originally planned to be test specimens
  - or
  - were duplicate specimens in the experiment
  - or
  - are specimens whose initial experiment objectives have been satisfied

<u>APPROACH</u>: Interactive discussions on analysis methodology

- Characterization
- Surface science
- Atomic oxygen
- Contamination
- Other parameters which define (or obscure) the data
- Specimen preservation and shipment

NASA
LONG DURATION EXPOSURE FACILITY

POLYMERIC MATERIALS CHARACTERIZATION

PHILIP R. YOUNG

NASA - LANGLEY RESEARCH CENTER
MEMBER, MSIG

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

CHEMICAL CHARACTERIZATION OF LDEF POLYMERIC MATERIALS

PHILIP R. YOUNG
NASA LANGLEY RESEARCH CENTER
MD - POLYMERIC MATERIALS BRANCH
HAMPTON, VA 23665

LDEF MATERIALS DATA ANALYSIS WORKSHOP
FEBRUARY, 1990
KENNEDY SPACE CENTER

CHARACTERIZATION OPPORTUNITIES

- UNIQUE ENVIRONMENTAL EXPOSURE
- LARGE VARIETY OF MATERIALS
- DIRECT APPLICATION TO CURRENT AND FUTURE SPACE ACTIVITIES
- VERIFICATION OF ENVIRONMENTAL PERFORMANCE MODELS
- FUNDAMENTAL INSIGHTS INTO SPACE ENVIRONMENTAL EFFECTS

POLYMERS

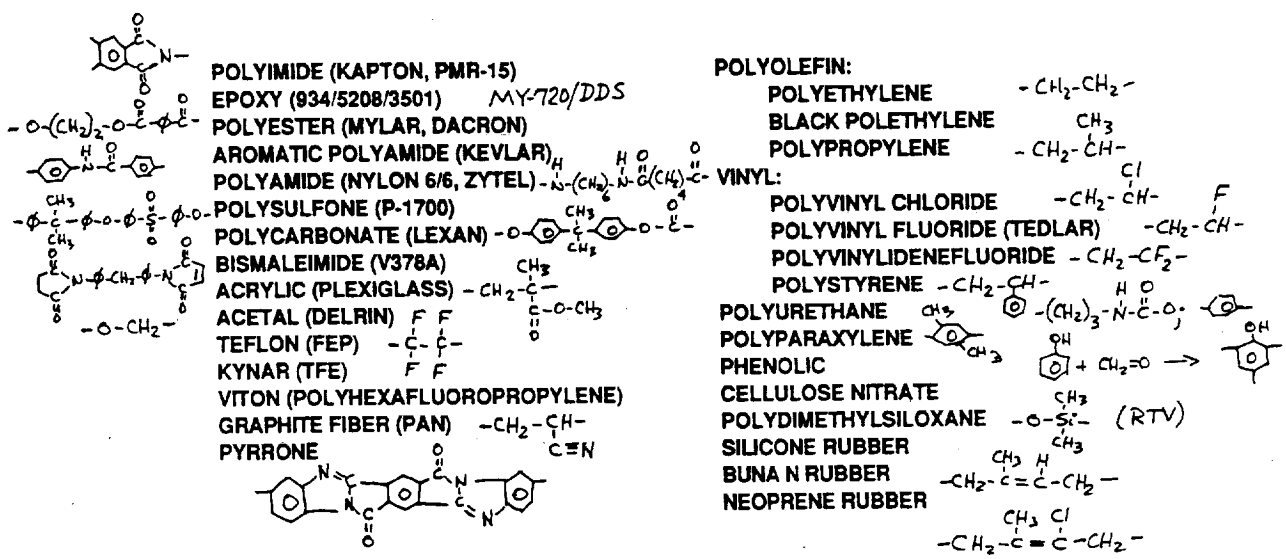
POLYIMIDE (KAPTON, PMR-15)
EPOXY (934/5208/3501)
POLYESTER (MYLAR, DACRON)
AROMATIC POLYAMIDE (KEVLAR)
POLYAMIDE (NYLON 6/6, ZYTEL)
POLYSULFONE (P-1700)
POLYCARBONATE (LEXAN)
BISMALEIMIDE (V378A)
ACRYLIC (PLEXIGLASS)
ACETAL (DELRIN)
TEFLON (FEP)
KYNAR (TFE)
VITON (POLYHEXAFLUOROPROPYLENE)
GRAPHITE FIBER (PAN)
PYRRONE

POLYOLEFIN:
- POLYETHYLENE
- BLACK POLETHYLENE
- POLYPROPYLENE

VINYL:
- POLYVINYL CHLORIDE
- POLYVINYL FLUORIDE (TEDLAR)
- POLYVINYLIDENEFLUORIDE
- POLYSTYRENE

POLYURETHANE
POLYPARAXYLENE
PHENOLIC
CELLULOSE NITRATE
POLYDIMETHYLSILOXANE
SILICONE RUBBER
BUNA N RUBBER
NEOPRENE RUBBER

POLYMERS



WHAT ELSE SHOULD WE DO?

- WHAT CAN BE LEARNED ABOUT SPACE ENVIRONMENTAL EFFECTS THAT HAS LASTING VALUE?
- WHAT "GOOD" SCIENCE CAN WE DO?
- WHAT ADDITIONAL WORK SHOULD BE PERFORMED TO ASSURE THAT THE "CORRECT" SCIENCE IS BEING DONE?
- WHAT IS THE "BEST" ANALYTICAL CHARACTERIZATION PLAN?

CHARACTERIZATION OF LDEF MATERIALS

OBJECTIVE: STIMULATE INTEREST AND AWARENESS OF OPPORTUNITY TO EXPAND THE LDEF DATA BASE BY CONSIDERING THE ENTIRE SPACECRAFT AS AN EXPERIMENT.

APPROACH: PRESENT DISCUSSIONS ON CHEMICAL CHARACTERIZATION, SURFACE SCIENCE, ATOMIC OXYGEN, CONTAMINATION, AND OTHER PARAMETERS WHICH DEFINE (OR OBSCURE) THE INFORMATION OF INTEREST.

OUTLINE

- RESPONSE OF POLYMERIC MATERIALS TO SPACE ENVIRONMENT
- ANALYTICAL CHARACTERIZATION
  - MOLECULAR WEIGHT
  - CHROMATOGRAPHY
  - DIFFUSE REFLECTANCE-FTIR
  - THERMAL ANALYSIS
  - MODEL COMPOUNDS
- RECOMMENDED CHARACTERIZATION PLAN

ANALYTICAL CHARACTERIZATION

MUST FOCUS ON

- DEVELOPMENT OF NEW AND IMPROVED MATERIALS
- THE LONG-LIFE CERTIFICATION OF SELECTED MATERIALS
- FUNDAMENTAL INFORMATION AT THE MOLECULAR LEVEL
  - STRONG AND WEAK CHEMICAL LINKS
  - IMPROVEMENTS TO MOLECULAR STRUCTURE
  - DEGRADATION MECHANISMS

CHARACTERIZE RESPONSE OF POLYMERIC MATERIALS TO LDEF ENVIRONMENT

- ATOMIC OXYGEN
- THERMAL CYCLING
- ULTRAVIOLET RADIATION
- IONIZING RADIATION (e^-, p^+)
- COSMIC RADIATION
- METEOROID AND DEBRIS
- VACUUM
- SYNERGISTIC EFFECTS

ABSORPTION OF RADIATION

Primary processes

Initial effects:

$P \rightsquigarrow P^{\cdot+} + e^-$	Ionization
$\rightsquigarrow P^*$	Excitation
$e^- \rightarrow e^-_{th}$	Energy loss
$P^{\cdot+} + e^-_{th} \rightarrow P$	Recombination

Subsequent effects:

$P^* \rightarrow R_1^\cdot + R_2^\cdot$	Homolytic cleavage
$P^* \rightarrow A^+ + B^-$	Heterolytic cleavage
$P^{\cdot+} \rightarrow C^+ + D\cdot$	Decomposition
$P^+ + P \rightarrow PX + D\cdot$	Ion-molecule

P = Polymer
R = Radical
A, B, C, D = Other molecular species

Secondary reactions

$R\cdot + R'-H \rightarrow R-H + R'\cdot$ } Abstraction
$R\cdot + R'-Cl \rightarrow R-Cl + R'\cdot$ } Abstraction

$R\cdot + CH_2 = CHR \rightarrow RCH_2-\dot{C}HR'$ addition

Decomposition $\rightarrow$ Small molecules (CO_2, HCl ...)

Chain scission and crosslinking

PHOTOCHEMICAL EFFECTS

ENERGY ABSORBED BY A MOLECULE:

$$E = h\upsilon = \frac{hc}{\lambda}$$

h = PLANCK'S CONSTANT
c = VELOCITY OF LIGHT
υ = FREQUENCY
λ = WAVELENGTH
N = AVAGADRO'S NUMBER

CONVERT MOLECULES TO MOLES:

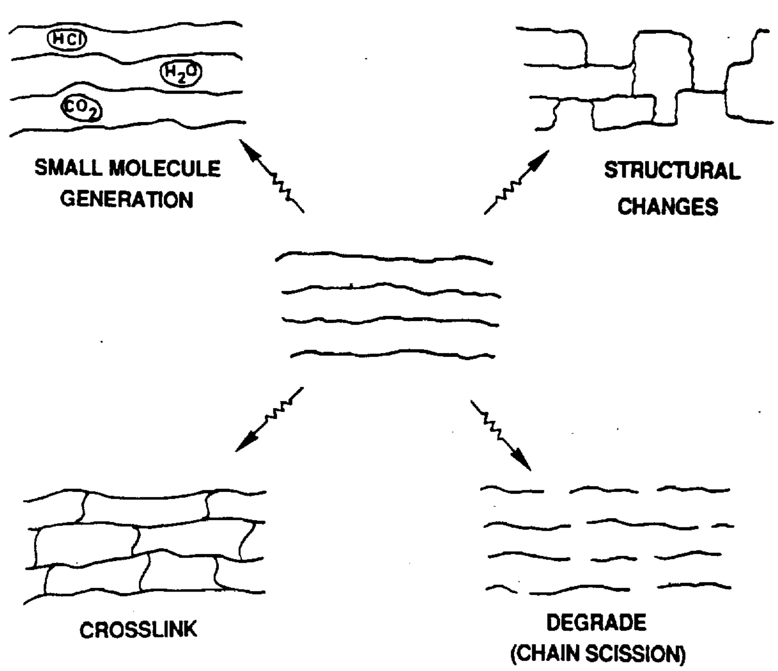
$$E = \frac{Nhc}{\lambda}$$

IF λ = 4000Å, E = 71.5 Kcal/mole
If λ = 2500Å, E = 114.4 Kcal/mole

TYPICAL BOND ENERGIES (Kcal/mole):

C-H	99	C-N	70	C-O	84
C-C	83	C=O	179	C-Cl	79
C=C	146	SiO	100	C≡N	212

RESPONSE OF POLYMERS TO EXPOSURE



INDUCED CHEMICAL CHANGES

1. CROSSLINKING
   - INCREASE IN MOLECULAR WEIGHT
   - MACROSCOPIC NETWORK
   - SOLUBLE FRACTION DECREASES WITH DOSE

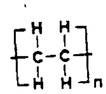
2. CHAIN SCISSION
   - DECREASE IN MOLECULAR WEIGHT
   - DECREASE IN TENSILE AND FLEXURAL STRENGTH
   - EMBRITTLEMENT
   - DISSOLUTION RATE INCREASES

3. SMALL MOLECULE PRODUCTS
   - RESULTS FROM SCISSION FOLLOWED BY ABSTRACTION/RECOMBINATION
   - INFORMATION ON DEGRADATION MECHANISMS
   - CRACKING AND CRAZING (CO_2, H_2 ...)
   - CONTAMINATION (HCl ...)

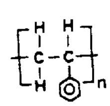
4. STRUCTURAL CHANGES
   - FOLLOWS PRODUCTION OF SMALL MOLECULES AND OTHER REACTIONS
   - CHANGE IN COLOR
   - LOSS OF CRYSTALLINITY
   - MICRO- AND MACROSCOPIC DIMENSIONAL CHANGES

RESPONSE TO RADIATION DEPENDS ON STRUCTURE

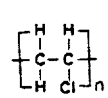
VINYL POLYMERS
(CROSSLINK)



POLYETHYLENE

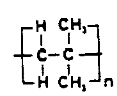


POLYSTYRENE

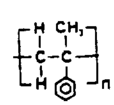


POLYVINYL CHLORIDE

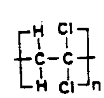
VINYLIDENE POLYMERS
(RUPTURE)



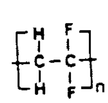
BUTYL RUBBER



POLYMETHYL STYRENE

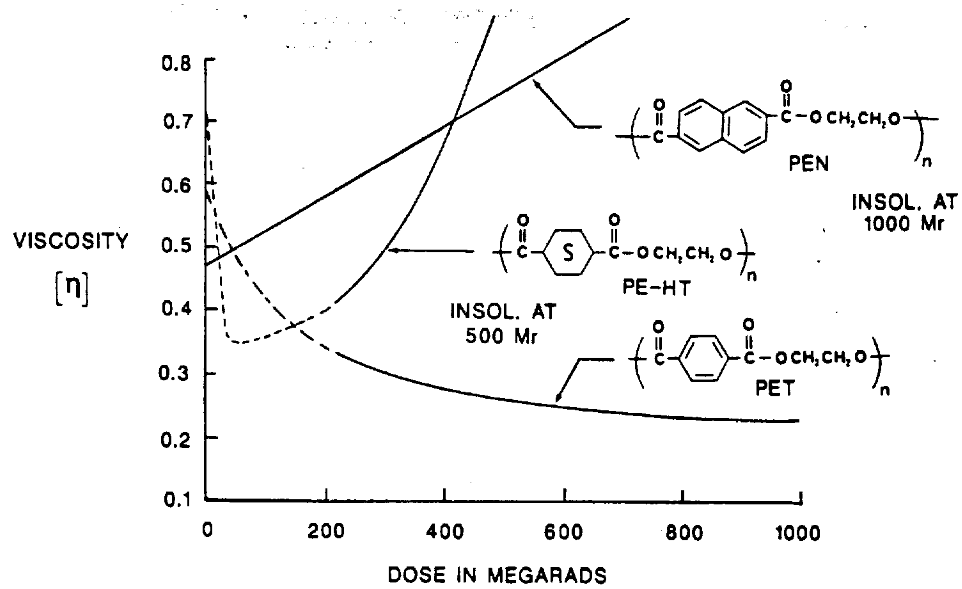


SARAN



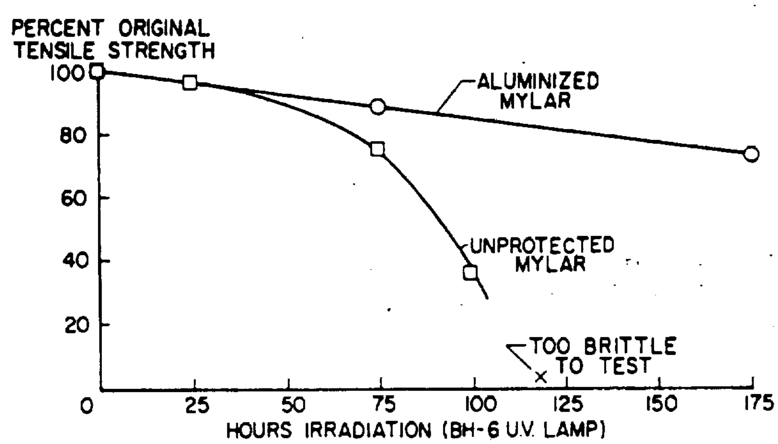
KYNAR

EFFECT OF AROMATICITY ON RADIATION STABILITY



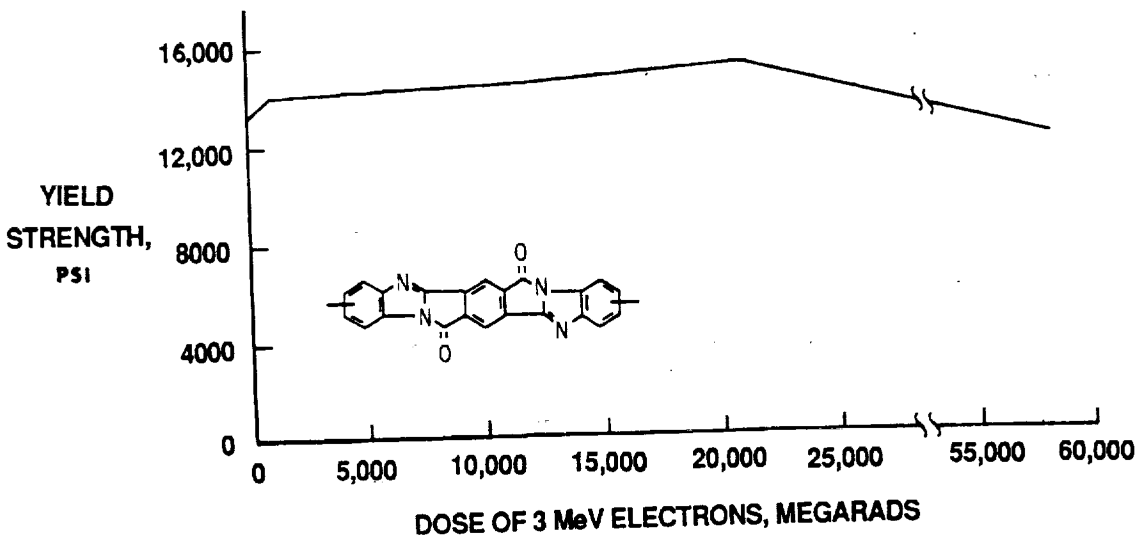
REF:V.L.Bell and G.F. Pezdirtz: J. Polym. Sci. Polym. Chem. Ed. 21, 3083(1983).

EFFECT OF UV RADIATION ON TENSILE STRENGTH OF MYLAR FILM

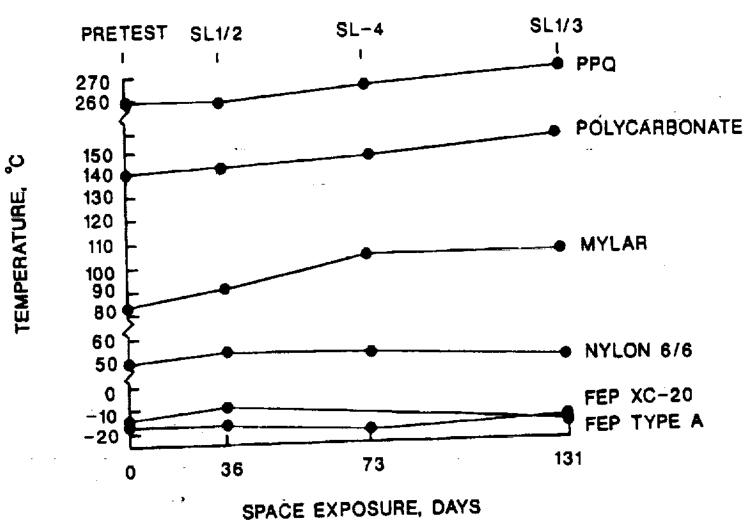


REF: W.S. Slemp, NASA Conference Publication 3035, Part 2, 1988.

EFFECT OF e⁻ RADIATION ON TENSILE STRENGTH OF PYRRONE FILM



EFFECT OF SPACE EXPOSURE ON T_g OF POLYMER FILMS



REF: C.J.Hurley and W.L. Lehn: AIAA Paper No. 75-689, AIAA 10th Thermophysics Conference, Denver,CO, May 1975.

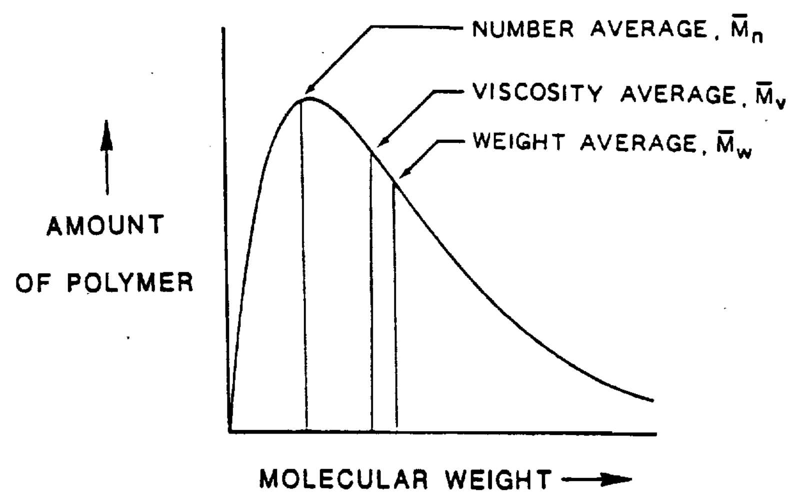
MOLECULAR WEIGHT

SINGLE MOST IMPORTANT PARAMETER GOVERNING PROPERTIES OF POLYMERS

SILICONE OIL →	SILLY PUTTY →	SUPER BALL
(VERY LOW Mw)	(LOW Mw, LIGHTLY CROSSLINKED)	(HIGH Mw)

THE ELEMENTAL ANALYSIS OF ALL THREE MATERIALS IS IDENTICAL.

DISTRIBUTION OF MOLECULAR WEIGHT IN A TYPICAL POLYMER

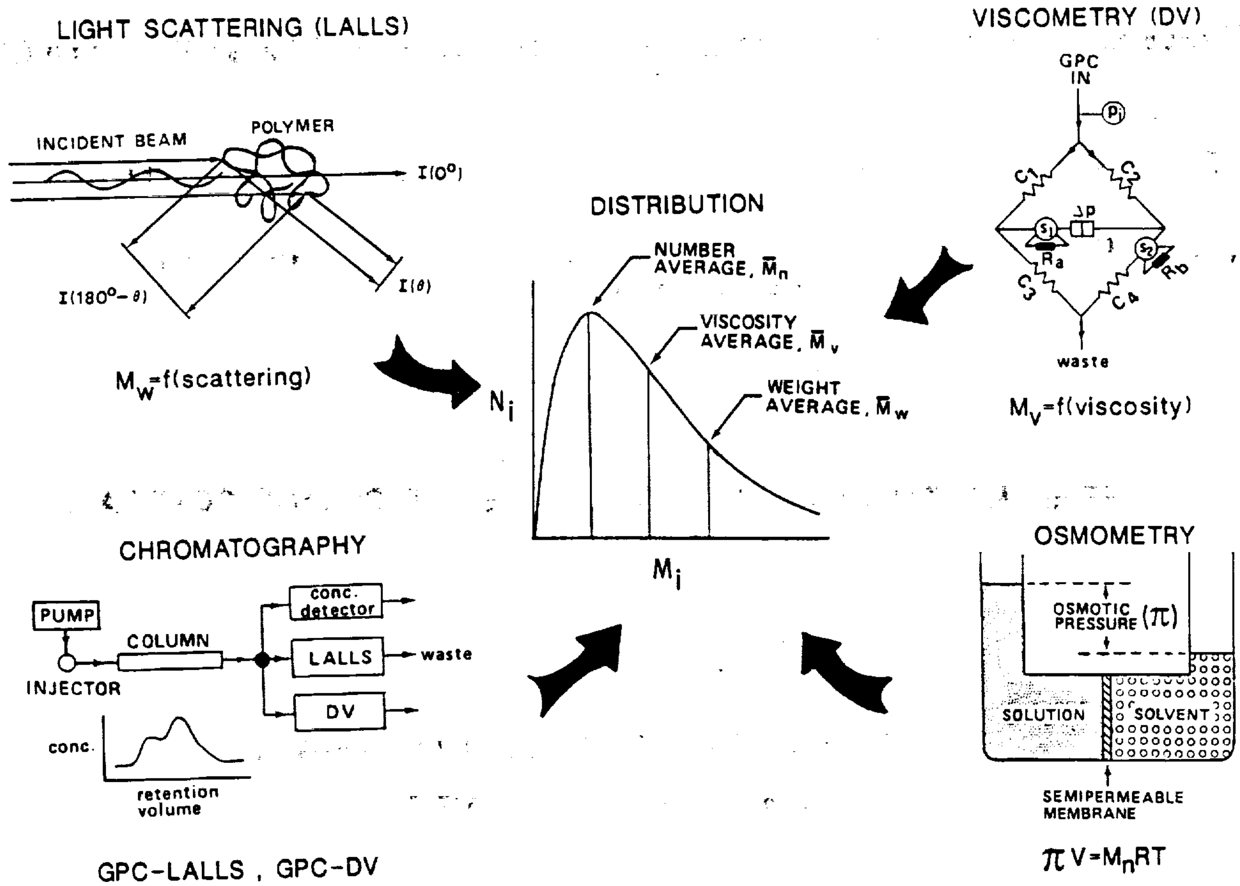


$$\bar{M}_n = \frac{\sum M_i N_i}{\sum N_i}$$

$$\bar{M}_w = \frac{\sum M_i^2 N_i}{\sum M_i N_i}$$

$$\bar{M}_v = \frac{\sum M_i^{(1+a)} N_i}{\sum (M_i N_i)^{1/a}}$$

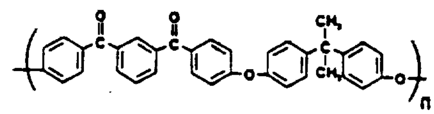
MOLECULAR WEIGHT CHARACTERIZATION



SELECTED PARAMETERS AS DETERMINED BY SEVERAL TECHNIQUES ON THE SAME POLY(ARYLENE ETHER KETONE) SAMPLE

Technique	$\overline{M}_n$ (g/mole)	$\overline{M}_w$ (g/mole)	$\overline{M}_v$ (g/mole)	[η] (dL/g)	$\overline{M}_w/\overline{M}_n$
Membrane Osmometry[1]	31,700 ± 300[8]				1.8
Static LALLS		58,000 ± 3000[2,8]			
		57,000 ± 1000[3,8]			
GPC-LALLS[4,9]	26,200 ± 100	52,400 ± 000			2.0
GPC-DV[5,9]	10,600 ± 600	45,000 ± 2000	38,000 ± 2000	0.52 ± 0.02	4.2
GPC[6,9]	19,100 ± 1000	69,200 ± 900			3.6
Solution Viscosity[7]				0.545 ± 0.002[8]	

[1]Four concentrations in anisole.
[2]Seven concentrations in chloroform; dn/dc = 0.221 ± 0.001.
[3]Five concentrations in chloroform; dn/dc =0.221 ± 0.001.
[4]Two analyses, two concentrations.
[5]Three analyses, two concentrations.
[6]Three analyses, two concentrations; relative to polystyrene.
[7]Five concentrations in chloroform.
[8]Uncertainty in y-axis intercept at zero concentration.
[9]Chloroform mobile phase.

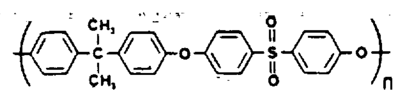


PAEK

EFFECT OF PROCESSING ON VARIOUS MOLECULAR WEIGHT PARAMETERS FOR A POLYSULFONE

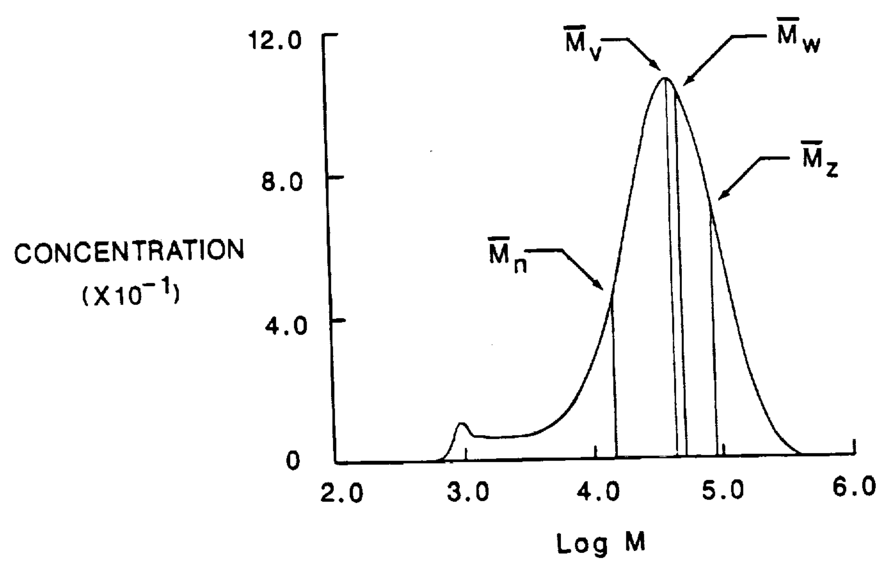
SAMPLE	$\bar{M}_w$	$\bar{M}_n$	$\bar{M}_v$	$\bar{M}_w/\bar{M}_n$	[η]
NEAT RESIN[1]	52,300	15,800	45,700	3.31	0.424
FRACTURED RESIN[2]	50,600	15,400	44,000	3.29	0.428
SOLVENT CAST FILM[2]	50,200	14,900	43,600	3.38	0.427
SOLVENT COATED PREPREG[3]	54,900	15,900	46,800	3.44	0.430
HOT MELT PREPREG[3]	53,200	16,300	45,500	3.27	0.409
COMPOSITE[3]	53,200	15,900	45,700	3.34	0.422
NEAT RESIN MOLDING[3]	54,600	16,700	47,500	3.27	0.402

[1]AVERAGE OF 5 ANALYSES
[2]AVERAGE OF 2 ANALYSES
[3]SINGLE ANALYSIS

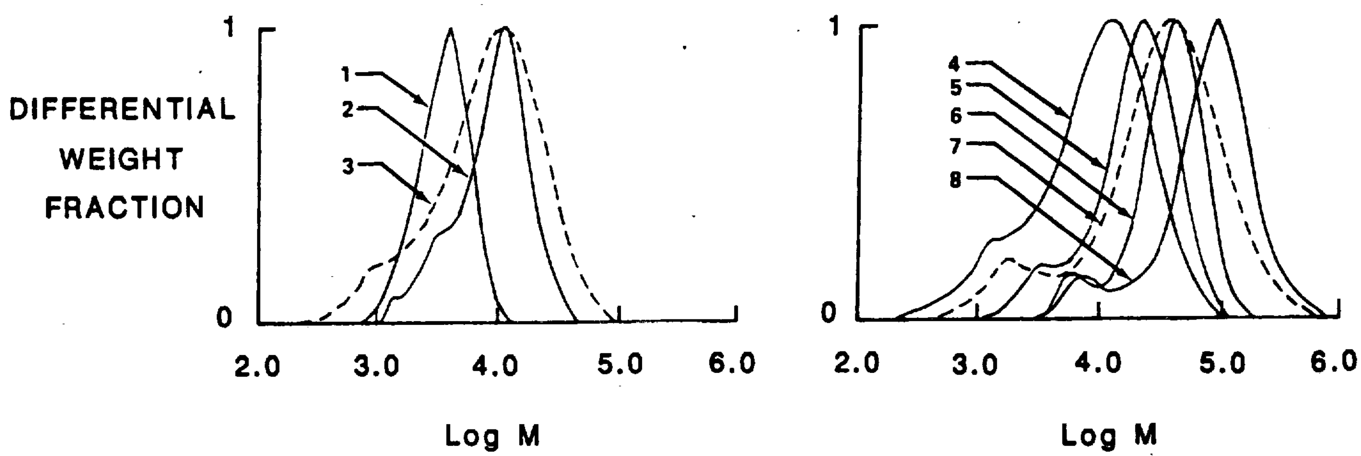


POLYSULFONE

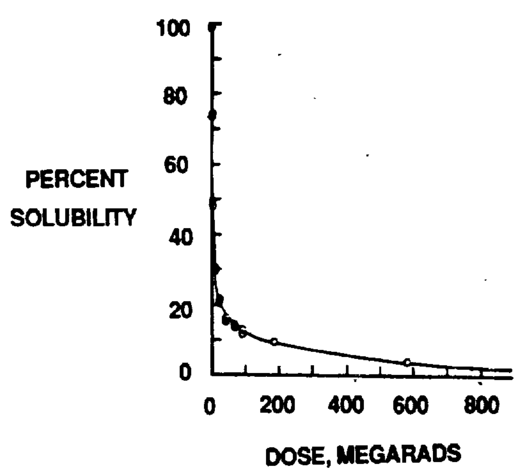
MOLECULAR WEIGHT DISTRIBUTION FOR POLYSULFONE RESIN



MOLECULAR WEIGHT DISTRIBUTIONS FOR EIGHT POLY(ARYLENE ETHER KEYTONES)

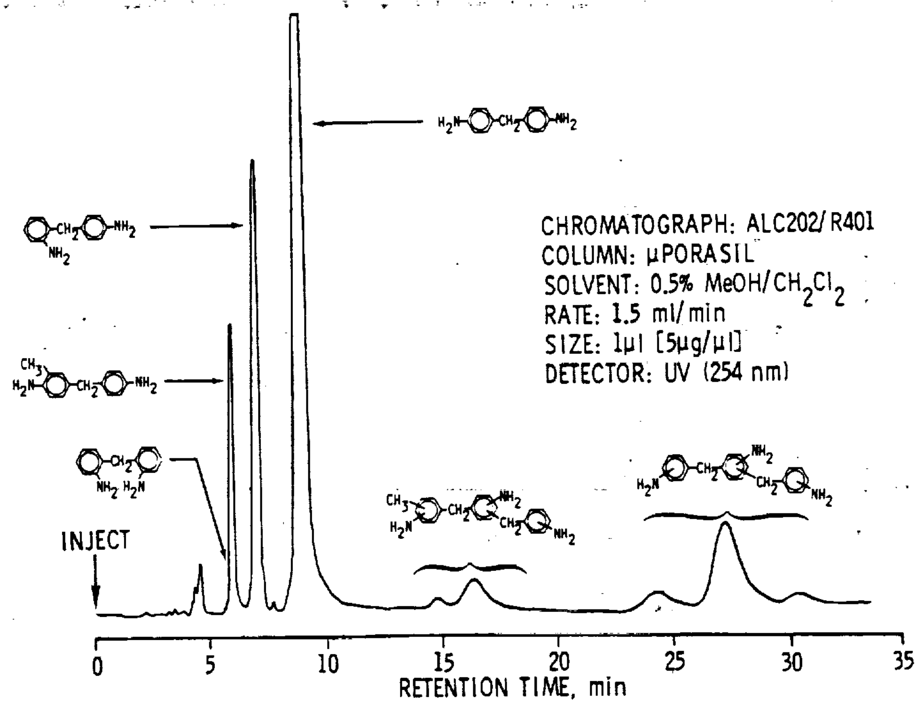


SOLUBILITY OF POLYVINYLIDINE FLUORIDE IN DMAc AS A FUNCTION OF DOSE



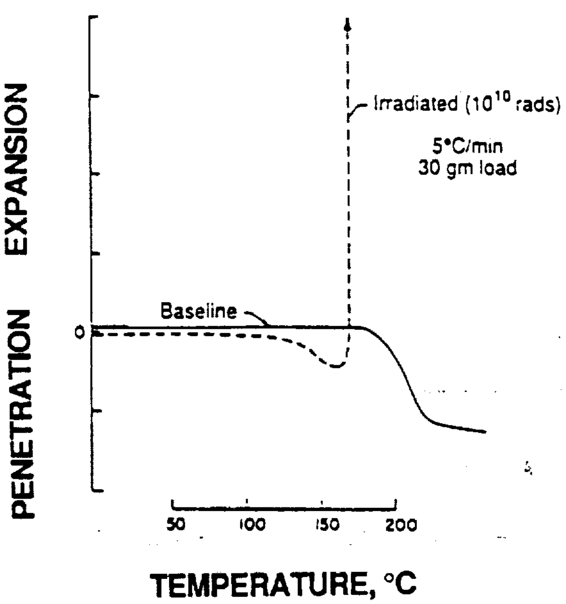
REF: G.D. Sands and G.F. Pezdirtz: Polymer Prints (ACS), 6(2), 987(1965).

ANALYTICAL CHROMATOGRAM OF AP-22

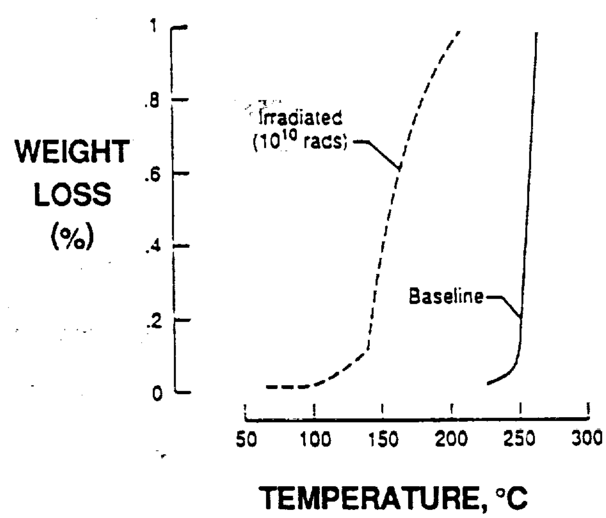


RADIATION EFFECTS IN T300/934 COMPOSITE

THERMOMECHANICAL ANALYSIS

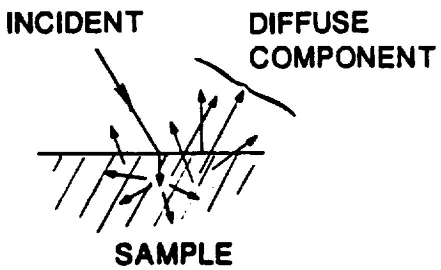


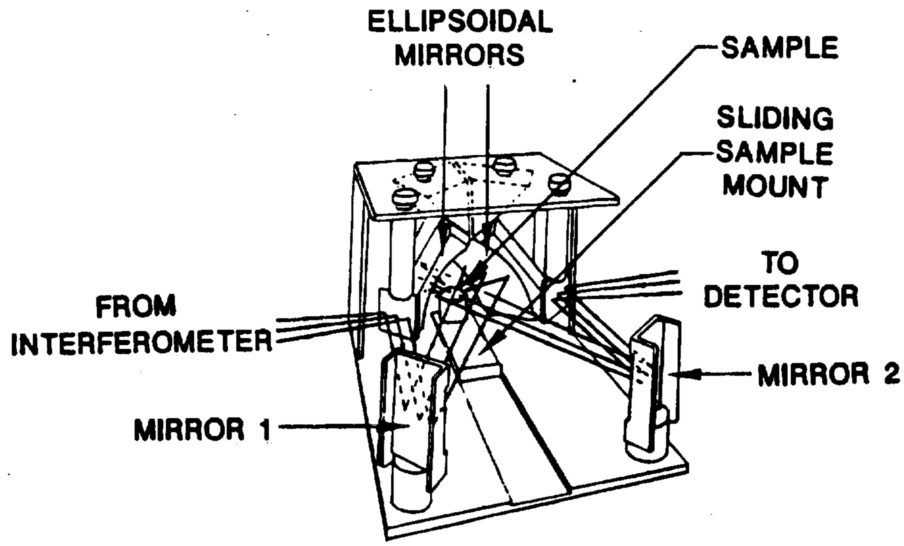
THERMAL VACUUM WEIGHT LOSS



REF: G.F. Sykes, S.M. Milkovich, and C.T. Herakovich: Polym. Matls. Sci. Engn., ACS, 52, 598(1985).

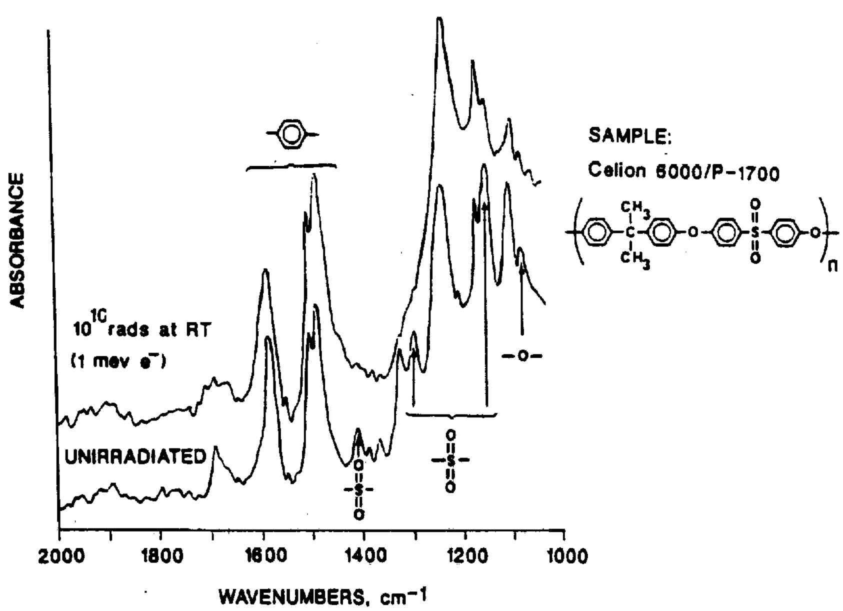
DIFFUSE REFLECTANCE SPECTROSCOPY



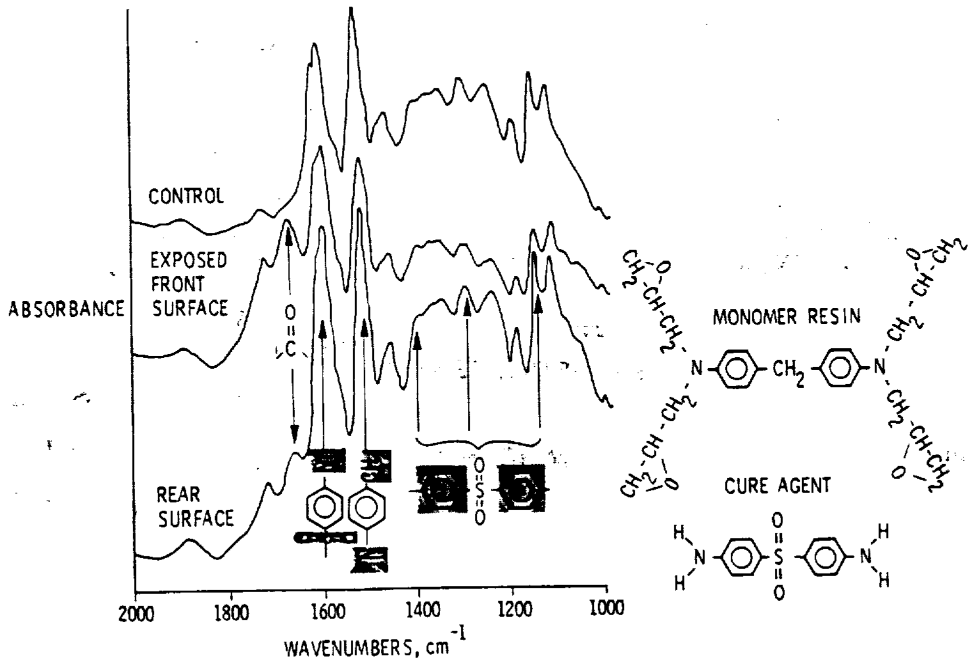


DR-FTIR SPECTRA OF GRAPHITE/POLYSULFONE COMPOSITE

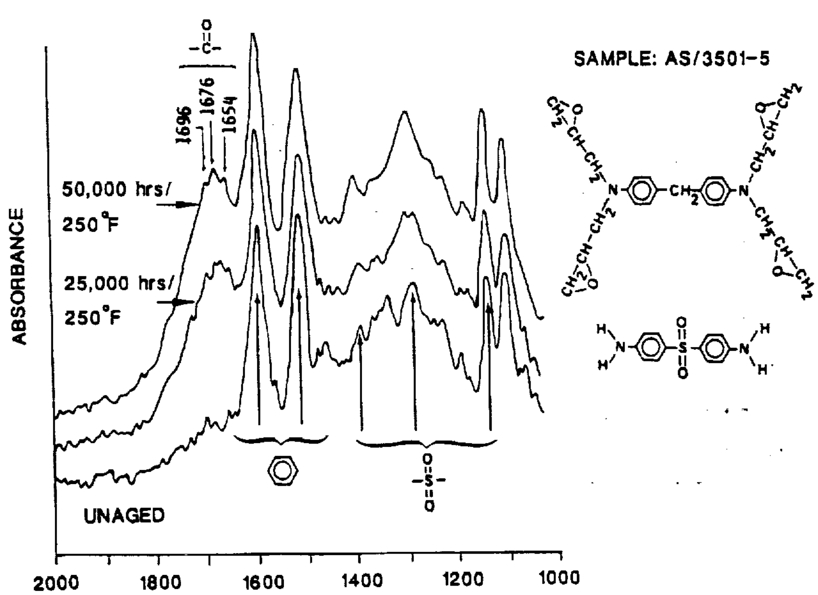
BEFORE AND AFTER RADIATION EXPOSURE



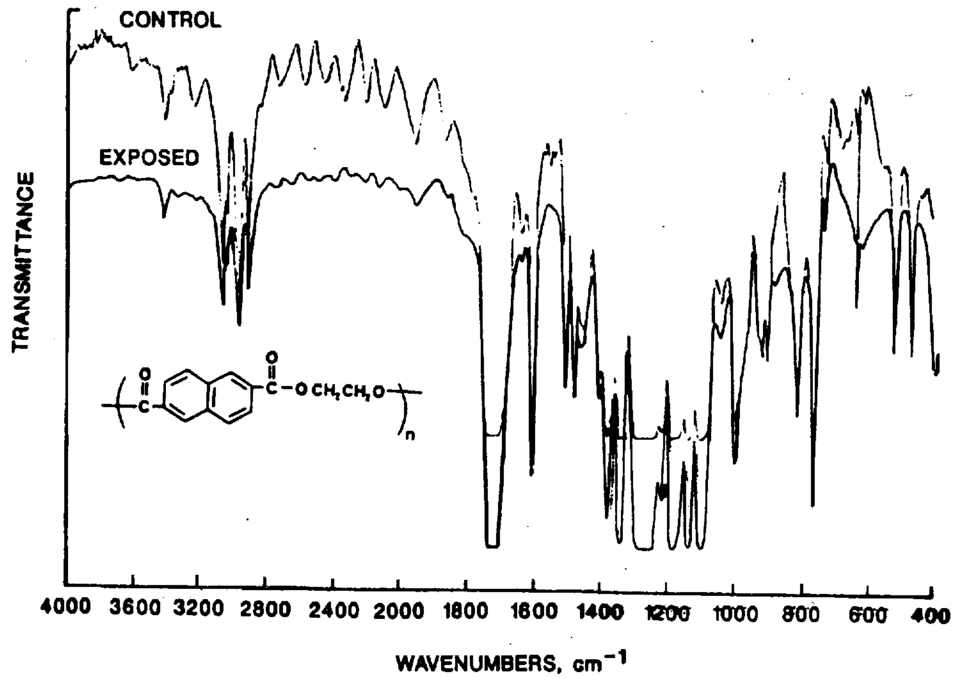
DR-FTIR SPECTRA OF 2-PLY T300/5208 COMPOSITE EXPOSED TO SPACE ENVIRONMENT



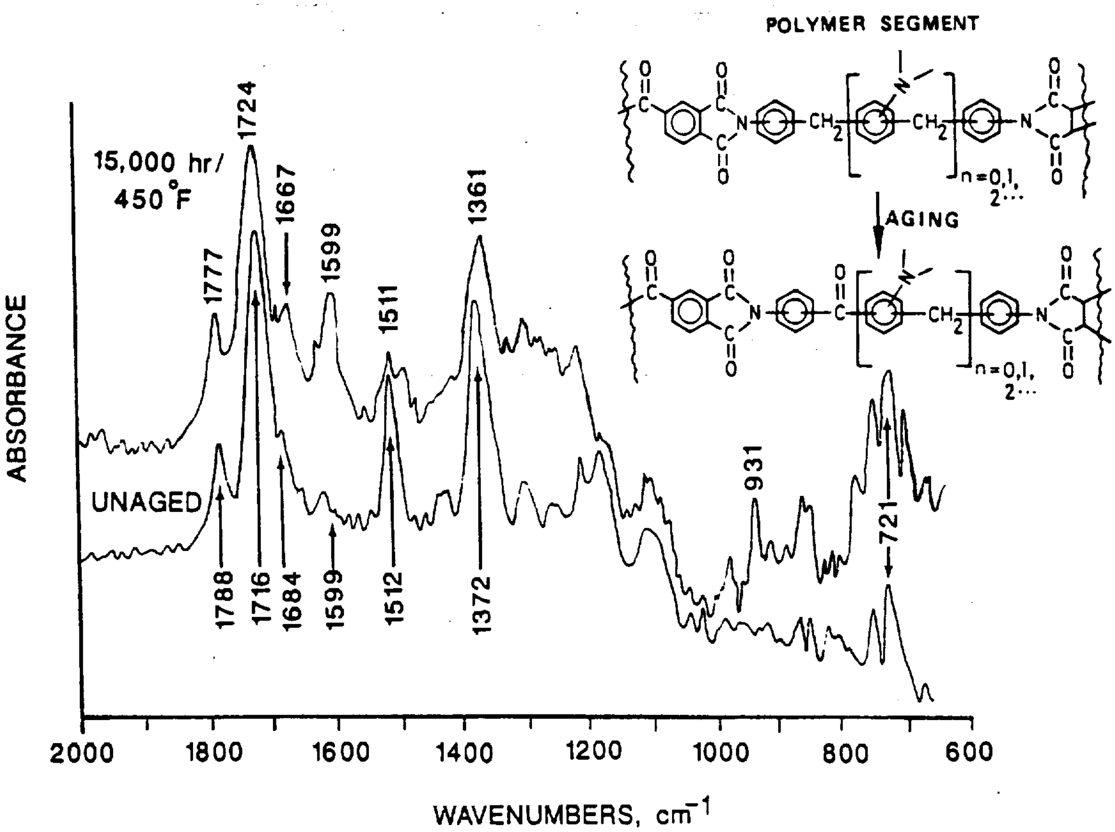
DR-FTIR SPECTRA OF GRAPHITE/EPOXY COMPOSITE BEFORE AND AFTER THERMAL AGING



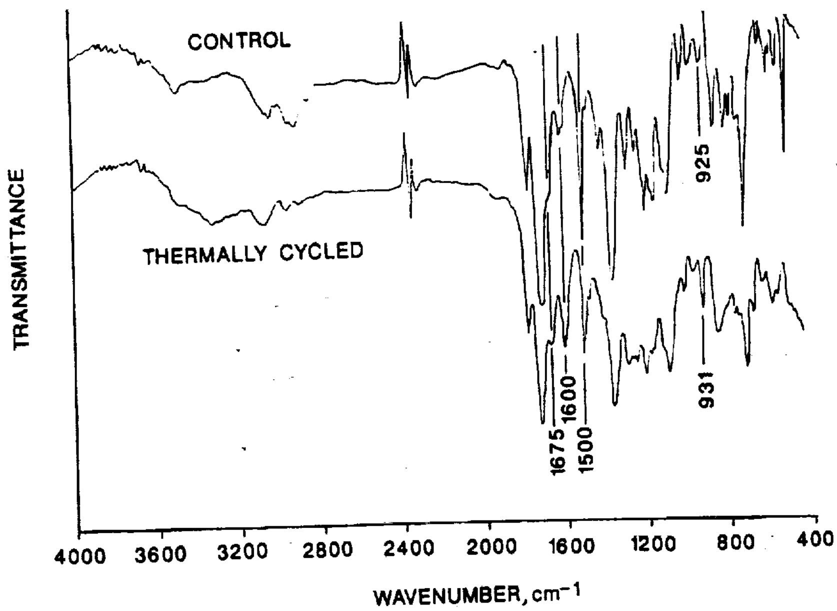
SPECTRA OF MODIFIED POLYESTER BEFORE AND AFTER SPACE EXPOSURE



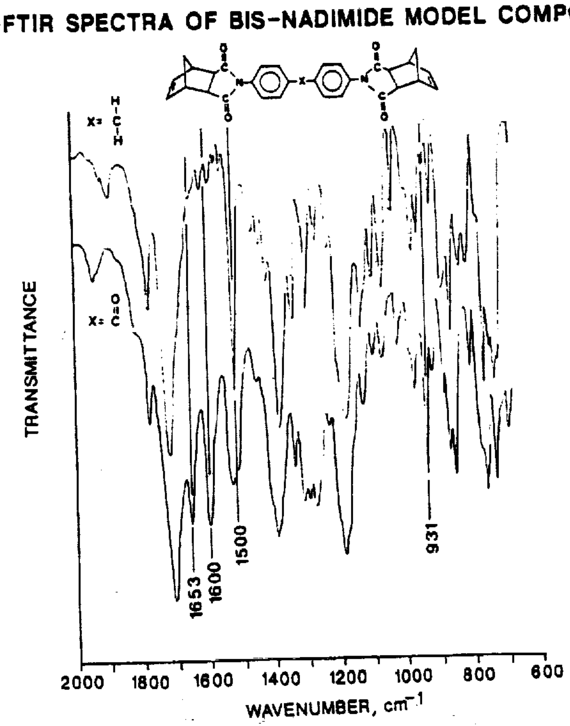
DR-FTIR SPECTRA OF CELION 6000/LARC-160 COMPOSITE BEFORE AND AFTER THERMAL AGING



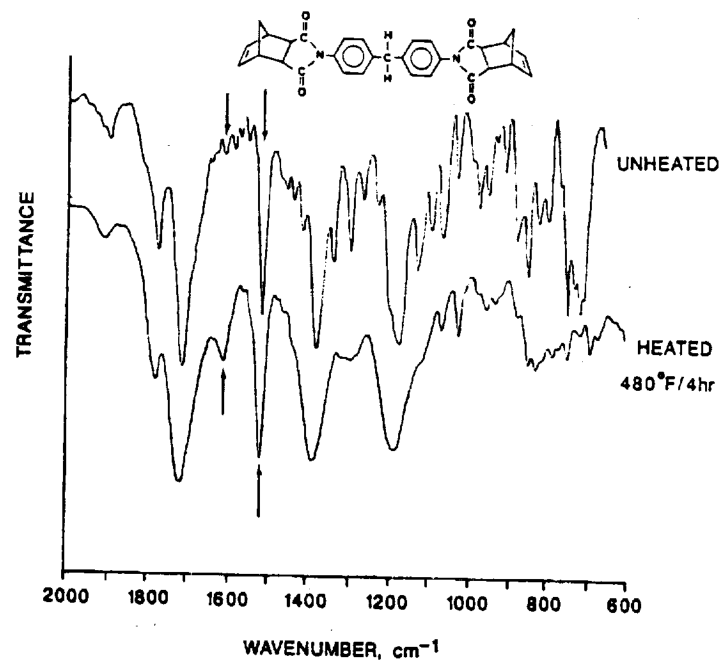
DR-FTIR SPECTRA OF THERMALLY CYCLED PMR-15 COMPOSITE



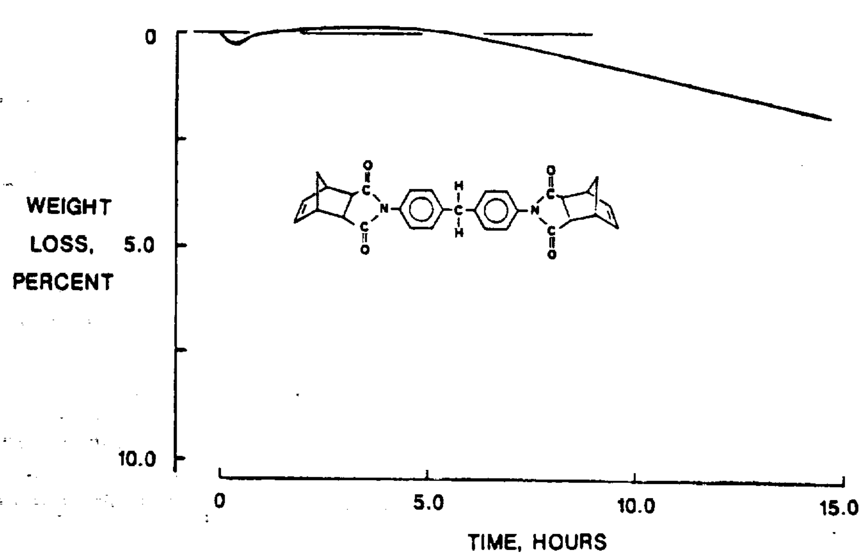
DR-FTIR SPECTRA OF BIS-NADIMIDE MODEL COMPOUND



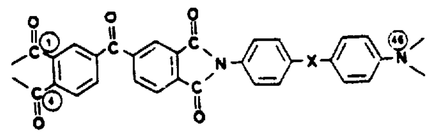
EFFECT OF THERMAL AGING ON NADIMIDE MODEL COMPOUND



ISOTHERMAL WEIGHT LOSS AT 500°F



MOLECULAR LEVEL EFFECTS



DIMENSIONS

ATOM	X	DISTANCE
C(1) — N(46)	$-CH_2-$	17.95 Å
	>C=O	18.65 Å
C(4) — N(46)	$-CH_2-$	17.46 Å
	>C=O	19.18 Å

GEOMETRY

X	BOND ANGLE	TORSIONAL ANGLE	
$-CH_2-$	109.54°	-43.3°	-35.5°
>C=O	120.21°	-30.5°	-24.4°

RECOMMENDED CHEMICAL CHARACTERIZATION

- **SOLUTION PROPERTIES**
  - HPLC - SEPARATES MOLECULAR MIXTURES INTO INDIVIDUAL COMPONENTS
  - GPC - SEPARATES LARGE MOLECULES ACCORDING TO SIZE
  - LALLS/OSMOMETRY/ VISCOMETRY - MOLECULAR WEIGHT AND MOLECULAR WEIGHT DISTRIBUTION DETERMINATION
- **SPECTROSCOPY**
  - MASS - IDENTIFICATION OF MOLECULAR SPECIES
  - UV-VIS-NIR - ELECTRONIC SPECTRA, CHROMOPHORE COMPOSITION, TRANSPARENCY, EXCITED STATE BEHAVIOR.
  - IR - VIBRATIONAL SPECTRA, CHEMICAL STRUCTURE, CONFORMATIONAL, CHEMICAL MODIFICATION.
  - MAGNETIC RESONANCE - ^1H & ^{13}C NMR: CHEMICAL STRUCTURE, TACTICITY, CONFORMATION, CHEMICAL MODIFICATION.
    - ESR: RADICALS, TRIPLET STATE STRUCTURE AND BEHAVIOR.

DETECTS CHANGES AT THE MOLECULAR LEVEL.

RECOMMENDED PHYSICAL CHARACTERIZATION

- THERMAL/THERMOMECHANICAL

DSC	- T_g, T_m, HDT, CRYSTALLINITY
TBA	- T_g, T_m, MECHANICAL SPECTRUM
TMA	- CTE, HDT, T_g, T_m
DMA	- RELAXATIONS, DAMPING COEFFICIENTS, MECHANICAL SPECTRUM
TGA	- VOLATILE PRODUCTS

DETECTS CHANGES IN POLYMER MACROSTRUCTURE.

CHARACTERIZATION PLAN - CONTINUED

ANALYTICAL RESULTS WILL DICTATE DIRECTION OF ADDITIONAL RESEARCH:

MEASUREMENT	TECHNIQUE
SURFACE CHEMISTRY	ESCA, α_S/ε, EDAX, AUGER
SURFACE MORPHOLOGY	SEM, STEM
METAL ION MIGRATION	ATOMIC ABSORPTION, ICP
SURFACE MOLECULAR AND ATOMIC RESOLUTION	SCANNING TUNNELING MICROSCOPY
THERMOSET SOLUBLE FRACTION	HPLC MASS SPEC/PYROLYSIS GC/PYROLYSIS

OBJECTIVE: MOLECULAR LEVEL RESPONSE TO ENVIRONMENTAL EXPOSURE.

CHARACTERIZATION PLAN - THERMOSETS

SAMPLE	MEASUREMENT	TECHNIQUE
FILMS	TRANSPARENCY, ELECTRONIC STRUCTURE MOLECULAR STRUCTURE	UV-VIS-NIR %T %T FTIR, ^{1}H % ^{13}C-NMR
COMPOSITES/ SOLIDS	MOLECULAR STRUCTURE	DIFFUSE REFLECTANCE-SOLID STATE NMR
	DEGRADATION/VOLATILE PRODUCTS	SOLVENT EXTRACTION/TGA
ALL	T_g, CTE, HDT, DEGREE OF CURE ... ELEMENTAL COMPOSITION CRYSTALLINITY SURFACE CONTAMINATION	DSC/TMA CHNO X-RAY DIFFRACTION MASS SPEC/BAKEOUT

CHARACTERIZATION PLAN - THERMOPLASTICS

IN ADDITION TO STANDARD THERMOSET ANALYSES:

MEASUREMENT		TECHNIQUE
CROSSLINK DENSITY		GEL FRACTION
MOLECULAR WEIGHT:	M_n	MEMBRANE OSMOMETRY
	M_w	LOW ANGLE LASER LIGHT SCATTERING (LALLS)
	M_v	DIFFERENTIAL VISCOMETRY (DV)
	$[\eta]$	VISCOMETRY
MOLECULAR WEIGHT DISTRIBUTION		GPC/LALLS, GPC/DV

KAPTON

	ROW: 9(RAM)	3(TRAIL)	6/12(±90°)
Film	A0134	S1002	S1001
Insulation	A0076	(also space end, A0133)	
Aluminized	A0076	M0002	S1001
	S0010	M0003	S1003
	M0002		M0002
	M0003		
		(also row 10 S0115 at A0178 at 16 locations)	
Tape	S0069		S1001
Washers			A0180

TEFLON

	ROW: 9(RAM)	3(TRAIL)	6/12(90°)
Teflon, PTFE	A0076	A0187	A0180
	A0201	A0201	S1001
	S0014	S1002	A0201
		(also row 8, A0147 and row 2, A0172)	
Teflon	M0003	M0003	M0002
	S0014	A0138	S1001
			A0038
		(also space end, A0038)	
Aluminized	(Row 4 and 10, A0054)		
Silvered	A0076	(also A0178 at 16 locations)	
SSM	S0010		
Kel F	S0114		
FEP Al			S1003
FEP	M0003		
	A0134	M0003	S1003
	M0002	M0002	
Viton	A0134	A0138	A0180
		(also earth end, A0139-A)	
Tedlar	M0003	M0003	
PVF			S1001
PVF_2	A0134	S1002	

THERMOSETS

PMR-15	A0175	M0003		
LARC-160	A0175	M0003		
Kapton	already noted			
Vespel	S1002	S0014	M0003	A0147
Gr/5208	A0019	A0134	A0180	
Gr/3501-6	M0003			
Gr/934	A0180	A0171	A0134	
	A0175	A0014	M0003	
Pyrrone	A0134			

THERMOPLASTICS

Mylar, film	A0139A	P0003	A0023	A0187	A0134
velcro	P0004	M0002	A0138	A0076	
	A0178 at 16 locations				
Polysulfone, film	A0171	M0003	A0134		
composite	(C3000/P1700)		A0134		
	(C6000/P1700)		A0134		
	(722/P1700)		M0003		
	(T300/P1700)		M0003		
	(Gr/P1700)		M0003		
	(T300/Polyethersulfone)		M0003		
Polycarbonate	M0001	M0002	A0015	M0003	S1001
	A0178 at 16 locations				
Teflon	already noted				

DESIRABLE SAMPLES FROM MATERIALS EXPERIMENTS

	EXPERIMENTAL LOCATION	MATERIAL	PI OBJECTIVE	REQUEST
1.	A0019 D12	5208/T300	Primarily, mechanical properties	Broken samples
2.	A0175 AI & A7	LARC-160 PMR-15 934 F178		
3.	A0180 12	Epoxy, Kevlar Kapton		
4.	S1006 E6	Nylons, PE Mylar, Kevlar	Space exposure of balloon materials	Redundant films
5.	S1003 E6	FEP, Kapton	α_s/ε (no chemistry)	Buttons after testing
6.	S1001 F12/H1	Kapton, Acrylics Urethanes, Silicones Epoxy, Polycarbonate PVF, Teflon	Heat pipe, plus films added for A0 exposure	Any redundant films

OTHER GENERAL REQUESTS

- **POLYETHYLENE**
- **POLY(ETHYLENE TEREPHTHALATE)**
- **POLYSTYRENE**
- **A0178 - DUPLICATE 16 TIMES ON VEHICLE**

PAINTS

CHEMGLAZE	OTHER: WHITE	BLACK	PRIMERS
9924 (PRIMER)	S-13G	3M NEXTEL	ASTRAL P123
A-276 (WHITE)	S-13GLO	CATALAC	DuPONT 46971
Z-306 (BLACK)	SPEREX AP-101	ECCOSORB	DC 1200
Z-93 (WHITE)	DC 92-007	IITRI D-111	Zn CHROMATE
Z-202 (WHITE)	YB-71	3M 101-C10	
Z-302 (WHITE)	Zn O-TITINATE	3M CR-110	
II-AS71 (RED)	MS-74	3M 401-C10	
9951 (THINNER)	PV 100 ML 101	ASTRAL	

ADHESIVES

EPOXY	SILICONE	URETHANE	OTHER
EPON 828 (SHELL)	DC 6-1104	HYSOL EM8-1107	FM 9600
934 (HYSOL)	DC 93500	SOLITHANE 152/ 112/113/TC-700	SCOTCH TAPE 5/ 465/415
EPI BOND (FURANE)	DC 43117		SCOTCH WELD 2216
ARALDITE (CIBA-GEIGY)			MYSTIC TAPE
TORRSEAL (VARIAN)	SYLGARD 182		STYCAST 1090
EPO-TEC 331	SYLGARD 105		NARMCO 328
ETCA E10-214	SLYGARD 186		C-34
STYCAST 2850	RTV 602/566/ 655/5000		AF-143
3M #401 C10			SR 585
TI-1300B			REDUZ BSL 312/319
WASATCH UH-3119			K-14

SUMMARY

- UNIQUE CHARACTERIZATION OPPORTUNITY
- MOLECULAR LEVEL INFORMATION ON POLYMERIC BEHAVIOR
- SAMPLE ARCHIVAL/DOCUMENTATION IS CRITICAL
- VOLUNTARY PARTICIPATION/CONTRIBUTION IS ENCOURAGED

NASA
LONG DURATION EXPOSURE FACILITY

SURFACE CHEMISTRY

JAMES WIGHTMAN

VIRGINIA TECH
MEMBER, LDEF ADVISORY COMMITTEE

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

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SURFACE ANALYSIS USING X-RAY PHOTOELECTRON SPECTROSCOPY (XPS OR ESCA)

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LDEF WORKSHOP
NASA - KSC
FEBRUARY 14, 1990

ACKNOWLEDGEMENTS

Alcoa	Boeing
Elf Aquitaine	Johnson Wax
NASA-LaRC (6)	NSF
ONR	Tioxide Intl
Virginia	

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Dr. Y. Kang	Dr. C. U. Ko
Mr. T. Lin	Dr. D. J. Moyer
Ms. K. Phillips	Ms. K. A. Sanderson
Dr. R. Seals	Dr. E. J. Siochi
Dr. J. A. Skiles	Mr. H. F. Webster

OUTLINE

INTRODUCTION

SEM

- Δ EXAMPLES

XPS or ESCA

- Δ PRINCIPLES
  - Δ EXPERIMENTAL
    - Δ APPLICATIONS
      - Metals
        - Particles/Fibers
          - Polymers/Composites

IRS

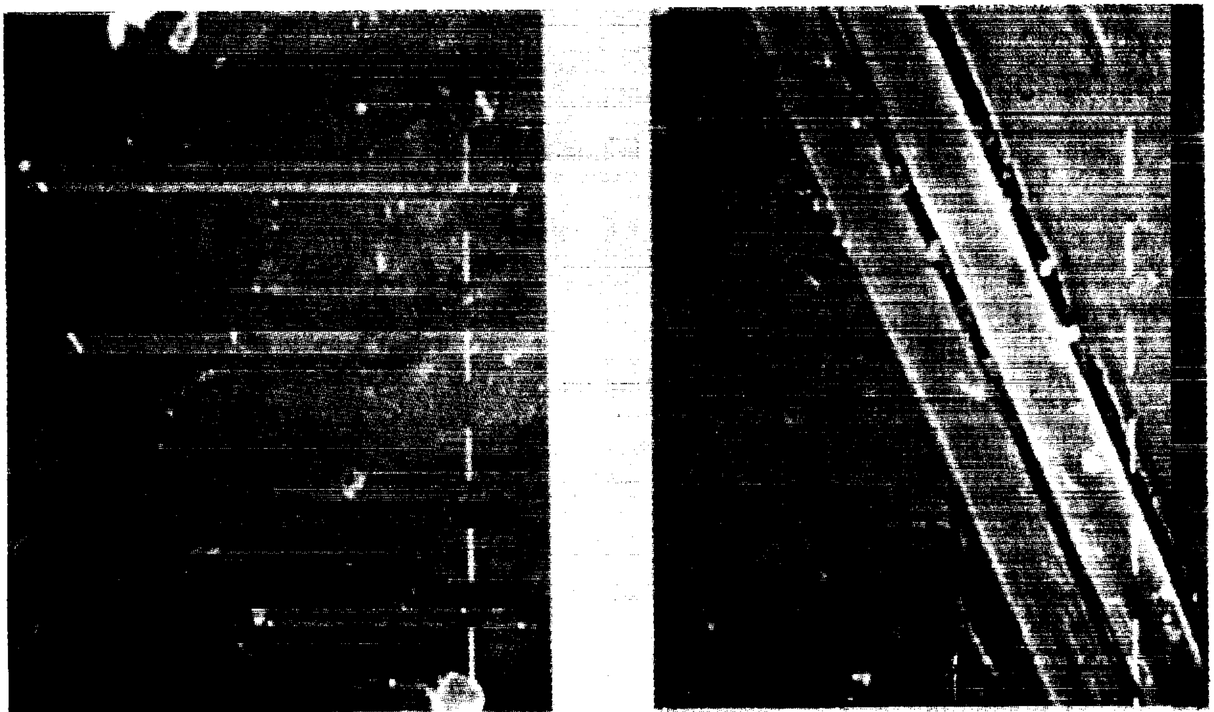
- Δ EXPERIMENTAL
  - Δ APPLICATIONS
    - Polymers/Composites

SUMMARY

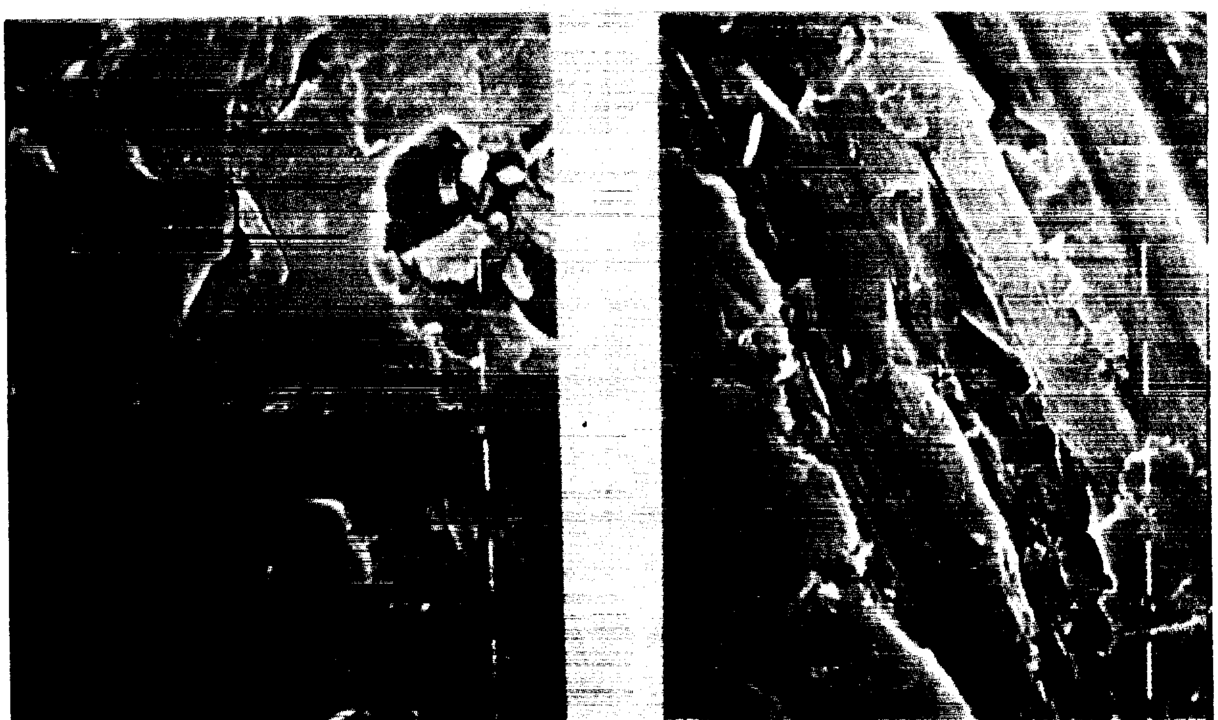
Key to acronyms and entries

AEAPS	Auger-electron appearance-potential spectroscopy
AEM	Auger-electron microscopy
AES	Auger-electron spectroscopy
AIM	Adsorption isotherm measurements
APS	Appearance-potential spectroscopy
ASW	Acoustic surface-wave measurements
ATR	Attenuated total reflectance
BIS	Bremsstrahlung isochromat spectroscopy
CIS	Characteristic isochromat spectroscopy
CL	Cathodoluminescence
COL	Colorimetry: IR, visible, UV, X-ray, and γ-ray absorption spectroscopy
CPD	Contact potential difference (work-function measurements)
DAPS	Disappearance-potential spectroscopy
EL	Electroluminescence
ELL	Ellipsometry
EELS	Electron energy-loss spectroscopy
EM	Electron microprobe
ES	Emission spectroscopy
ESDI	Electron-stimulated desorption of ions
ESDN	Electron-stimulated desorption of neutrals
ESR	Electron-spin resonance
EXAFS	Extended X-ray absorption fine structure
FD	Flash desorption
FDM	Field-desorption microscopy
FDS	Field-desorption spectroscopy
FEM	Field-emission microscopy
FEES	Field-electron energy spectroscopy
FIM	Field-ion microscopy
FIM-APS	Field-ion microscope – atom probe spectroscopy
FIS	Field-ion spectroscopy
GDMS	Glow-discharge mass spectroscopy
GDOS	Glow-discharge optical spectroscopy
HA	Heat of adsorption
HEED	High-energy electron diffraction
IIRS	Ion-impact radiation spectroscopy
IIXS	Ion-induced X-ray spectroscopy
IMMA	Ion microprobe mass analysis
IMXA	Ion microprobe X-ray analysis
INS	Ion-neutralization spectroscopy
IRS	Internal reflectance spectroscopy
IS	Ionization spectroscopy
ISD	Ion-stimulated desorption
ISS	Ion-scattering spectroscopy
ITS	Inelastic tunneling spectroscopy
LEED	Low-energy electron diffraction
LMP	Laser microprobe
LS	Light scattering
MBRS	Molecular-beam reactive scattering
MBSS	Molecular-beam surface scattering
MOSS	Mossbauer spectroscopy
NIRS	Neutral impact radiation spectroscopy
NMR	Nuclear magnetic resonance
NRS	Nuclear reaction spectroscopy
PD	Photodesorption
PEM	Photoelectron microscopy
PES	Photoelectron spectroscopy
RBS	Rutherford backscattering spectroscopy
RHEED	Reflection high-energy electron diffraction
SC	Surface capacitance
SDMM	Scanning desorption molecule microscopy
SEE	Secondary-electron emission
SEM	Scanning electron microscopy
SEXAFS	Surface extended X-ray absorption fine structure
SI	Surface ionization
SIIMS	Secondary-ion imaging mass spectroscopy
SIMS	Secondary-ion mass spectroscopy

PARTIAL LISTING OF SURFACE ANALYSIS TECHNIQUES—C. J. POWELL.



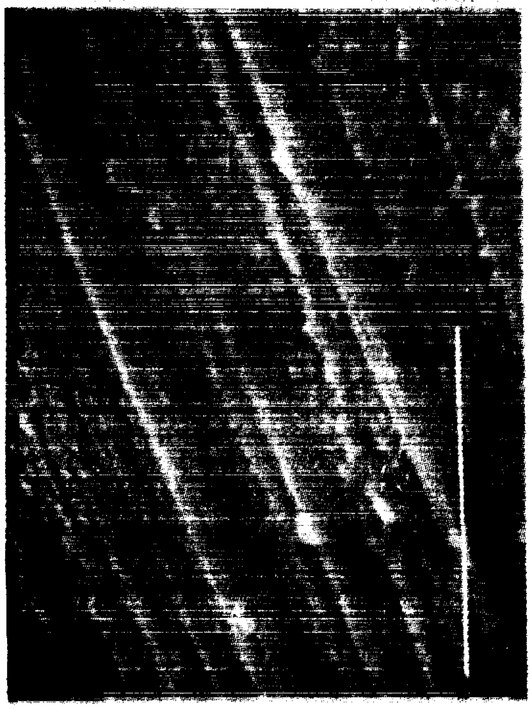
Methanol Wash 1600X



Gritblast 1600X

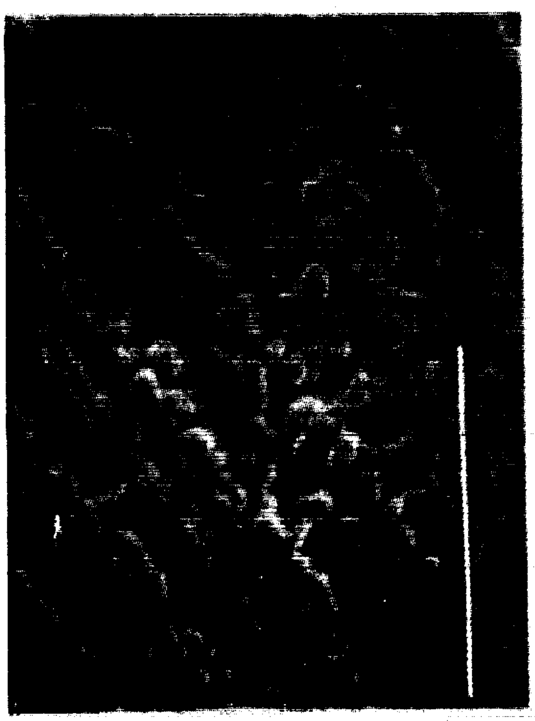
SEM PHOTOMICROGRAPHS OF CARBON FIBER/POLYIMIDE MATRIX COMPOSITES—MOYER & WIGHTMAN.

SEM PHOTOS OF PRETREATED SURFACES

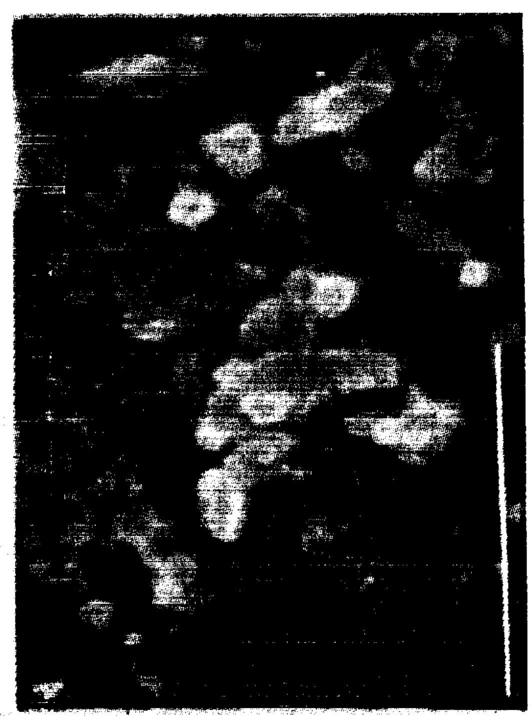


Oxygen Plasma 1 min 100,000X

Oxygen Plasma 5 min 100,000X

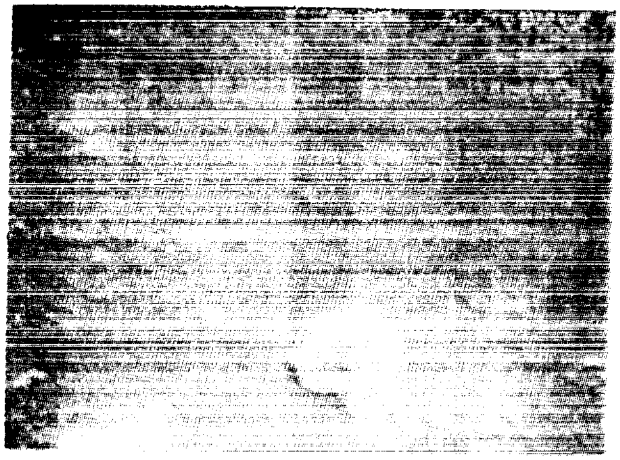


Oxygen Plasma 10min 100,000X

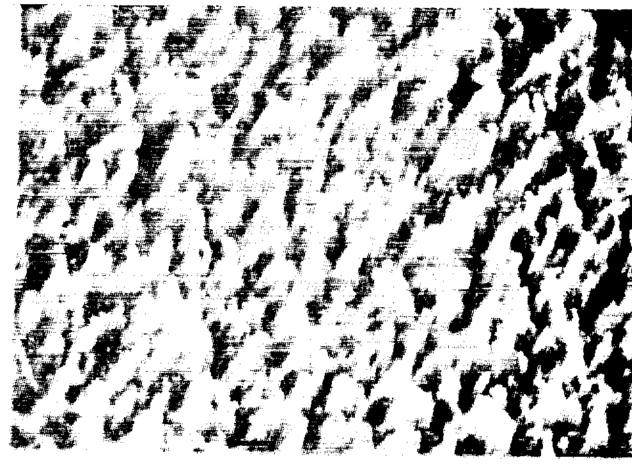


Oxygen Plasma 20min 100,000X

SEM PHOTOMICROGRAPHS OF CARBON FIBER/POLYIMIDE MATRIX COMPOSITES—MOYER & WIGHTMAN.

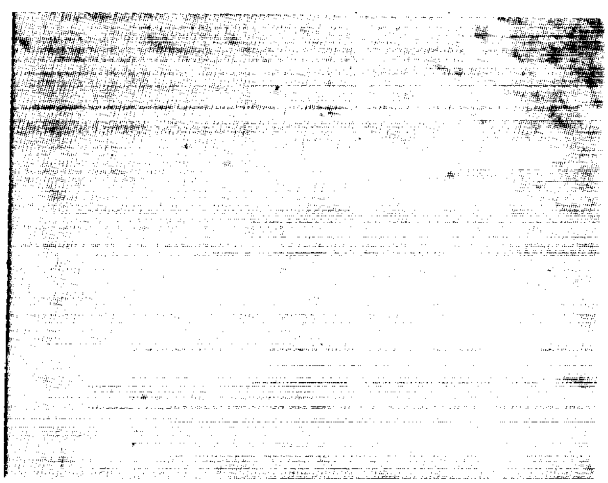


Unexposed



Exposed

SEM PHOTOMICROGRAPHS OF KAPTON BEFORE AND AFTER EXPOSURE TO ATOMIC OXYGEN—STS 8—McGRATH.



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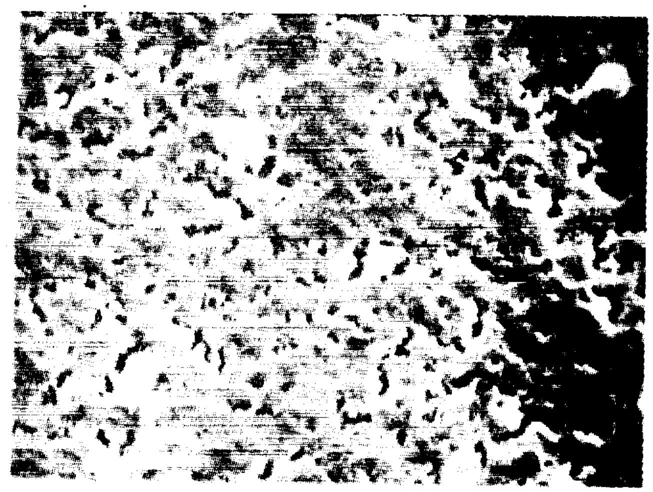

Exposed

SEM PHOTOMICROGRAPHS OF POLYIMIDE—SILOXANE BEFORE AND AFTER EXPOSURE TO ATOMIC OXYGEN—STS 8—McGRATH.

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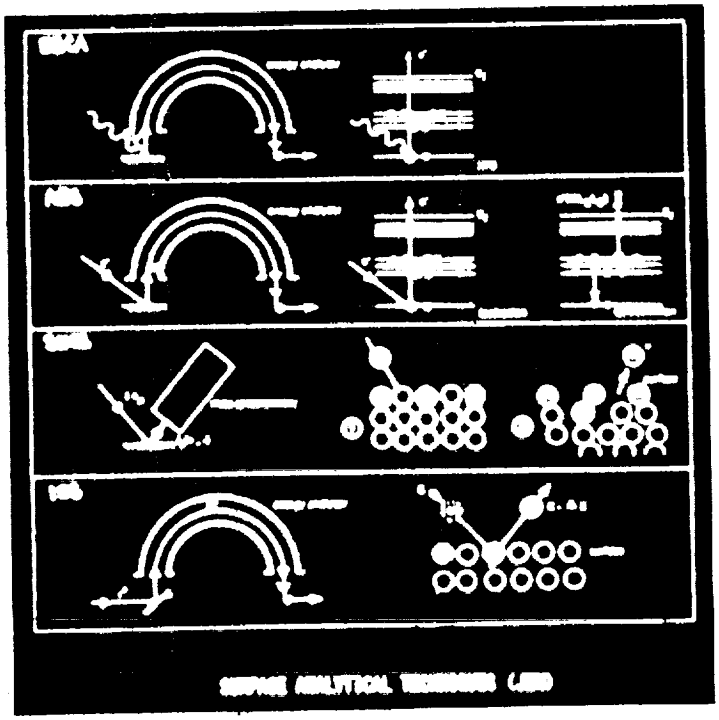
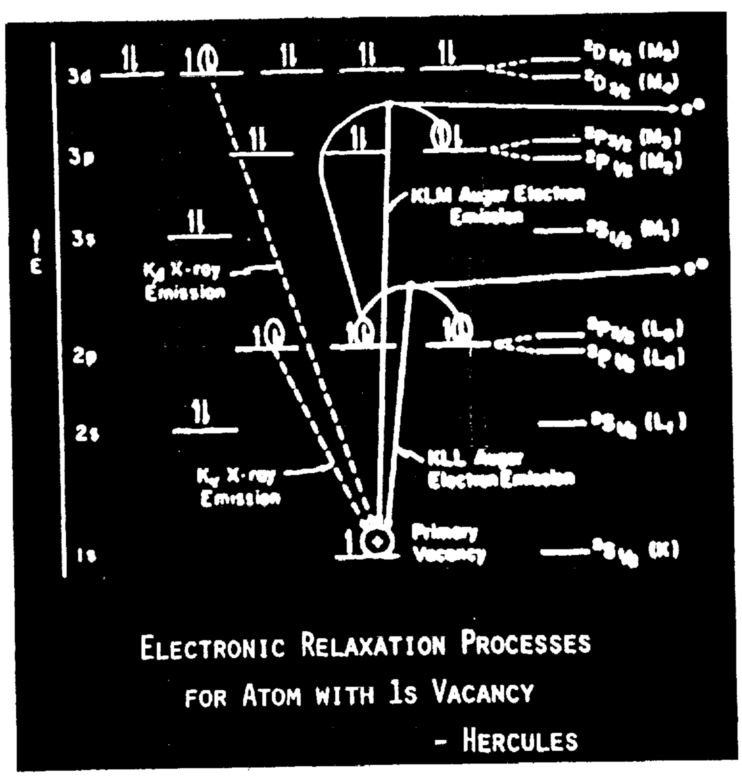
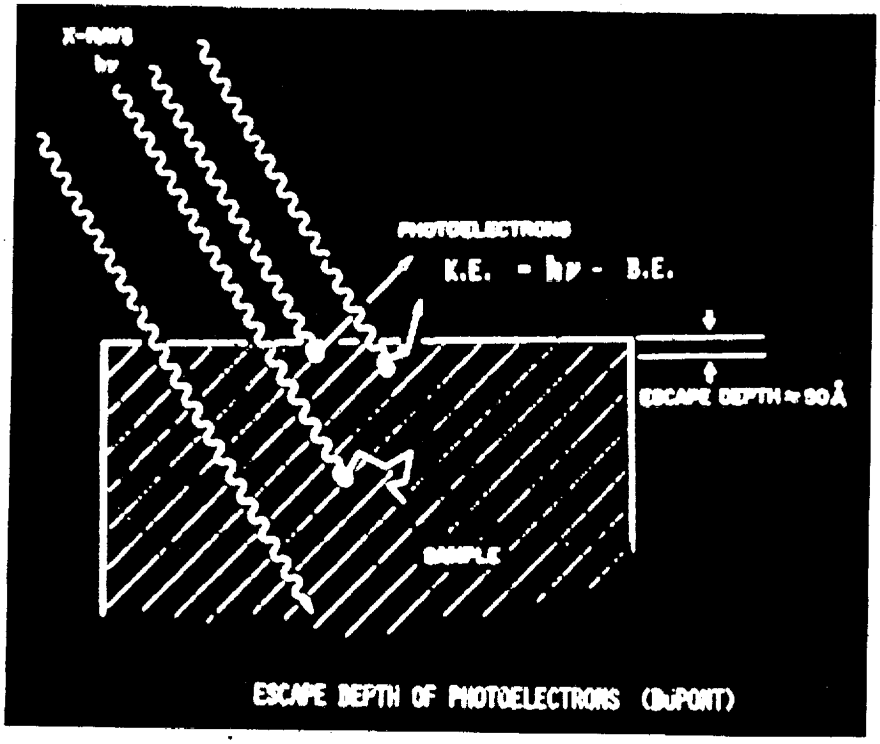


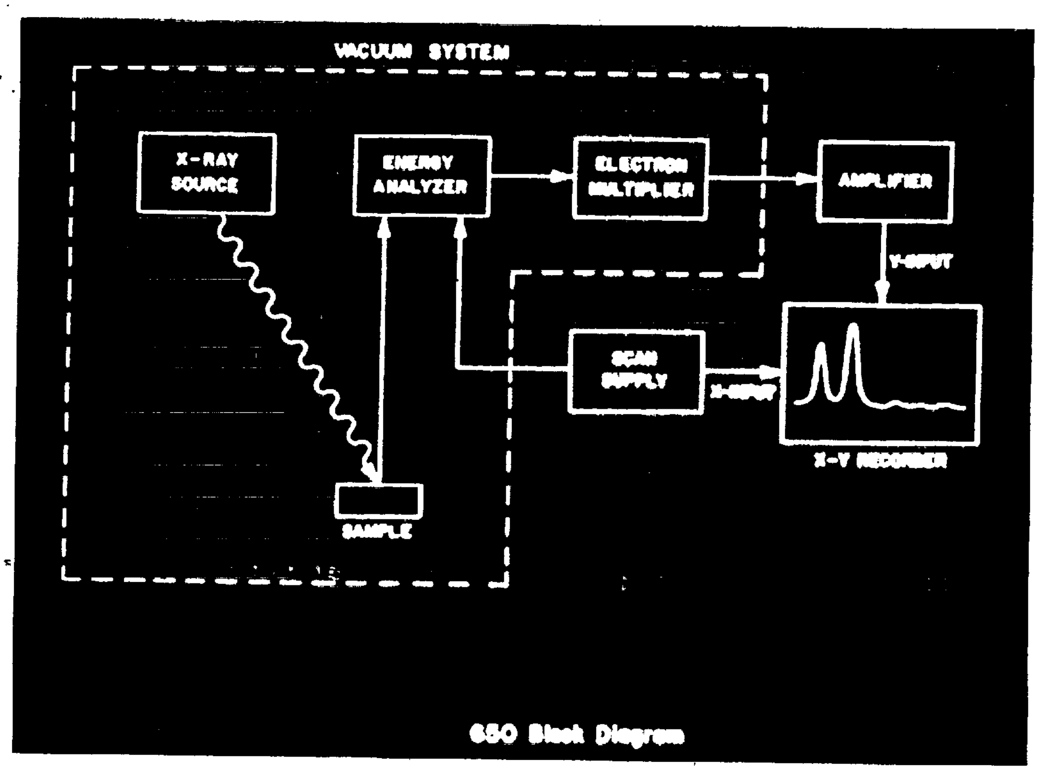
SCHEMATIC DIAGRAMS OF THE FOUR WORKHORSE SURFACE ANALYTICAL TECHNIQUES—D. M. HERCULES/J. S. JEN.



ENERGY LEVEL DIAGRAM FOR X-RAY PHOTOELECTRON SPECTROSCOPY (XPS)—D. M. HERCULES.



SCHEMATIC DIAGRAM FOR XPS TECHNIQUE—DuPONT.



SCHEMATIC DIAGRAM OF XPS SPECTROMETER—DuPONT.

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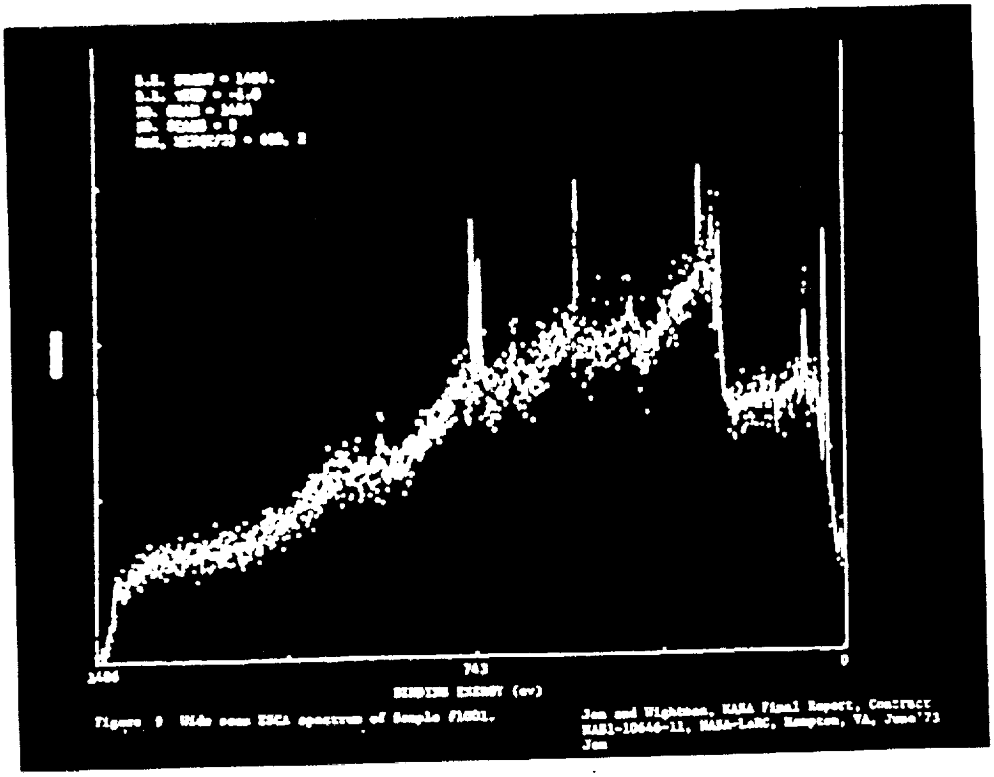
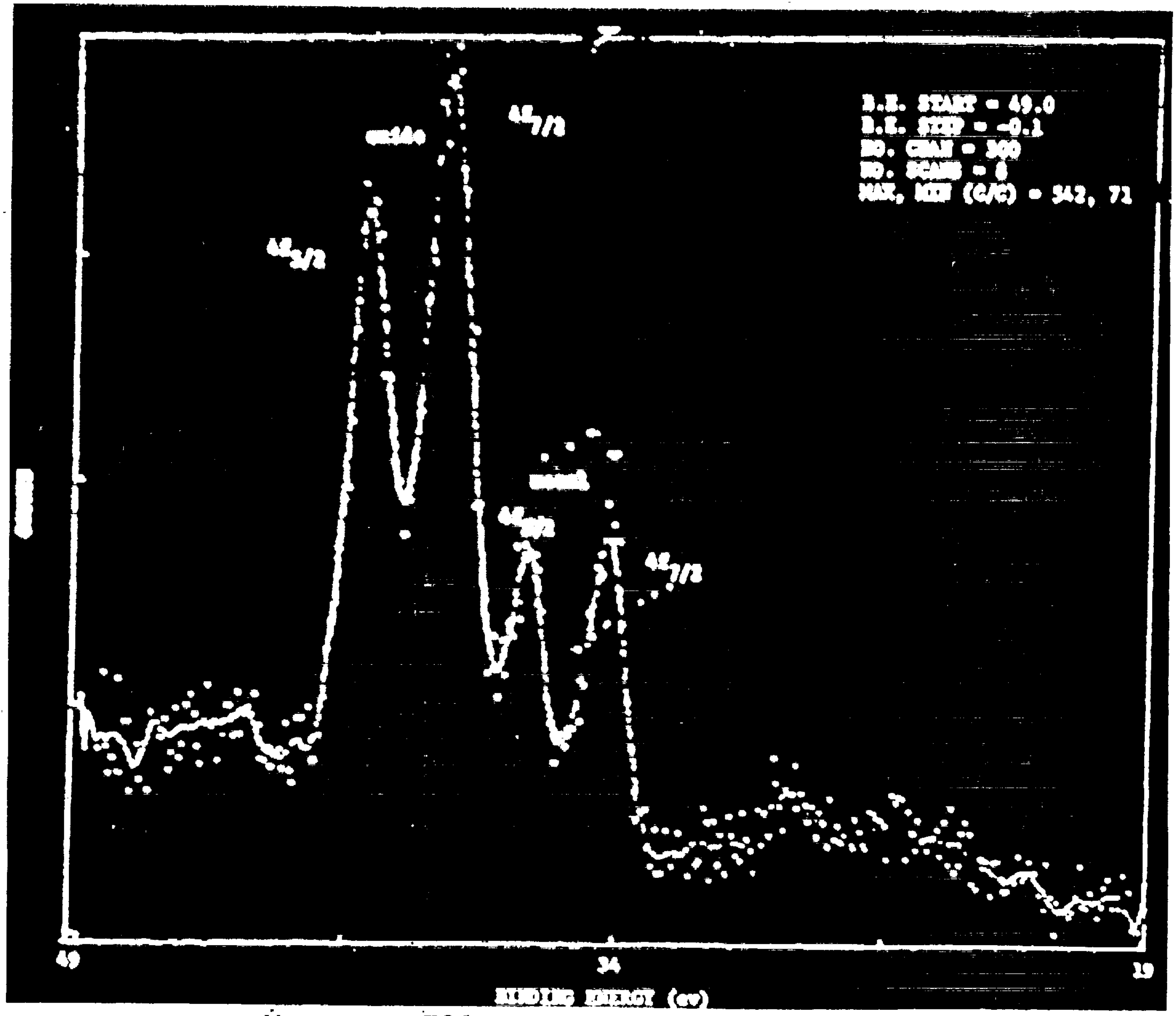
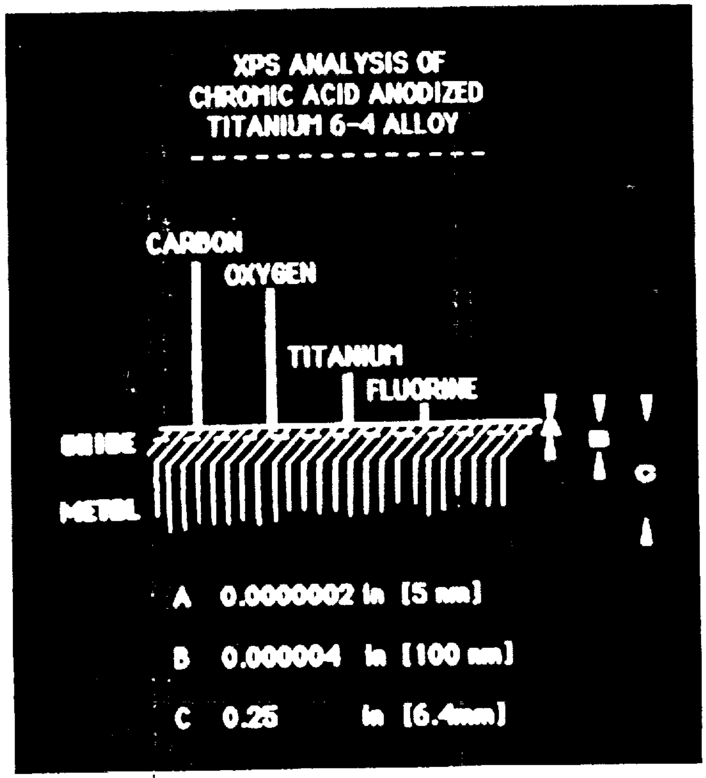


WIDE SCAN XPS SPECTRUM OF CESIUM DOPED TUNGSTEN FILAMENT—JEN & WIGHTMAN.

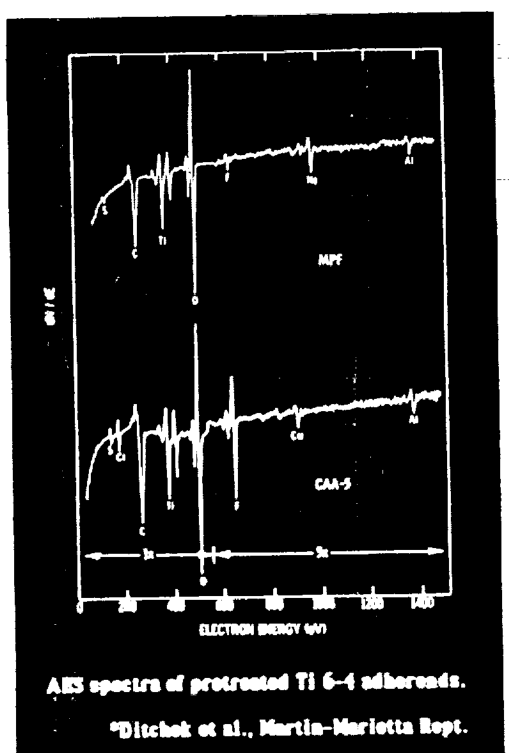


Narrow scan ESCA spectrum of W in Sample #1001.

NARROW SCAN XPS SPECTRUM OF THE TUNGSTEN 4F REGION—JEN & WIGHTMAN.



XPS ANALYSIS OF CHROMIC ACID ANODIZED TITANIUM 6-4 (Ti 6-4) ALLOY—FILBEY & WIGHTMAN.



AUGER ELECTRON SPECTROSCOPY (AES) SURVEY SCAN OF PRETREATED Ti 6-4 ADHERENDS—DITCHEK et al.

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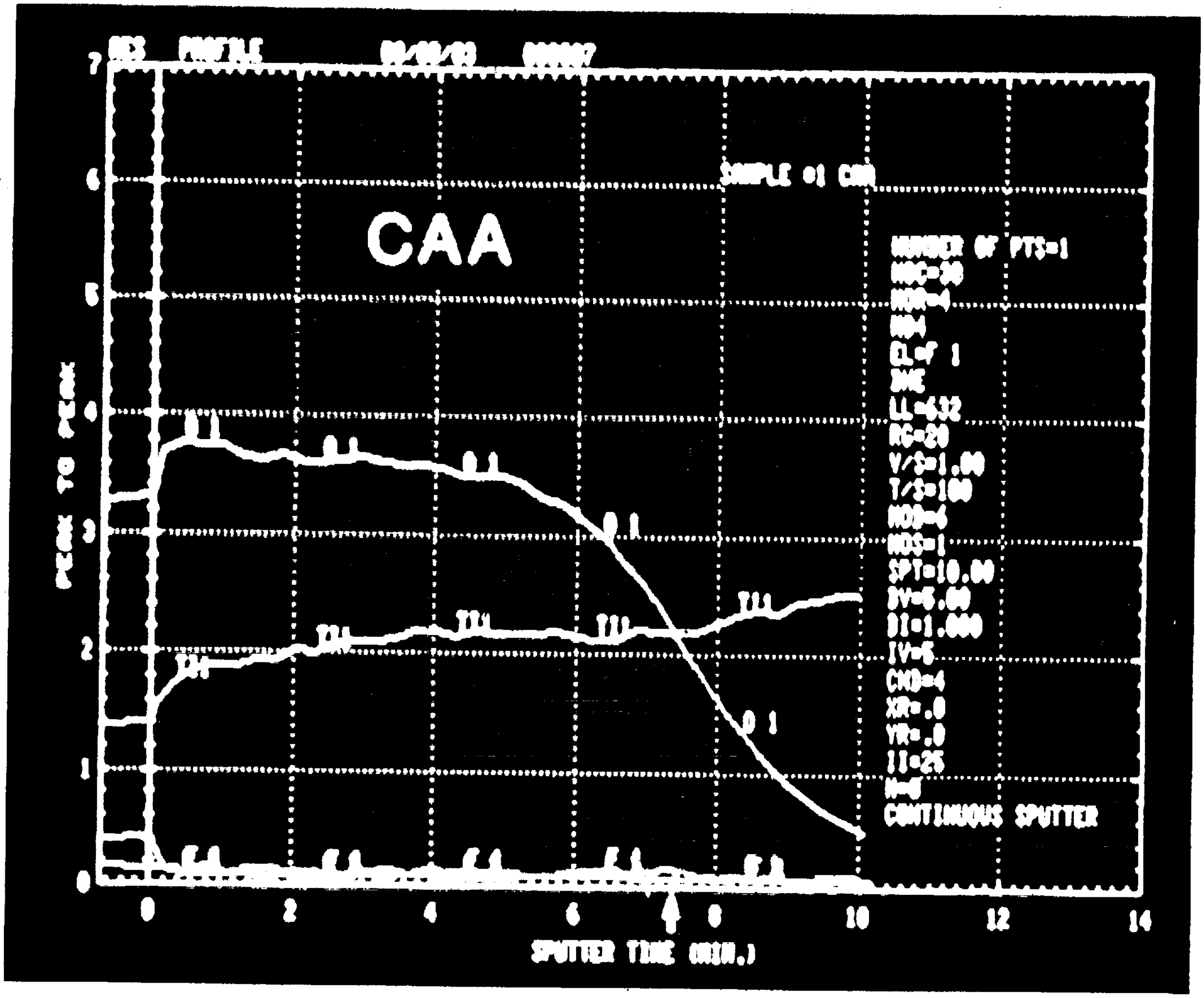

AES DEPTH PROFILE ANALYSIS OF CHROMIC ACID ANODIZED Ti 6-4 ALLOY—FILBEY & WIGHTMAN.

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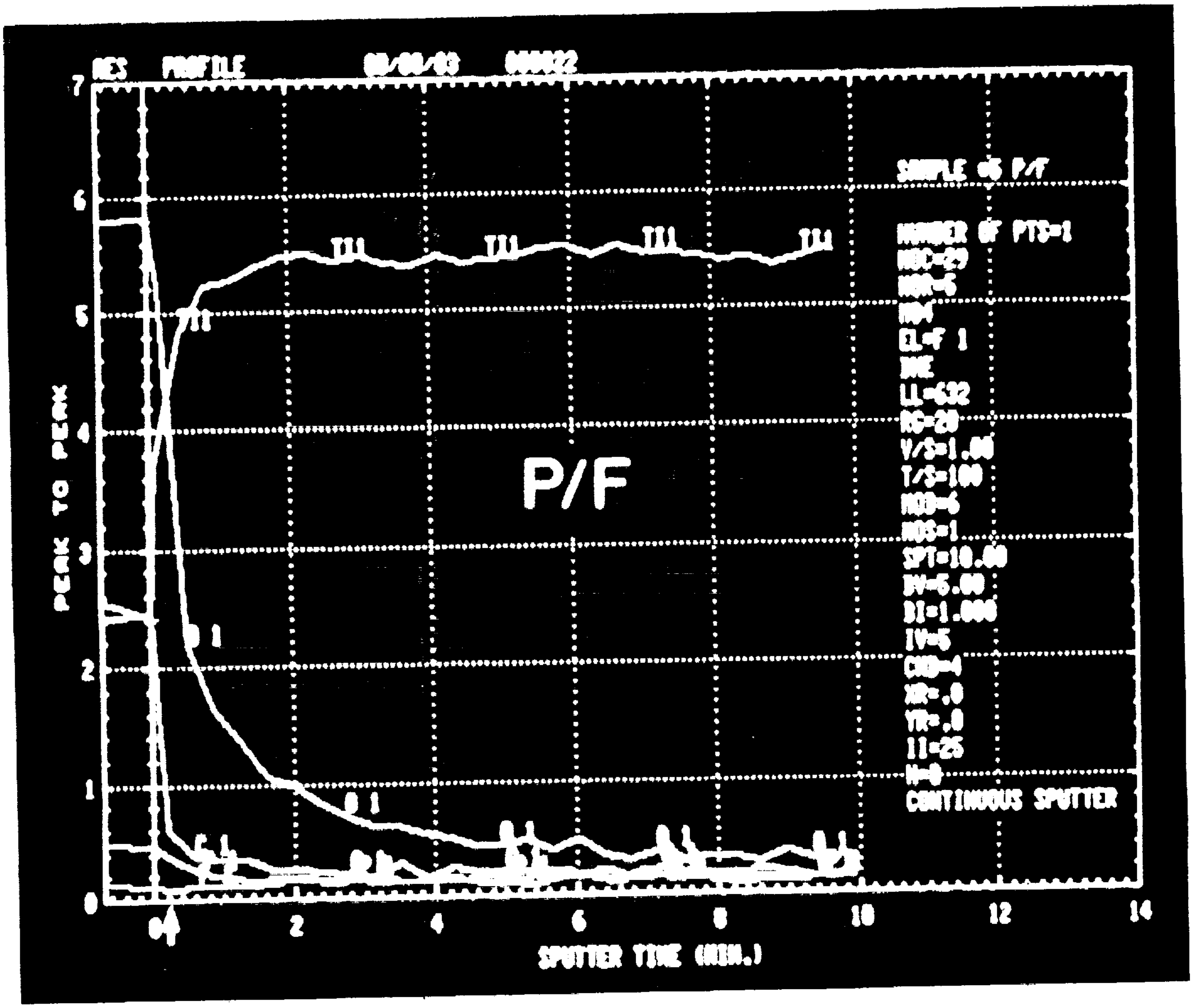

AES DEPTH PROFILE ANALYSIS OF ACID ETCHED Ti 6-4
ALLOY—FILBEY & WIGHTMAN.

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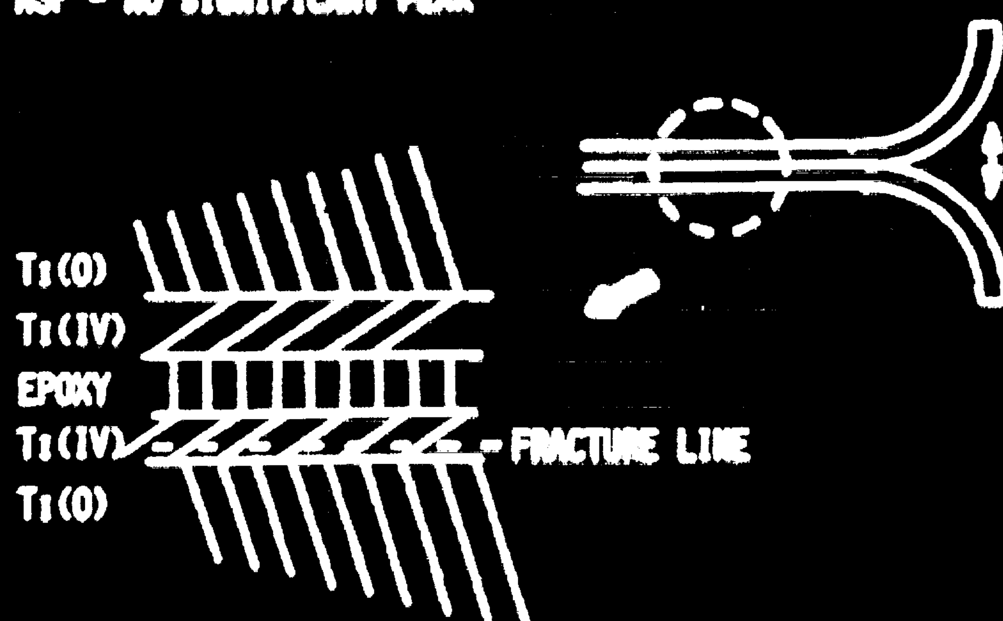
ATOMIC COMPOSITION OF ANODIZED Ti 6-4 SAMPLES

ELEMENT	ATOM PERCENT #1	#2	#3
F 1s	1.2	0.4	2.4
O 1s	13.2	23.6	16.9
V $2p_{3/2}$	0.1	0.1	NSP*
Ti(IV) $2p_{3/2}$	6.9	7.8	7.1
Ti(0) $2p_{3/2}$	NSP	0.4	NSP
N 1s	0.6	0.7	0.9
C 1s	76.6	65.5	71.3
Cl 2p	0.4	0.3	NSP
Al 2s	1.0	1.3	1.4

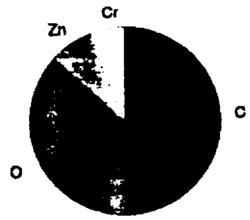
*NSP - NO SIGNIFICANT PEAK



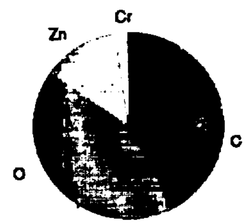
XPS ANALYSIS OF UNBONDED (#1) AND FAILED T-PEEL SAMPLE (#2 & #3) OF Ti 6-4 ALLOY BONDED WITH EPOXY—MARCEAU, SKILES & WIGHTMAN.

A 527

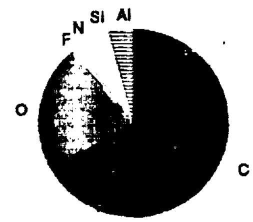
ESCA A527 DEGREASED



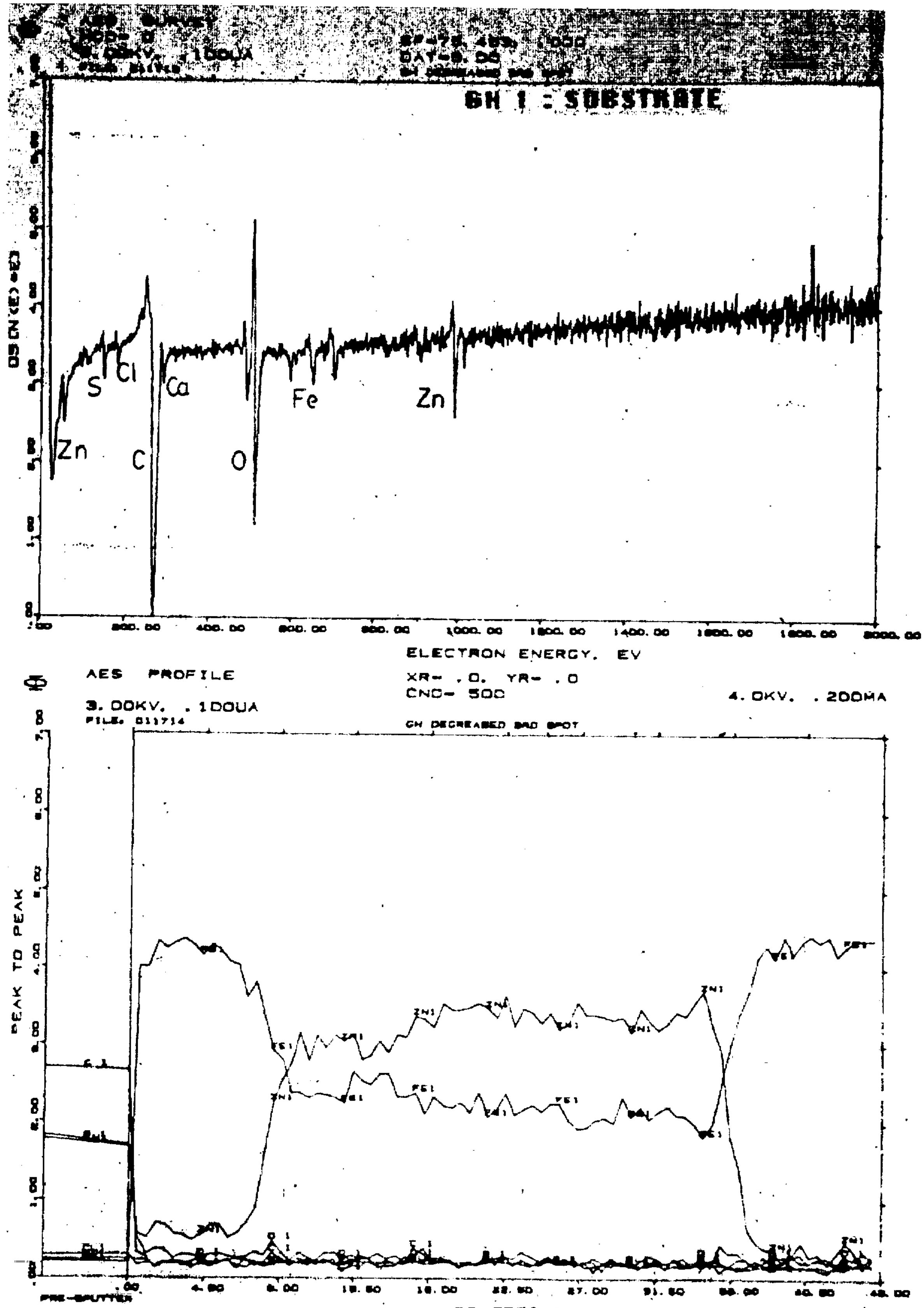
ESCA A527 METAL SIDE



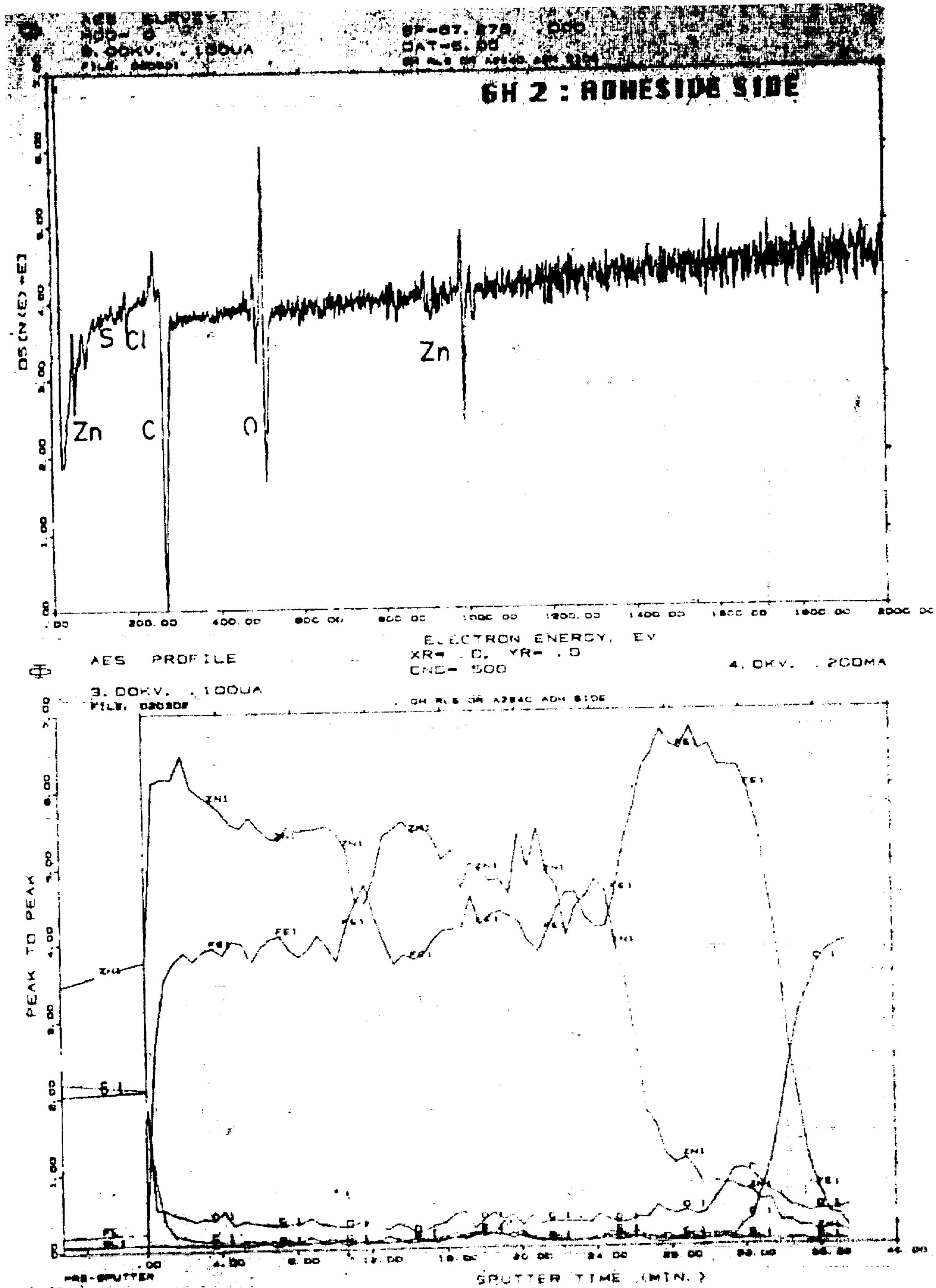
ESCA A527 ADHESIVE SIDE



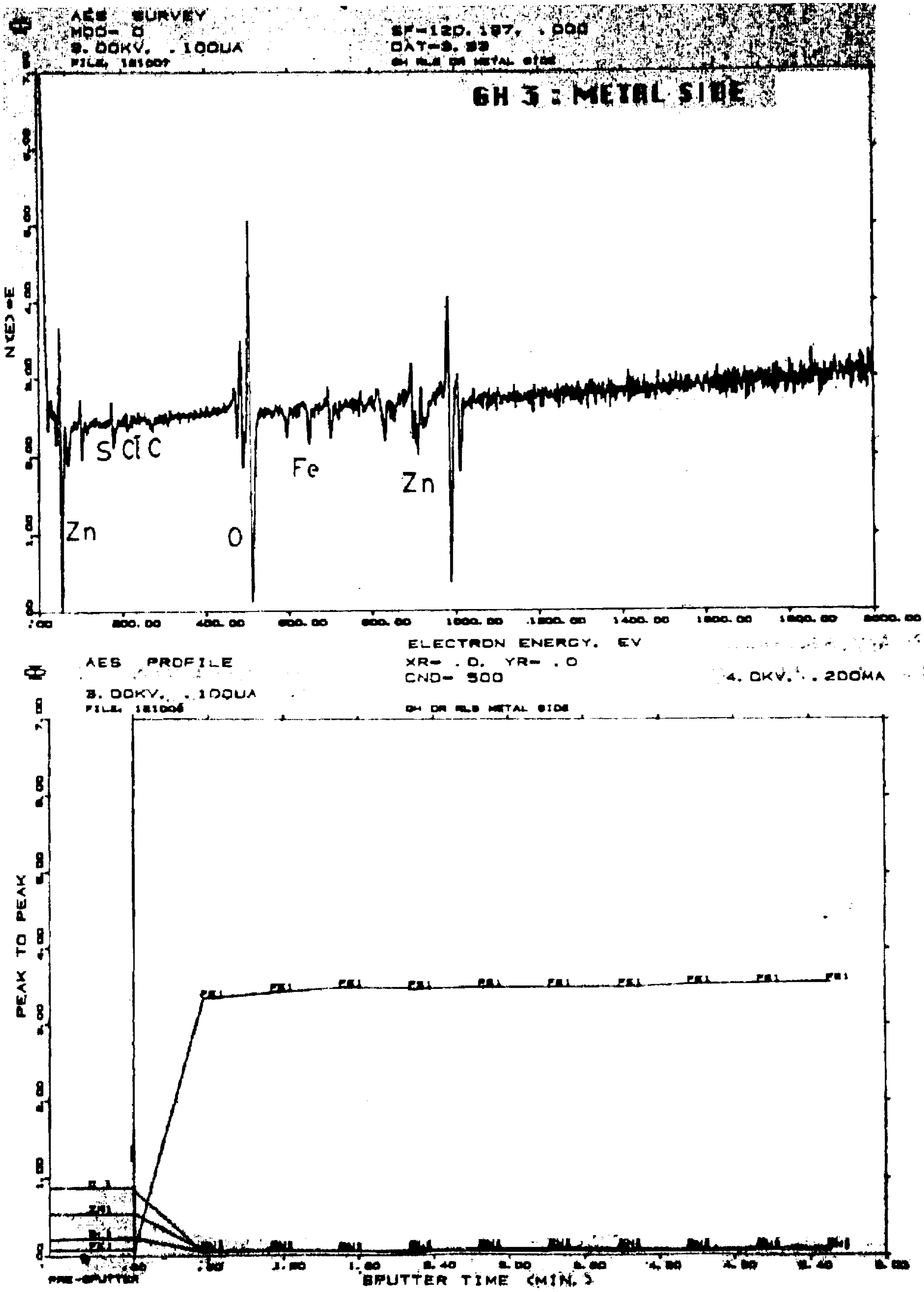
XPS ANALYSIS OF DEGREASED AND FAILED LAP SHEAR SAMPLE (METAL AND ADHESIVE SIDES) OF GALVANIZED STEEL BONDED WITH EPOXY—COMMERÇON & WIGHTMAN.



AES SURVEY (TOP) AND DEPTH PROFILE ANALYSIS OF GALVANIZED STEEL SUBSTRATE PRIOR TO BONDING—COMMERÇON & WIGHTMAN.



AES SURVEY (TOP) AND DEPTH PROFILE ANALYSIS OF ADHESIVE SIDE OF GALVANIZED STEEL BONDED WITH EPOXY FOLLOWING LAP SHEAR FAILURE—COMMERÇON & WIGHTMAN.



AES SURVEY (TOP) AND DEPTH PROFILE ANALYSIS OF METAL SIDE OF GALVANIZED STEEL BONDED WITH EPOXY FOLLOWING LAP SHEAR FAILURE—COMMERÇON & WIGHTMAN.

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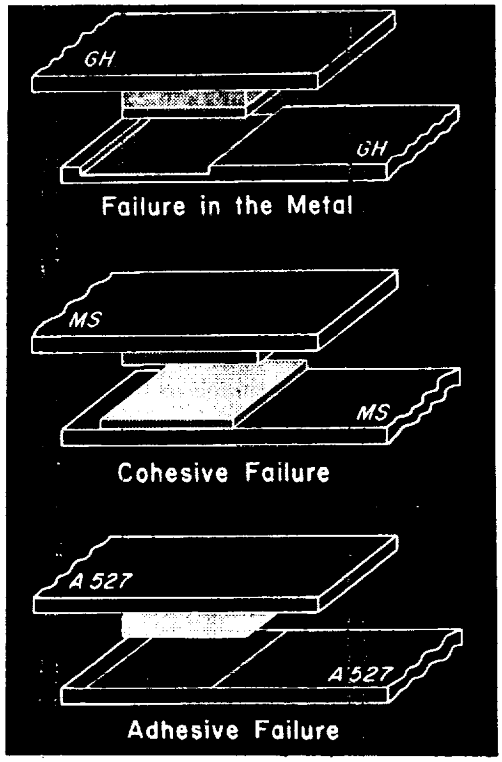
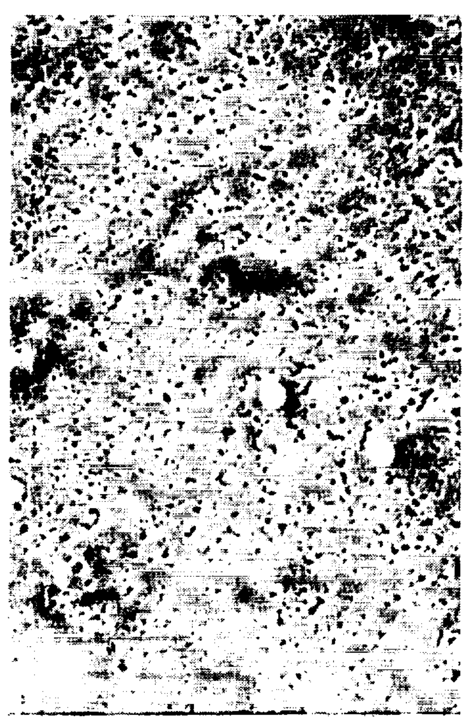


DIAGRAMS SHOWING LOCUS OF FAILURE FOR THREE GALVANIZED STEEL (GH, MS, A527) BONDED WITH EPOXY—COMMERÇON & WIGHTMAN.



SEM PHOTOMICROGRAPH OF SHUTTLE EXHAUST PARTICLES COLLECTED BY AIRCRAFT ON A NUCLEOPORE FILTER—COFER & WIGHTMAN.

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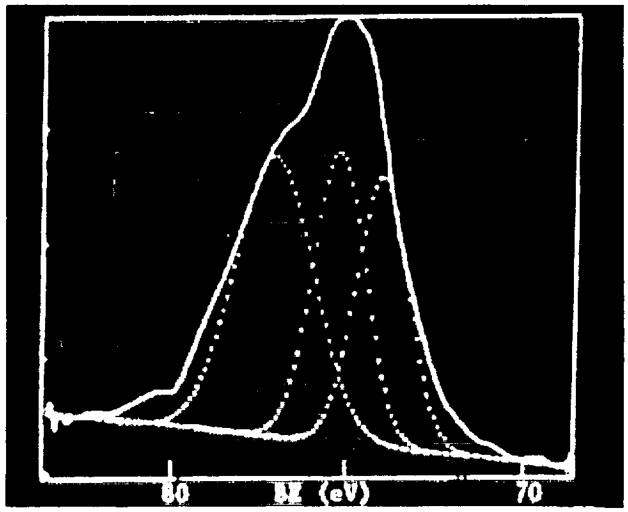
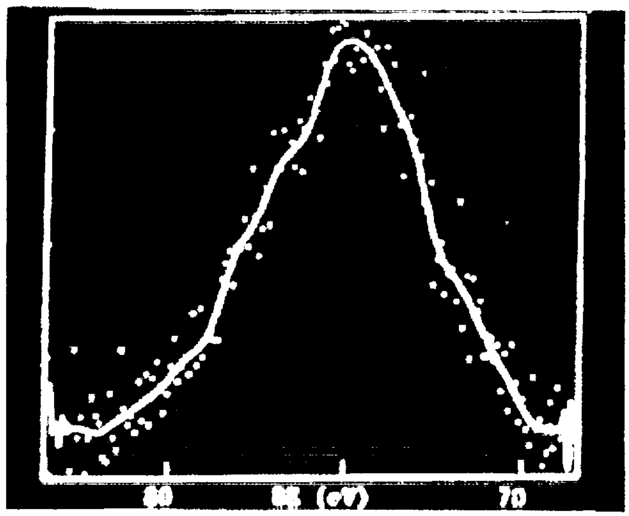
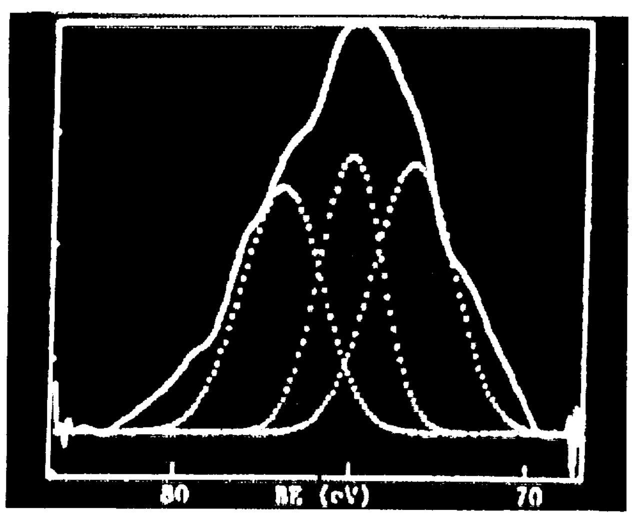


Al 2p Photopeak—NASA 75-A-20—Raw Data and Deconvoluted Components



Al 2p Photopeak—NASA 75-A-47—Raw Data



Al 2p Photopeak—NASA 75-A-47—Raw Data and Deconvoluted Components

XPS CURVE-FITTED ALUMINUM 2P PHOTOPEAKS OF SHUTTLE EXHAUST PARTICLES—COFER & WIGHTMAN.

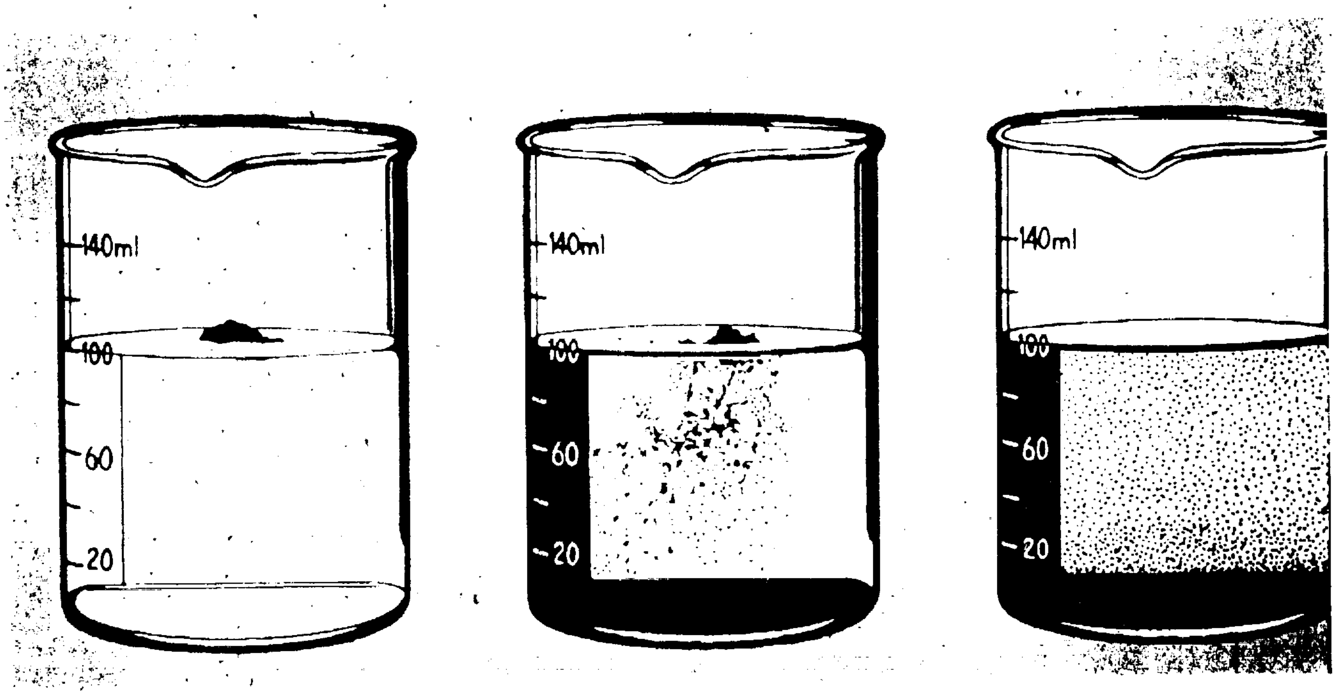
SEM PHOTOMICROGRAPHS OF MOUNT ST. HELENS (MSH)
ASH—KANG & WIGHTMAN.

ESCA ATOMIC FRACTION RESULTS FOR MOUNT ST. HELENS ASH

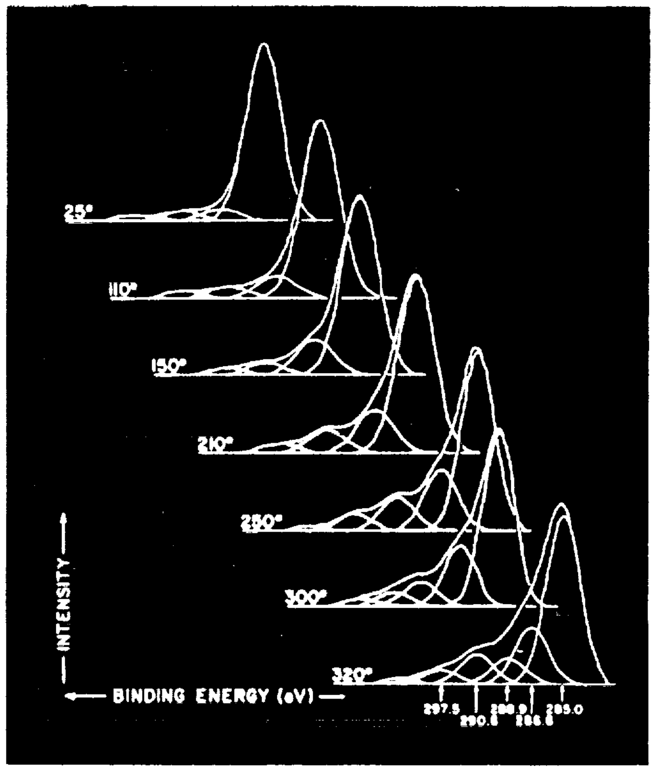
RATIO	MOL	VAD	YAK-I	YAK-II	ELL	GLE	SPO	AVG	BULK**
O/Si	2.8	3.1	3.4	2.0	3.4	3.0	2.6	3.0±0.4	
Al/Si	0.43	0.32	0.28	0.27	0.32	0.25	0.44	0.33±0.06	0.30
Na/Si	0.13	0.14	0.095	0.072	0.14	0.10	0.16	0.12±0.03	0.14
Ca/Si	0.085	--	0.049	0.041	0.028	--	0.069	0.054±0.018	0.081
Cl/Si	0.018	--	0.11	--	0.035	--	--	0.054±0.037	--

**Fruchter et al., Science, 209, 1116 (1980)

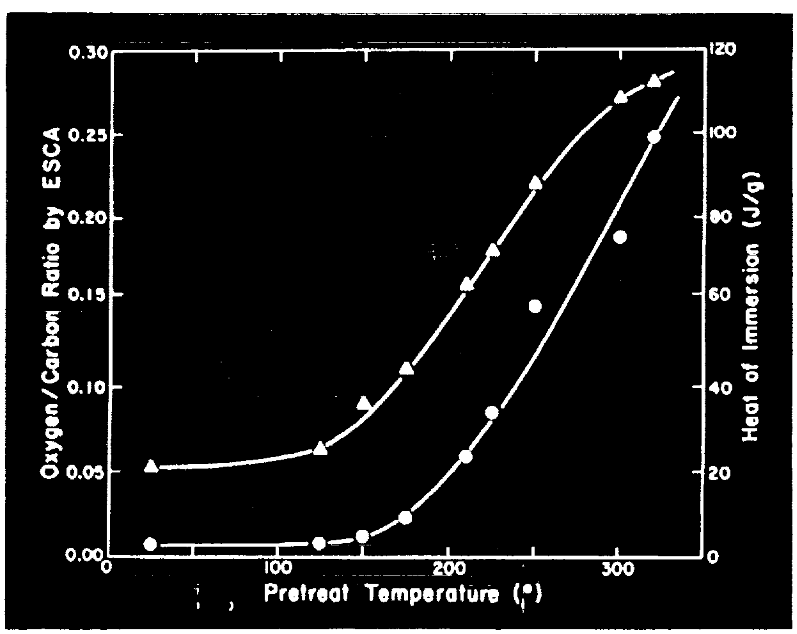
XPS (ESCA) ANALYSIS OF MSH ASH—KANG & WIGHTMAN.



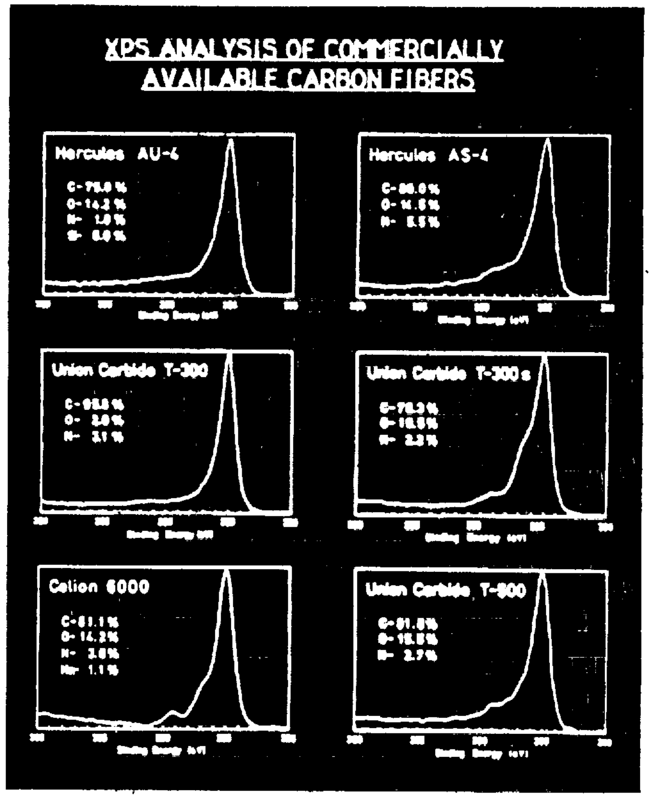
WETTING OF COAL—GLANVILLE & WIGHTMAN.



XPS CURVE FITTED CARBON 1S PHOTOPEAKS OF COAL HEATED TO DIFFERENT TEMPERATURES IN AIR—PHILLIPS & WIGHTMAN.



OXYGEN/CARBON RATIO OF COAL DETERMINED BY XPS (ESCA) AS A FUNCTION OF PRETREATMENT TEMPERATURE—PHILLIPS & WIGHTMAN.



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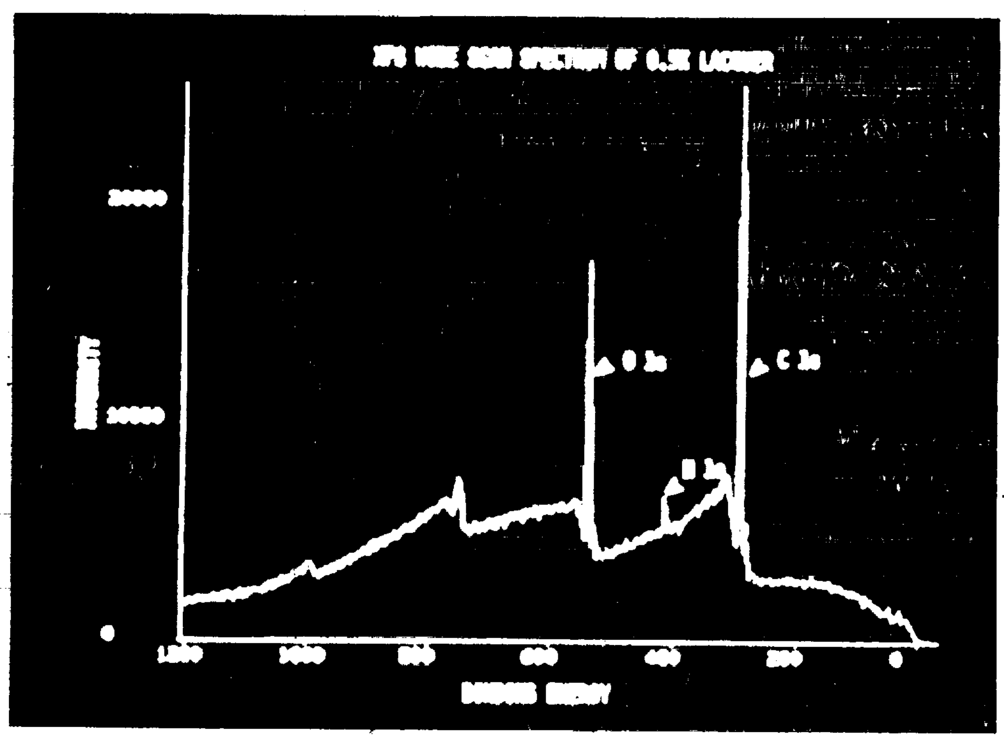
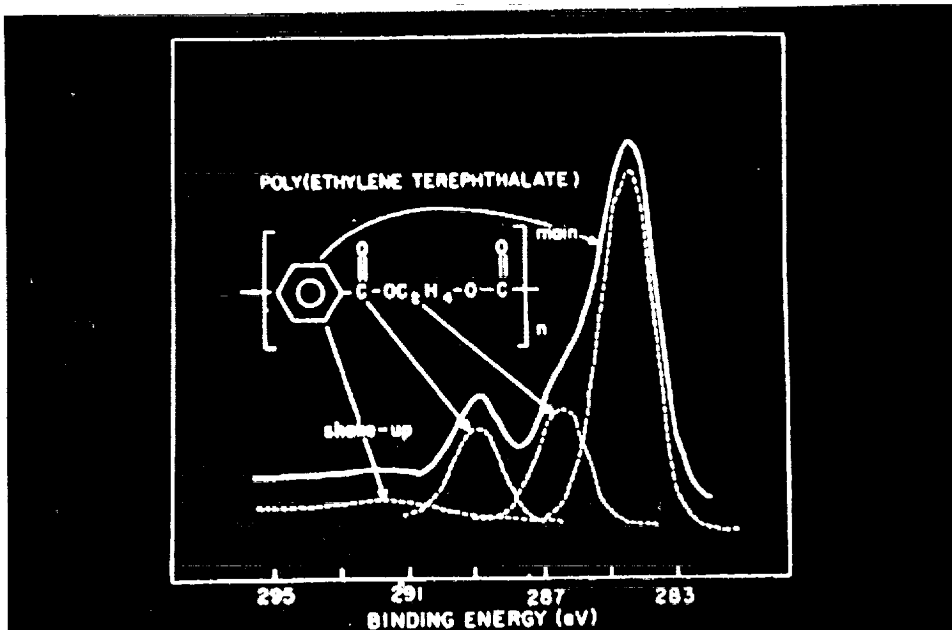
XPS ANALYSIS OF COMMERCIALLY AVAILABLE CARBON FIBERS—DeVILBISS & WIGHTMAN.

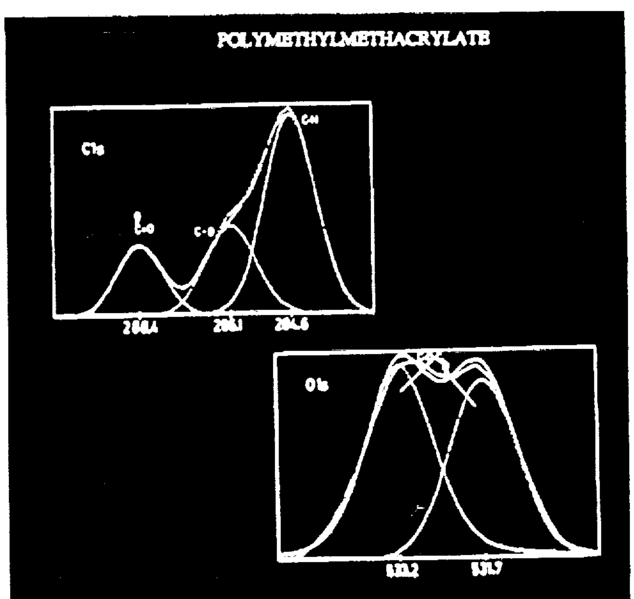


XPS WIDE SCAN SPECTRUM OF NITROCELLULOSE LACQUER—WEBSTER & WIGHTMAN.



Carbon 1*s* ESCA spectrum from poly(ethylene terephthalate) Mylar film. Experimental peak shape is shown by the solid line. After deconvolution into four Gaussian components (dashed lines), the assignments to the structural features indicated was straightforward. The 6:2:2 ratio of carbon functionality is reflected approximately by the component peak areas.

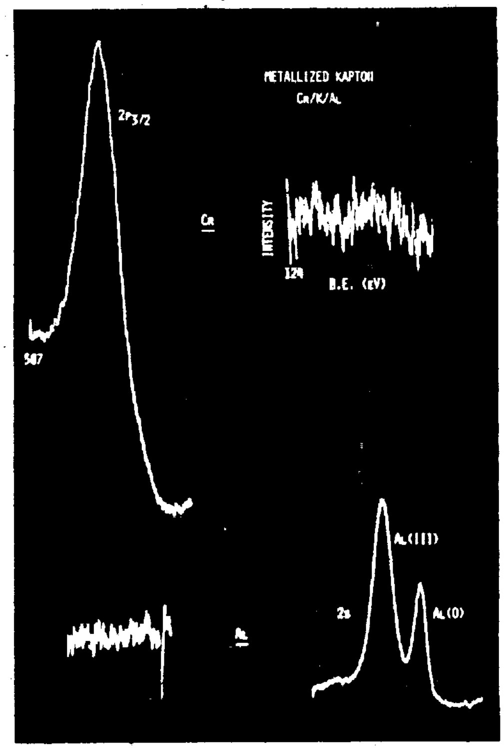
XPS CURVE FITTED CARBON 1S PHOTOPEAKS OF POLYETHYLENETEREPHTHALATE—DWIGHT, McGRATH & WIGHTMAN.



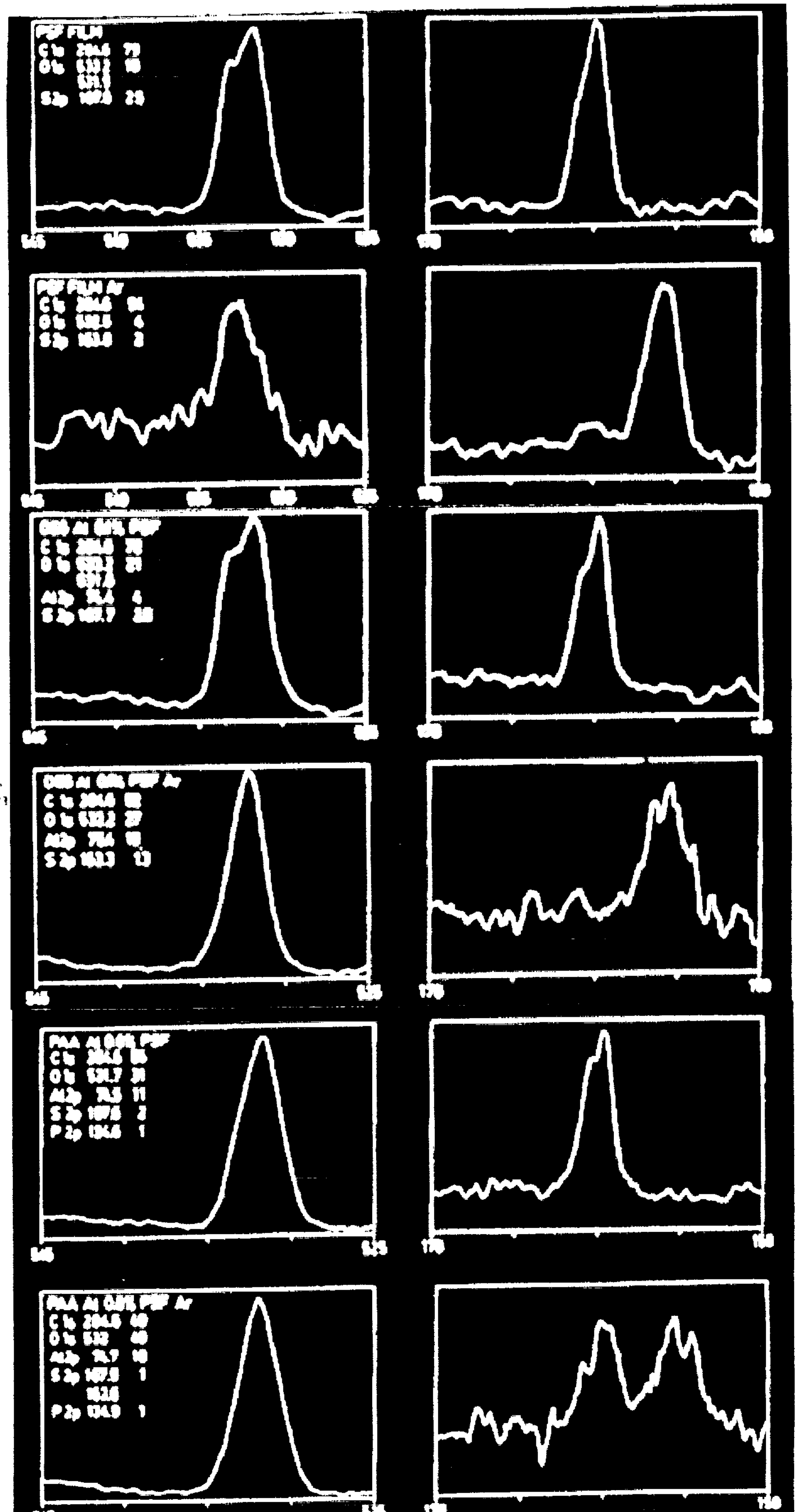
QUANTITATIVE ANALYSES

ANGLE	O:C RATIO KRATOS	O:C RATIO PHI	O:C RATIO EXPECTED
90	0.29	0.36	0.40
30	0.25	0.34	0.40
10	0.25	0.33	0.40

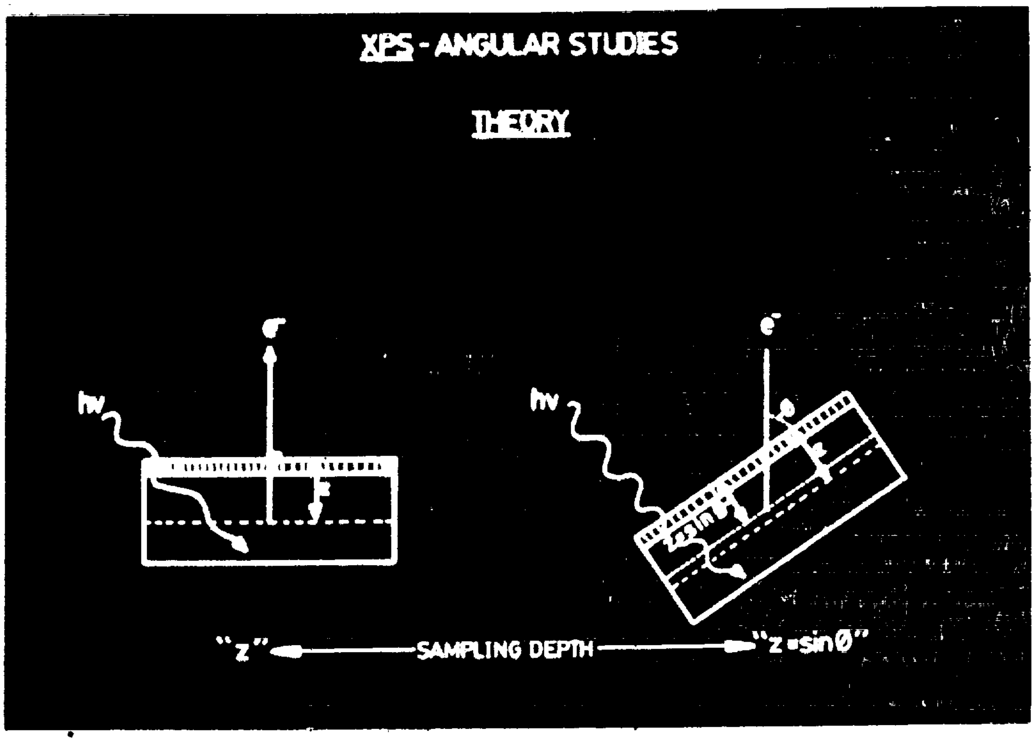
XPS CURVE FITTED CARBON 1S AND OXYGEN 1S PHOTOPEAKS FOR POLYMETHYLMETHACRYLATE—WEBSTER & WIGHTMAN.



XPS SPECTRA OF METALLIZED KATPON
TOP—CHROMIUM AND ALUMINUM PHOTOPEAKS ON CHROMIUM SIDE
BOTTOM—CHROMIUM AND ALUMINUM PHOTOPEAKS ON ALUMINUM SIDE
—WIGHTMAN.



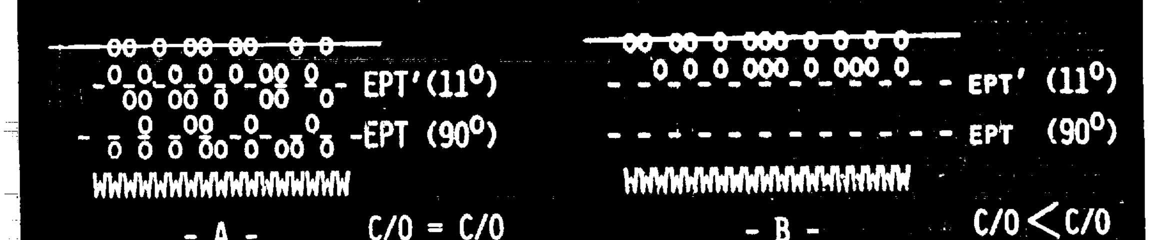
CARBON 1S AND SULFUR 2P XPS PHOTOPEAKS FOR POLYSULFONE (PSF) FILM (TOP SPECTRA) AND PSF FILM SPUTTERED WITH ARGON (NEXT SPECTRA)—KO & WIGHTMAN.



SCHEMATIC DIAGRAM FOR ANGLE DEPENDENT XPS STUDIES—WEBSTER.

ESCA ANALYSIS OF POLYMER FILMS

FILM	θ	O	C	C/O
UNEXPOSED	90°	0.003	0.997	415
	90°	0.002	0.998	
EXPOSED	90°	0.021	0.979	41
	90°	0.028	0.972	
	11°	0.097	0.903	9



XPS (ESCA) ANALYSIS OF POLYOLEFIN FILMS BEFORE AND AFTER EXPOSURE TO OXYGEN PLASMA—WIGHTMAN.

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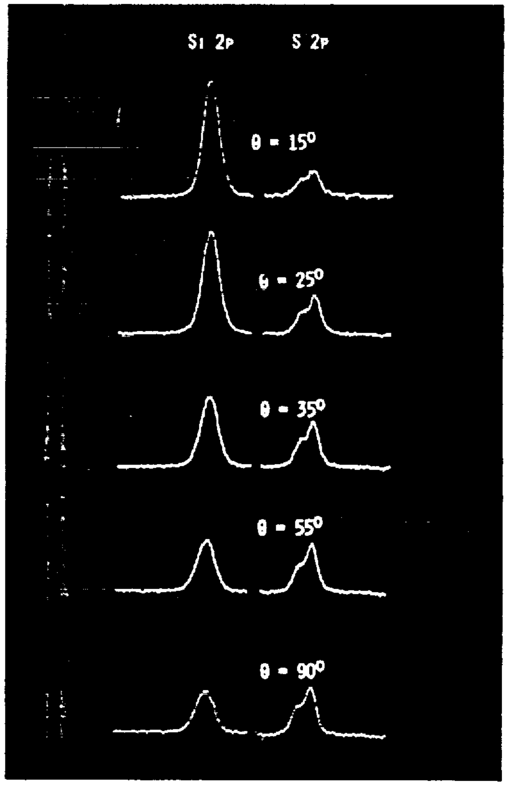
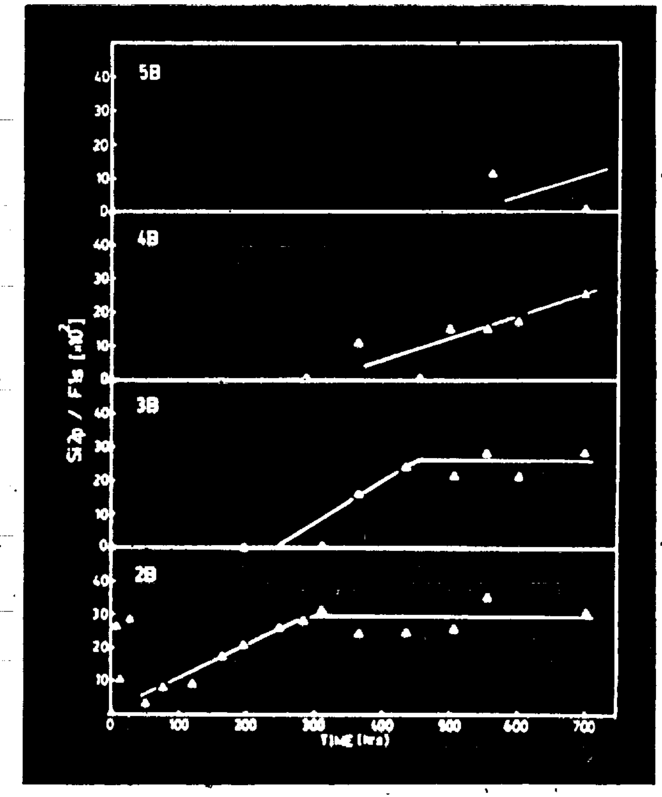


SILICON 2P AND SULFUR 2P XPS PHOTOPEAKS IN SILOXANE CONTAINING POLYMER—LIN, McGRATH & WIGHTMAN.

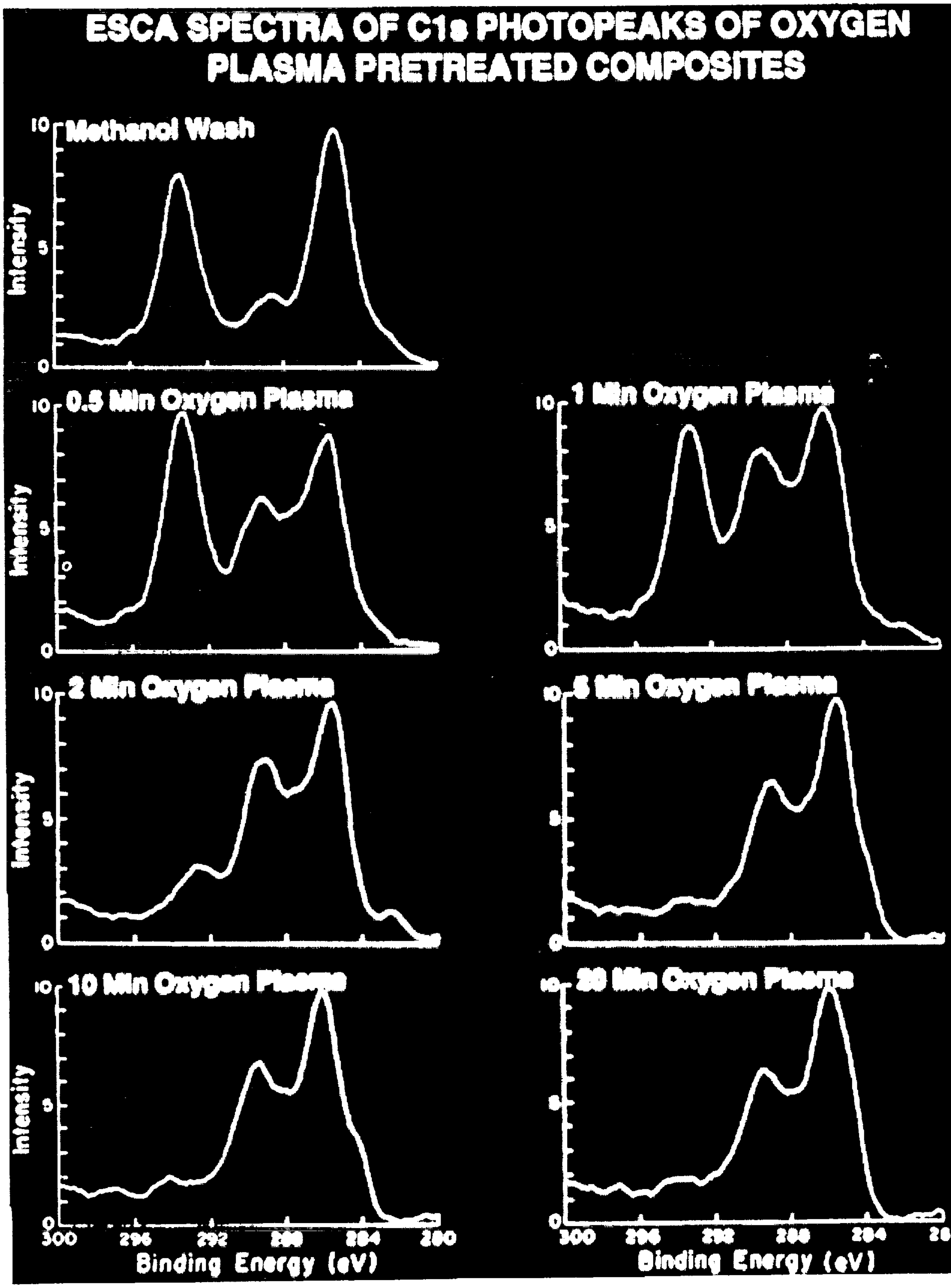
XPS ELEMENTAL RATIOS BEFORE AND AFTER ROAD EXPOSURE

SAMPLE	C/O	C/F	C/S	C/AL
KYNAR	6.8	1.2	-	-
N-5D-0.2	7.1	1.4	-	-
TEFLON	13.7	1.0	-	-
TFE-3A-0.2	13.3	1.0	-	-
POLYSULFONE	6.3	-	27.0	-
PSF-4A-0.2	6.0	-	34.0	-
POLYMETHYLMETHACRYLATE	3.5	-	-	-
PMMA-3B-0.2	3.5	-	-	-
CONTROL	1.2	-	-	2.6
C-5-0.2	1.2	-	-	4.3

XPS RATIOS BEFORE [POLYMER NAME ONLY] AND AFTER [NUMBER DESIGNATION] ROAD EXPOSURE OF COATED PLATES MOUNTED ON AUTO—SIOCHI & WIGHTMAN.



SILICONE/FLUORINE RATIO AS DETERMINED BY XPS FOR **SILICONE OIL** MIGRATION ACROSS POLYMER SUBSTRATE—WEBSTER & **WIGHTMAN.**



XPS (ESCA) RESULTS OF OXYGEN PLASMA TREATED COMPOSITES--MOYER & WIGHTMAN.

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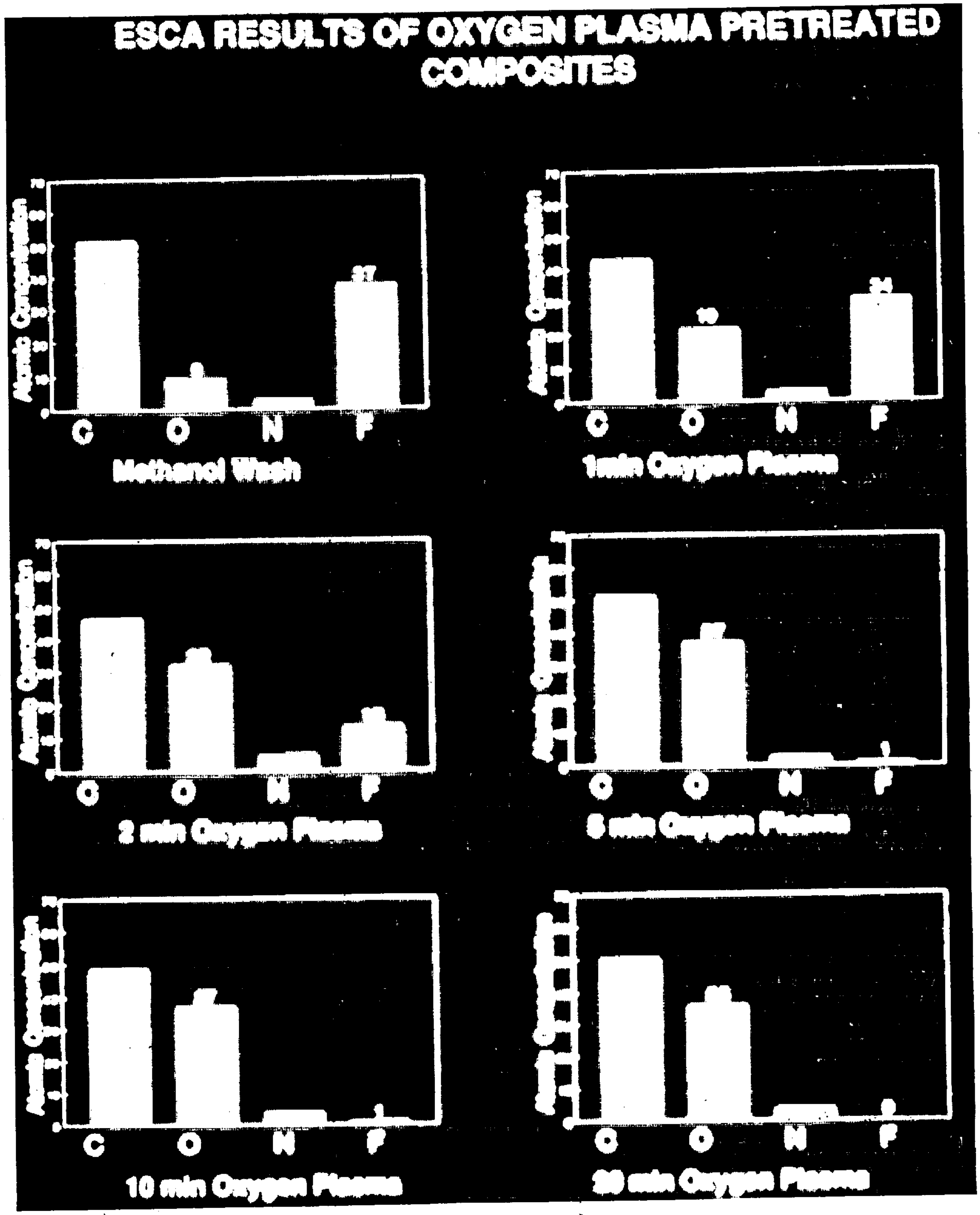
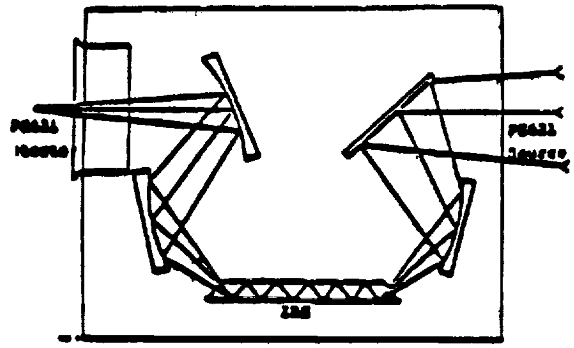
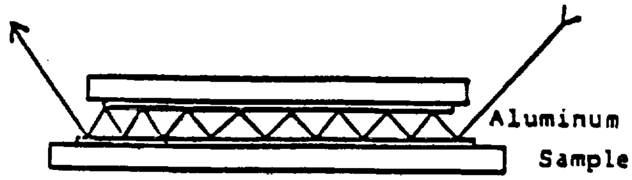


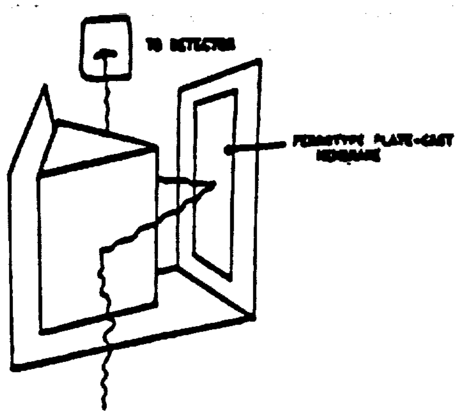
XPS (ESCA) SPECTRA OF CARBON 1S PHOTOPEAKS OF OXYGEN PLASMA TREATED COMPOSITES—MOYER & WIGHTMAN.



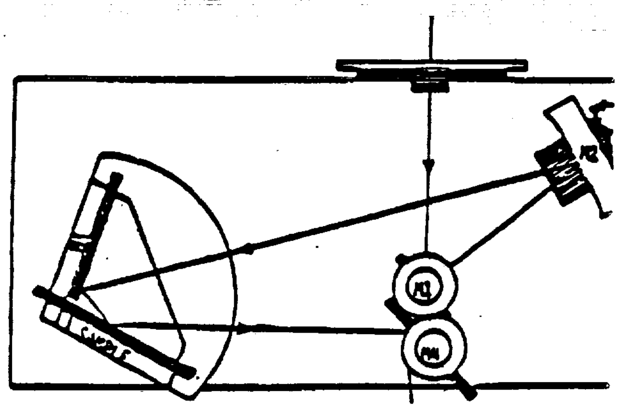
(a) ATR - IRE



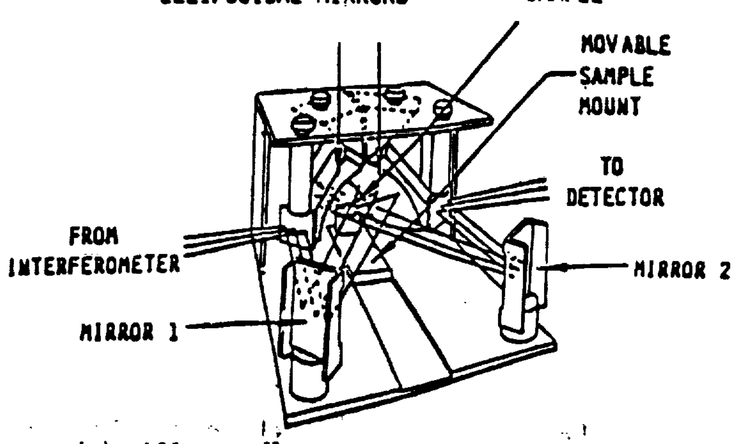
(b) specular - multiple reflections



(c) specular - single reflection



(d) specular - grazing angle

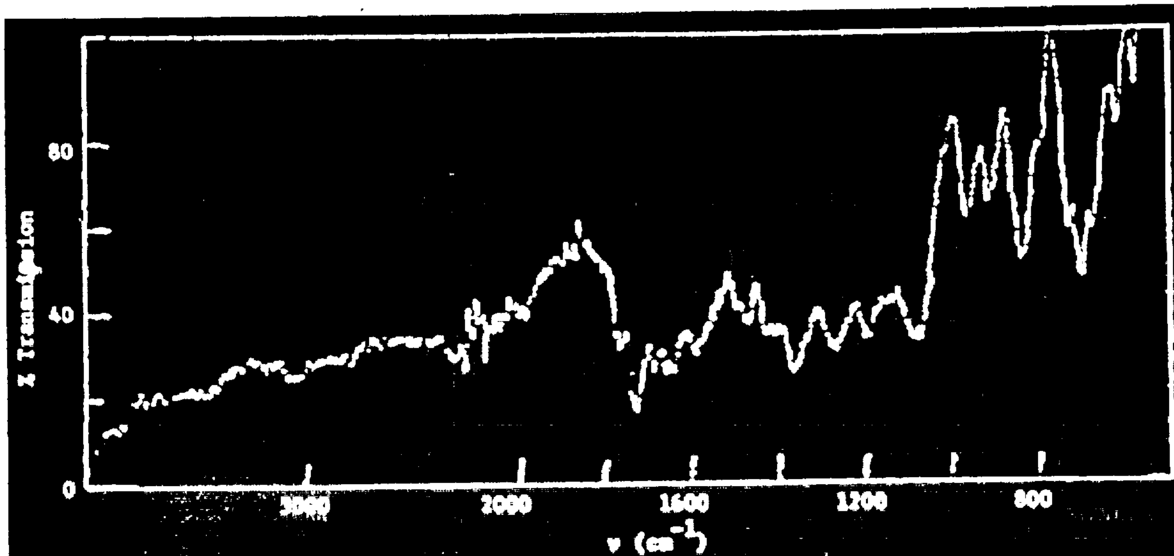


(e) diffuse reflectance

PHOTOACOUSTIC

SRS attachments.

DIAGRAMS OF VARIOUS REFLECTANCE INFRARED ACCESSORIES—
HONEYCUTT, WEBSTER, YOUNG AND WIGHTMAN.



Reflectance infrared spectrum of Sample lmp2-516.

PEAK ASSIGNMENTS OF SRIS OF FRACTURE SURFACES

$\bar{\nu}$(cm^{-1})	Assignment
580	SAR*
700	SAR
735	C-H rock
840	SAR
920	SAR
970	SAR
1088	SAR
1200	ϕNR_2, SAR
1270	$\phi_2C{=}O$
1370	ϕNR_2
1730	O-CHR$_2$, $\phi_2C{=}O$
3000	C-H stretch

*SAR - skeletal aromatic rock

REFLECTANCE IR SPECTRUM OF FAILED TITANIUM LAP SHEAR SAMPLE BONDED WITH POLYIMIDE ADHESIVE—COUNTS & WIGHTMAN.

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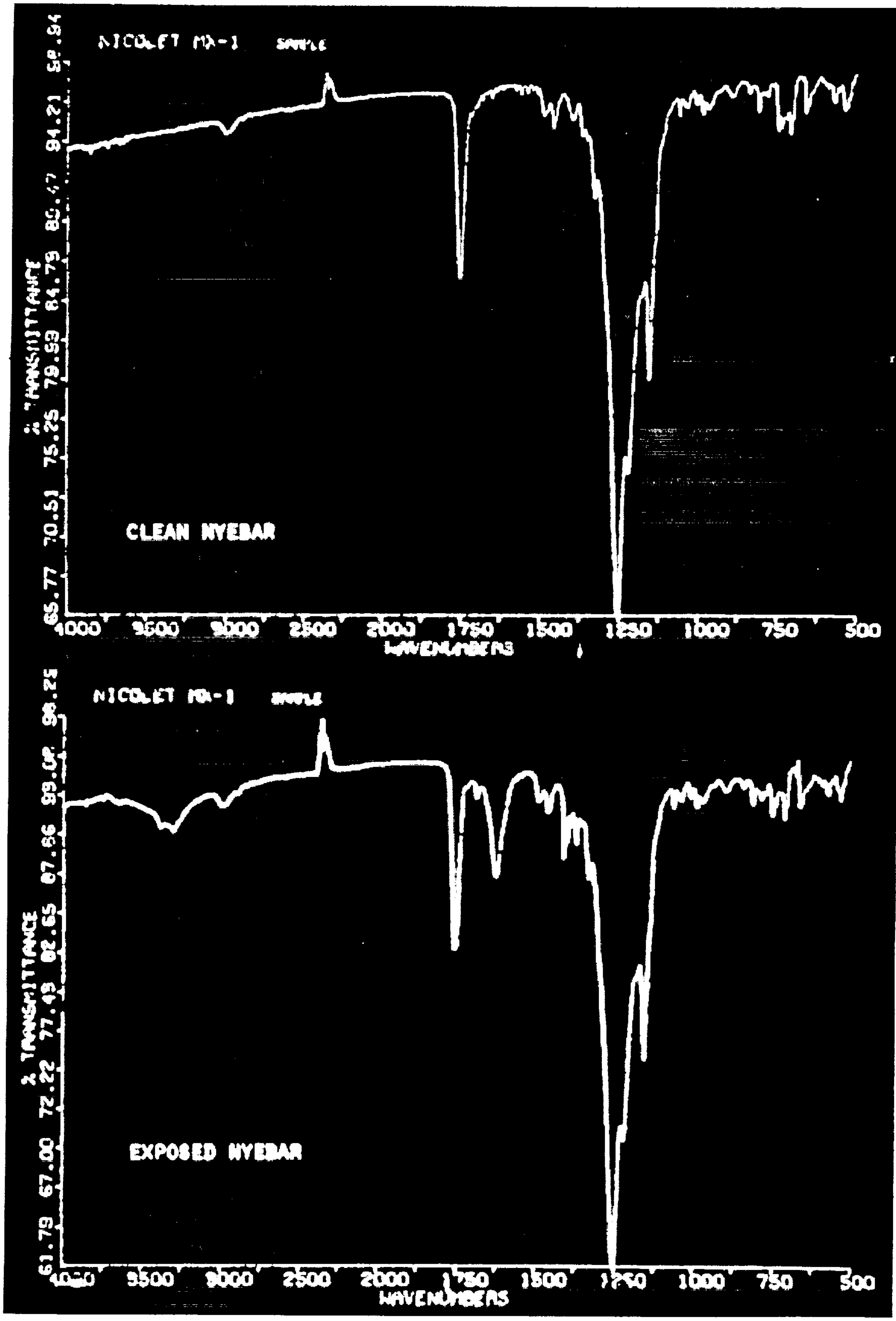

REFLECTANCE IR SPECTRA OF UNEXPOSED (TOP) AND ROAD EXPOSED (BOTTOM) FLUOROPOLYMER COATED PLATES—SIOCHI & WIGHTMAN.

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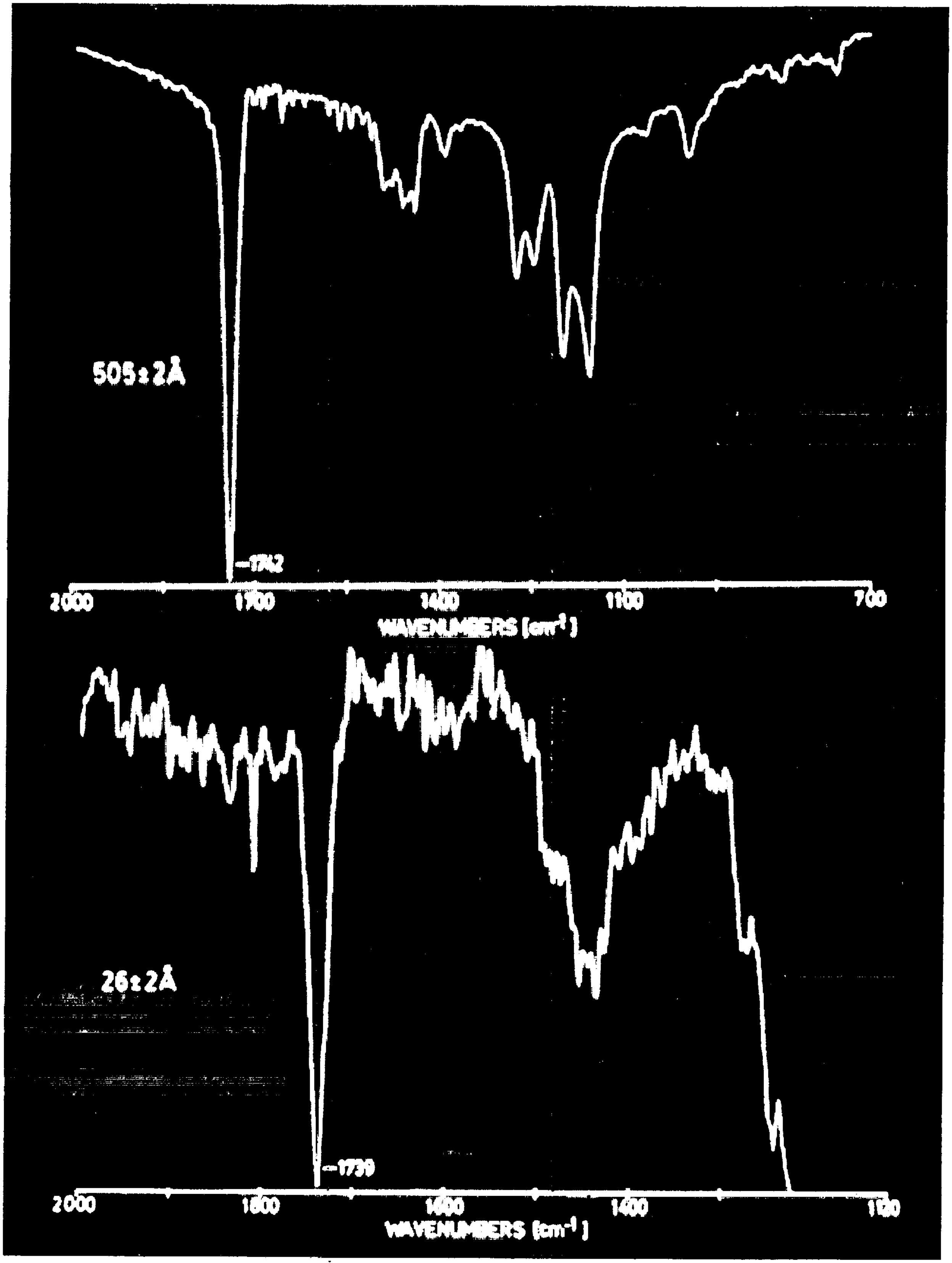

REFLECTANCE IR SPECTRA OF TWO THICKNESSES OF
POLYMETHYLMETHACRYLATE ON CHROME STEEL—WEBSTER & WIGHTMAN.

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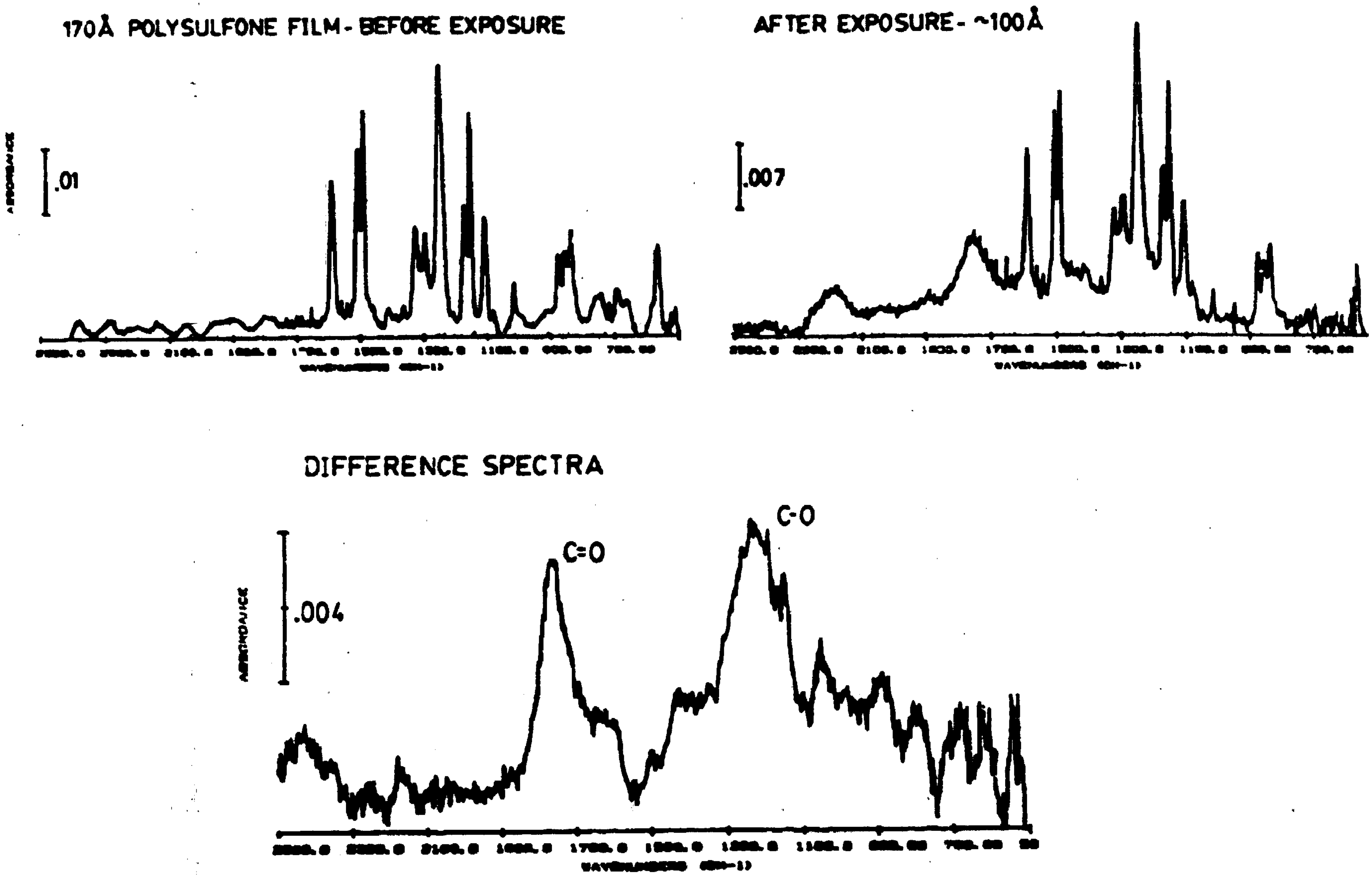
OF POOR QUALITY



REFLECTANCE IR SPECTRA OF POLYSULFONE FILMS BEFORE AND AFTER EXPOSURE TO OXYGEN PLASMA—WEBSTER & WIGHTMAN.

SUMMARY

XPS (ESCA) IS A SENSITIVE SURFACE ANALYTICAL TECHNIQUE PAR EXCELLENCE GIVING ATOMIC COMPOSITION. THE TECHNIQUE

- Δ IS MODERATELY FAST
  - Δ IS SAMPLE FORGIVING
- Δ HAS GOOD SENSITIVITY FOR ALL ELEMENTS
  - Δ DOES DISCRIMINATE BETWEEN VALENCE STATES
- Δ DOES MINIMAL SAMPLE DAMAGE

AUGER ELECTRON SPECTROSCOPY IS A USEFUL ANCILLARY TECHNIQUE FOR NON-POLYMERIC SUBSTRATES GIVING DEPTH PROFILES

INFRARED SPECTROSCOPY IS ANOTHER COMPLEMENTARY TECHNIQUE FOR POLYMER SUBSTRATES GIVING GROUP IDENTIFICATION

NASA
LONG DURATION EXPOSURE FACILITY

ATOMIC OXYGEN

BRUCE A. BANKS

NASA - LEWIS RESEARCH CENTER
MEMBER, MSIG

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

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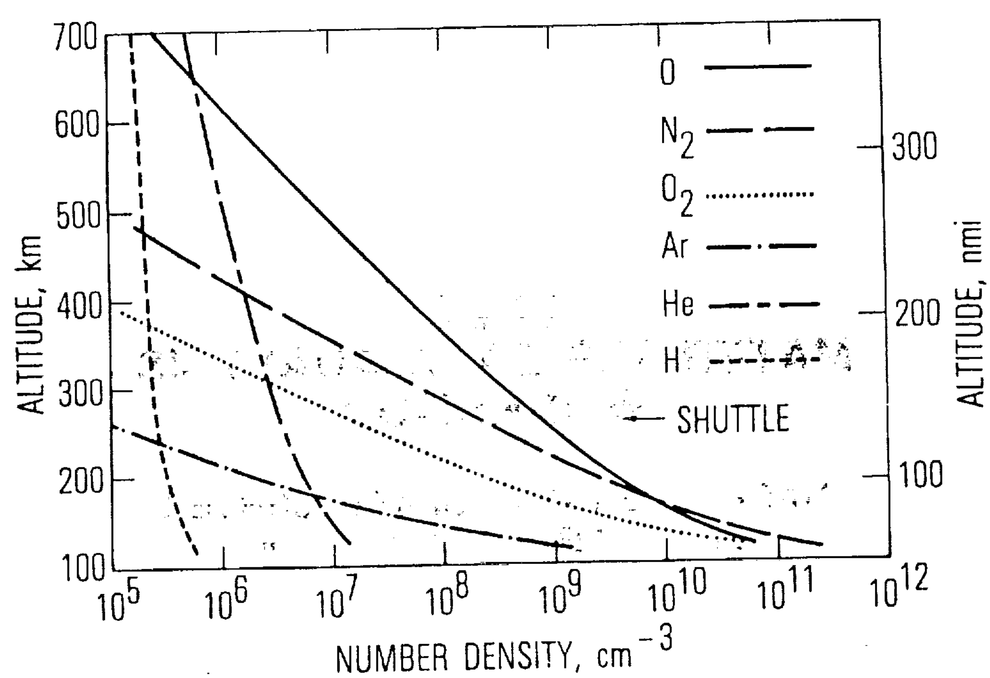
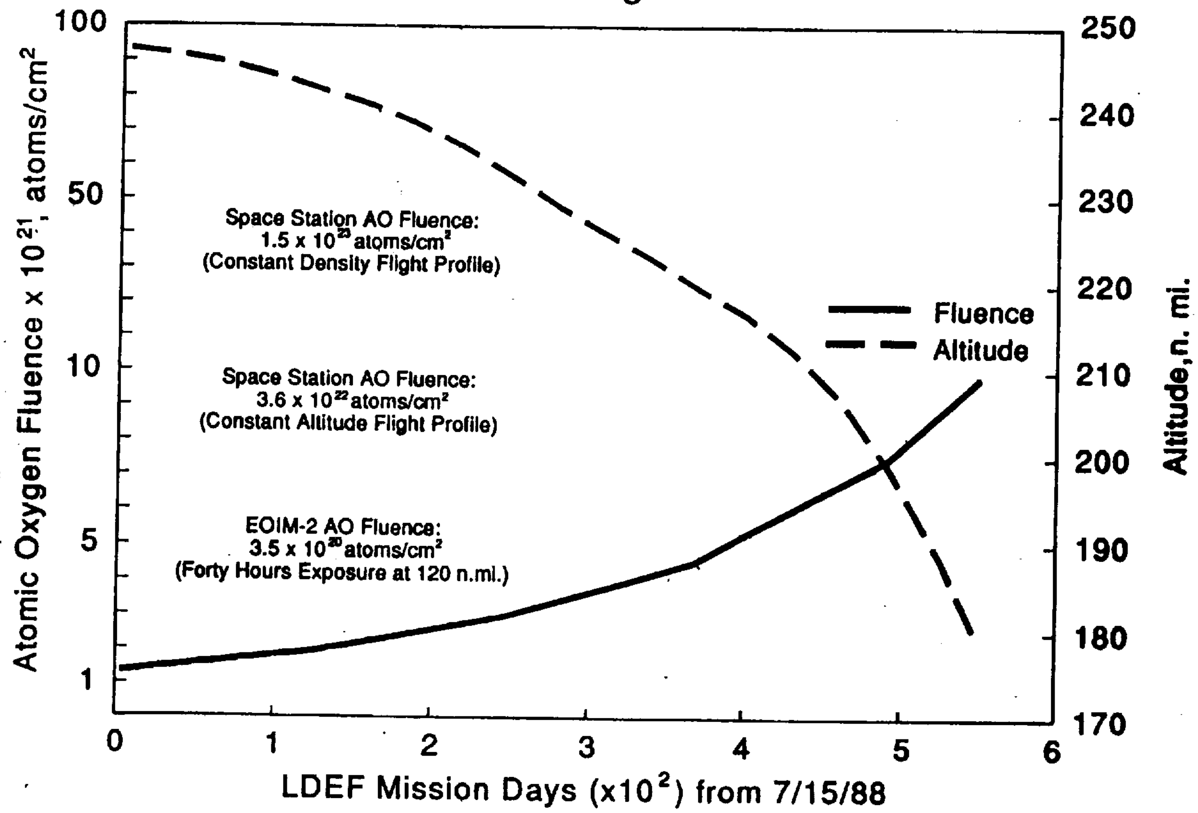
ATOMIC OXYGEN INTERACTION WITH MATERIALS ON LDEF

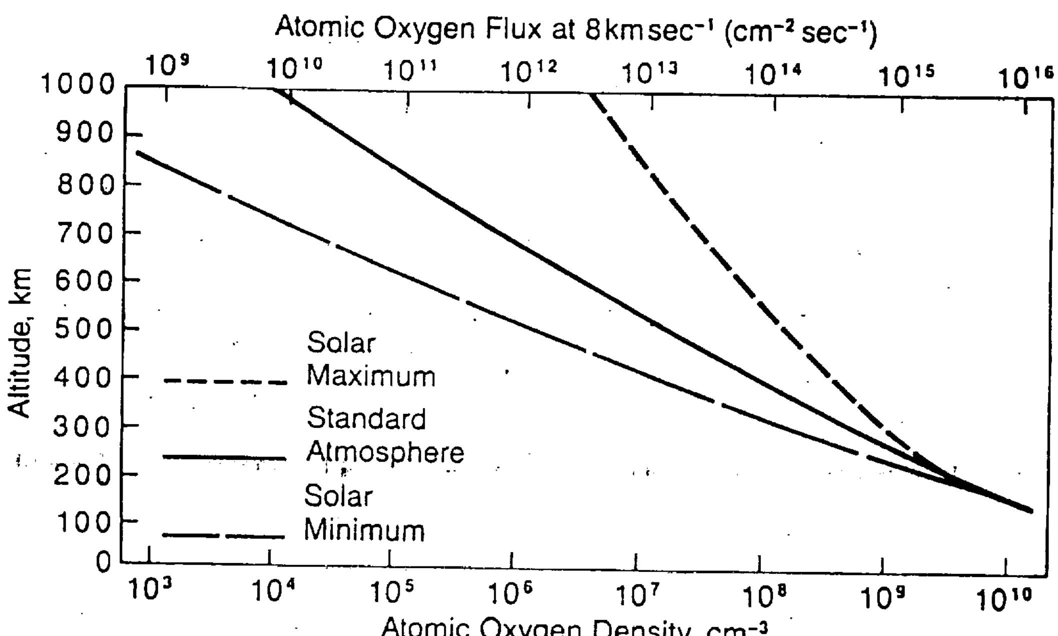
Bruce A. Banks
NASA Lewis Research Center
(216) 433-2308 FTS 297-2308

LOW EARTH ORBITAL ENVIRONMENT



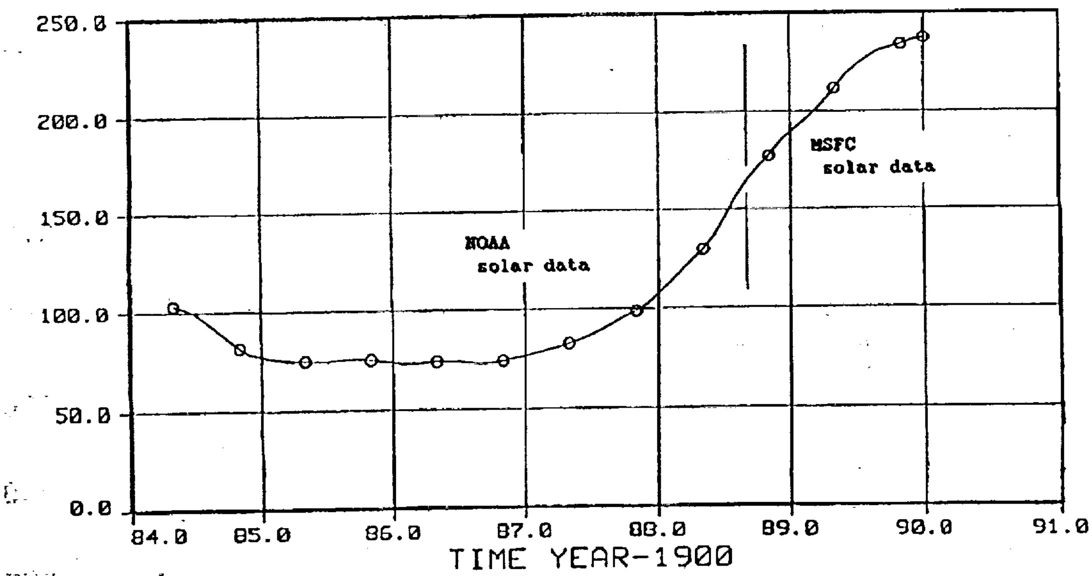
LDEF (Long Duration Exposure Facility) Atomic Oxygen Fluence on Forward-Facing Surfaces



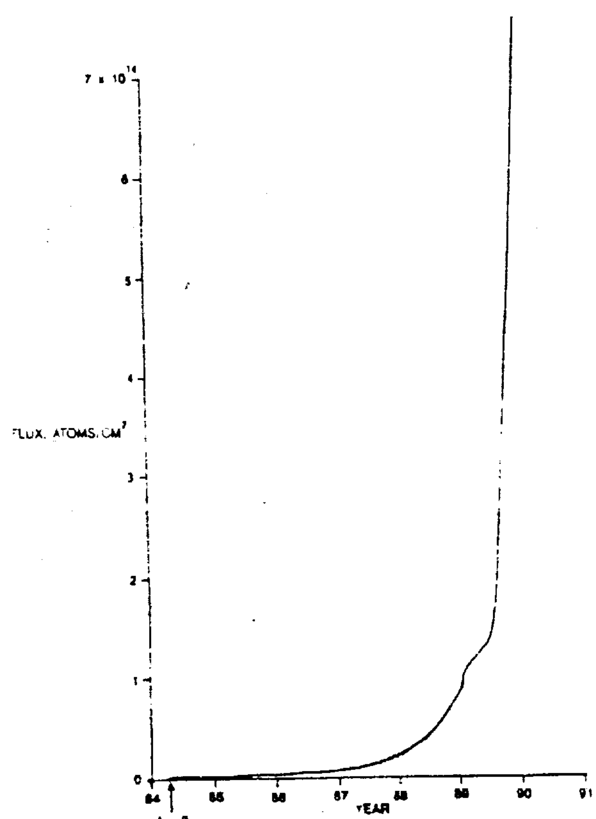


Atmospheric atomic oxygen density and flux in low Earth orbit.

F10.7 SOLAR FLUX



LDEF FLUX



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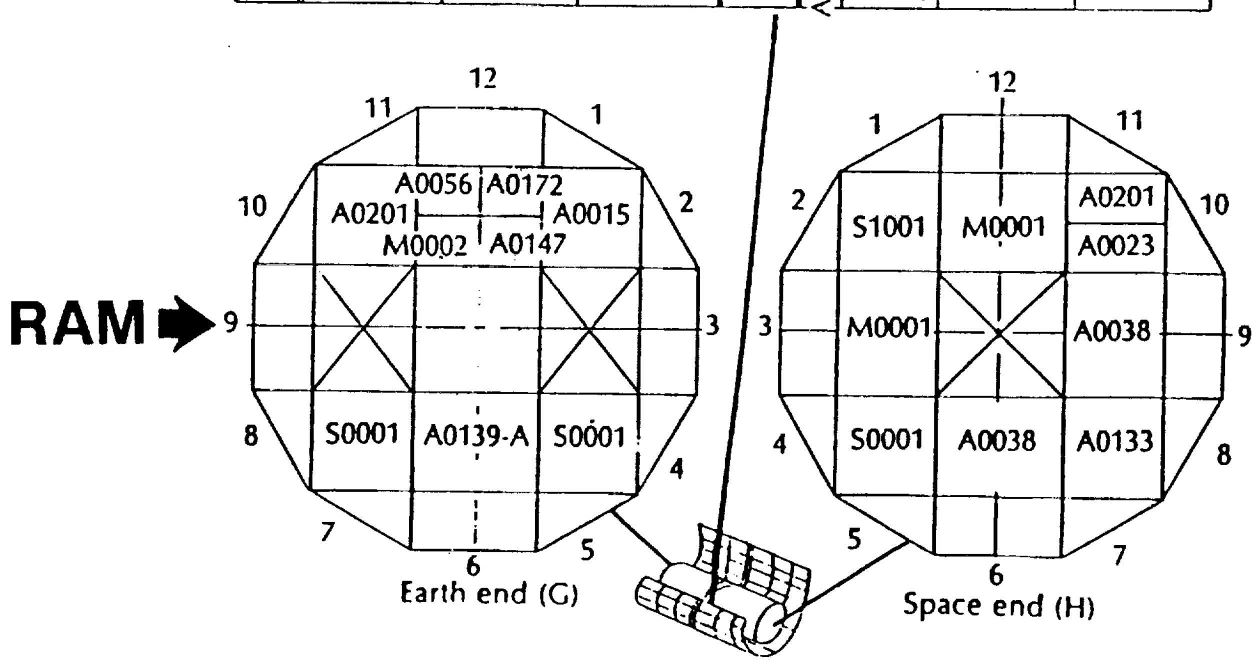
LDEF EXPERIMENT INTEGRATION MODEL.

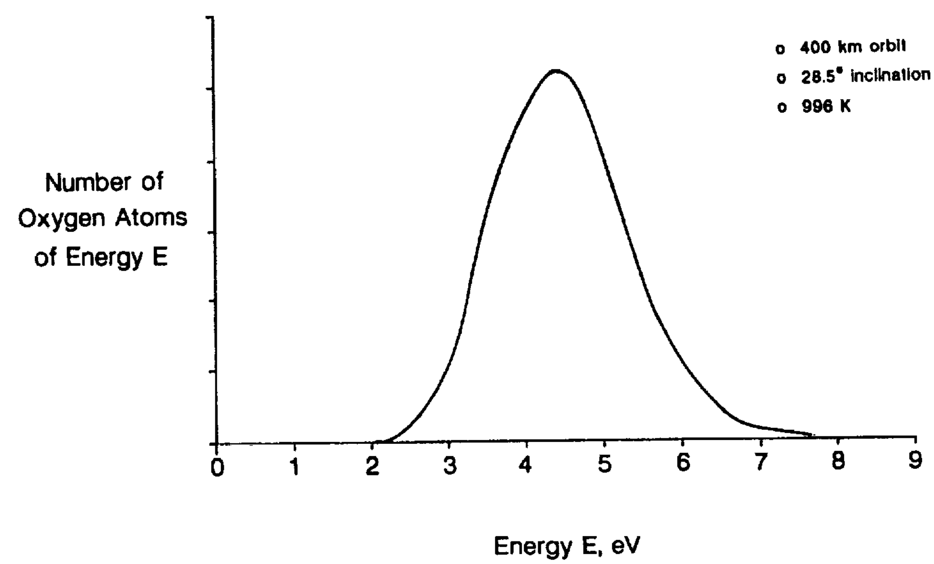
Bay / Row	A	B	C		D	E	F
1	A0175	S0001	Grapple		A0178	S0001	S0001
2	A0178	S0001	A0015 A0187 M0006		A0189 A0172 S0001	A0178	P0004 P0006
3	A0187	A0138	A0023 A0034 A0114 A0201		M0003 M0002	A0187 S1002	S0001
4	A0178	A0054	S0001		M0003	S0001	A0178
5	S0001	A0178	A0178	P0003 P0005	A0178	S0050 A0044 A0135	S0001
6	S0001	S0001	A0178		A0201 S0001	A0023 S1006 S1003 M0002	A0038
7	A0175	A0178	S0001		A0178	S0001	S0001
8	A0171	S0001 A0056 A0147	A0178		M0003	A0187	M0004
9	S0069	S0010 A0134	A0023 A0034 A0114 A0201		M0003 M0002	S0014	A0076
10	A0178	S1005	Grapple		A0054	A0178	S0001
11	A0187	S0001	A0178		A0178	S0001	S0001
12	S0001	A0201	S0109		A0023 A0019 A0180	A0038	S1001

Trailing edge (rows 1–3)

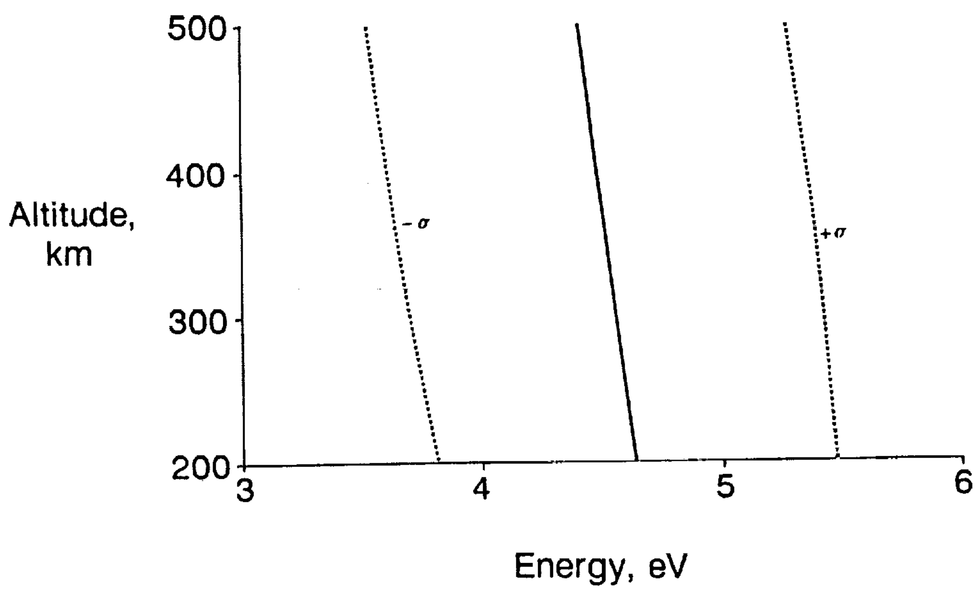
Leading edge (rows 7–9)



LOW EARTH ORBITAL
ATOMIC OXYGEN ENERGY DISTRIBUTION



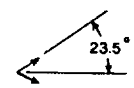
ATOMIC OXYGEN RAM ENERGY



ATOMIC OXYGEN IMPACT VELOCITY RELATIVE TO SPACECRAFT SURFACES
(AT 333 km = 180 nmi)

	Magnitude km/sec
o Orbital Ram Velocity, $\vec{v}_o$	7.9
o Atmospheric Rotation Velocity, $\vec{v}_A$	0.49
o Random Maxwellian Thermal Velocity, $\vec{v}_T$	0.41 (avg)

o Orbital Ram Velocity, $\vec{v}_o$ — 7.9

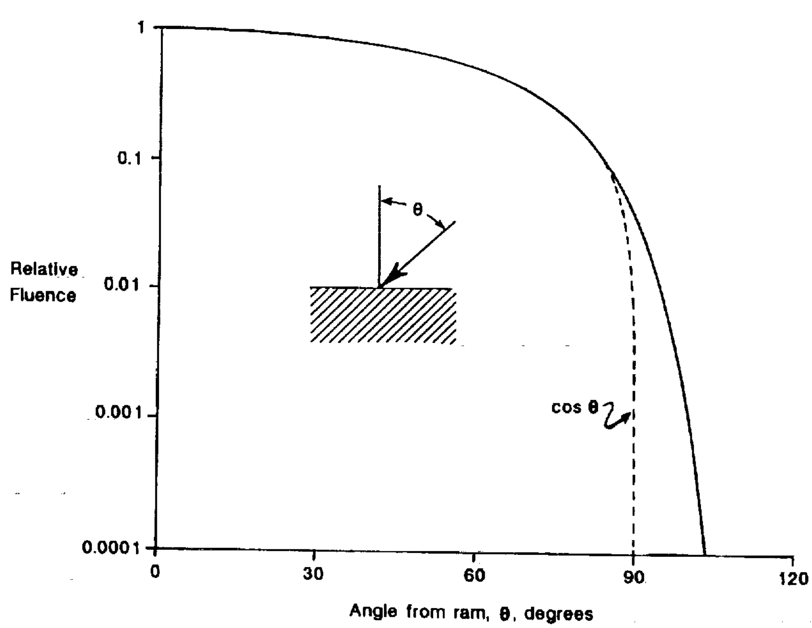


o Atmospheric Rotation Velocity, $\vec{v}_A$ — 0.49
  - Magnitude and direction varies around orbit due to inclination, latitude and altitude
  - Reduces ram energy by 11%
  - Reduces normal incident ram fluence by 5.6%
  - Fluence effects cancel to first order on surfaces 90° to ram

o Random Maxwellian Thermal Velocity, $\vec{v}_T$ — 0.41 (avg)
  - Maxwellian tail allows atomic oxygen impact on surfaces >90° to ram

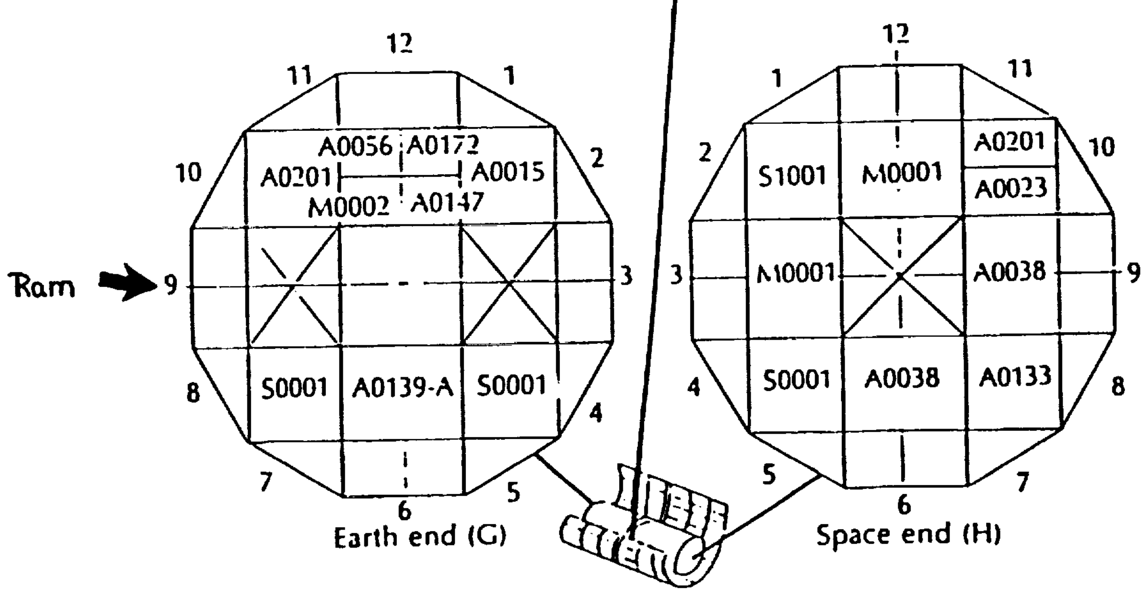
o Total Impact Velocity, $\vec{v}_T = \vec{v}_O + \vec{v}_A + \vec{v}_T$
  - Evidence of atomic oxygen attack on LDEF at 105° to ram

ATOMIC OXYGEN FLUENCE DEPENDENCE ON ARRIVAL ANGLE

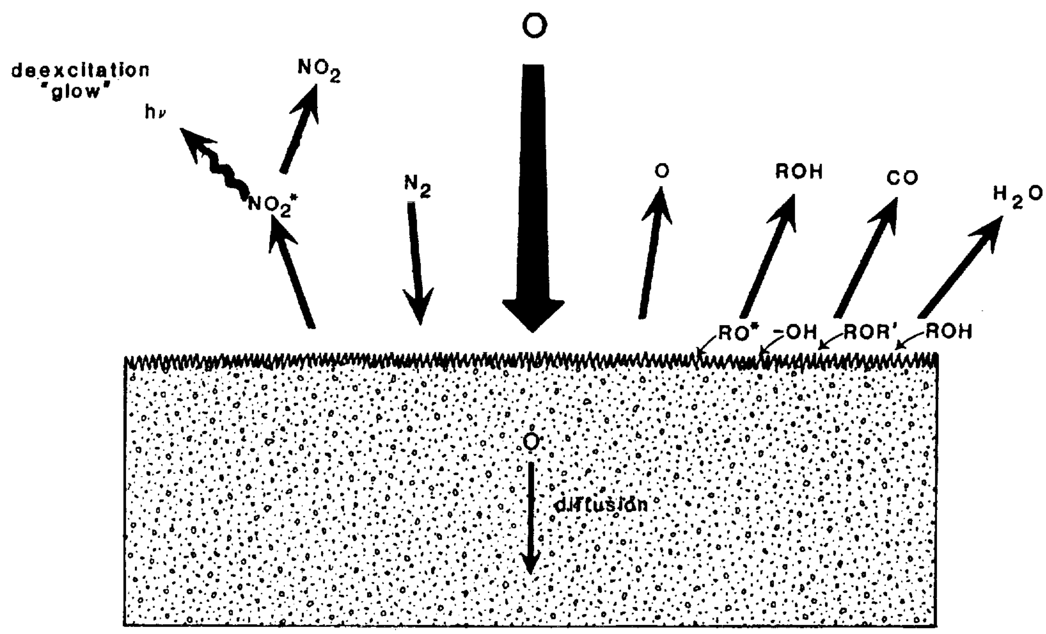


CALCULATED ATOMIC OXYGEN FLUENCE BY SPACECRAFT ROW.

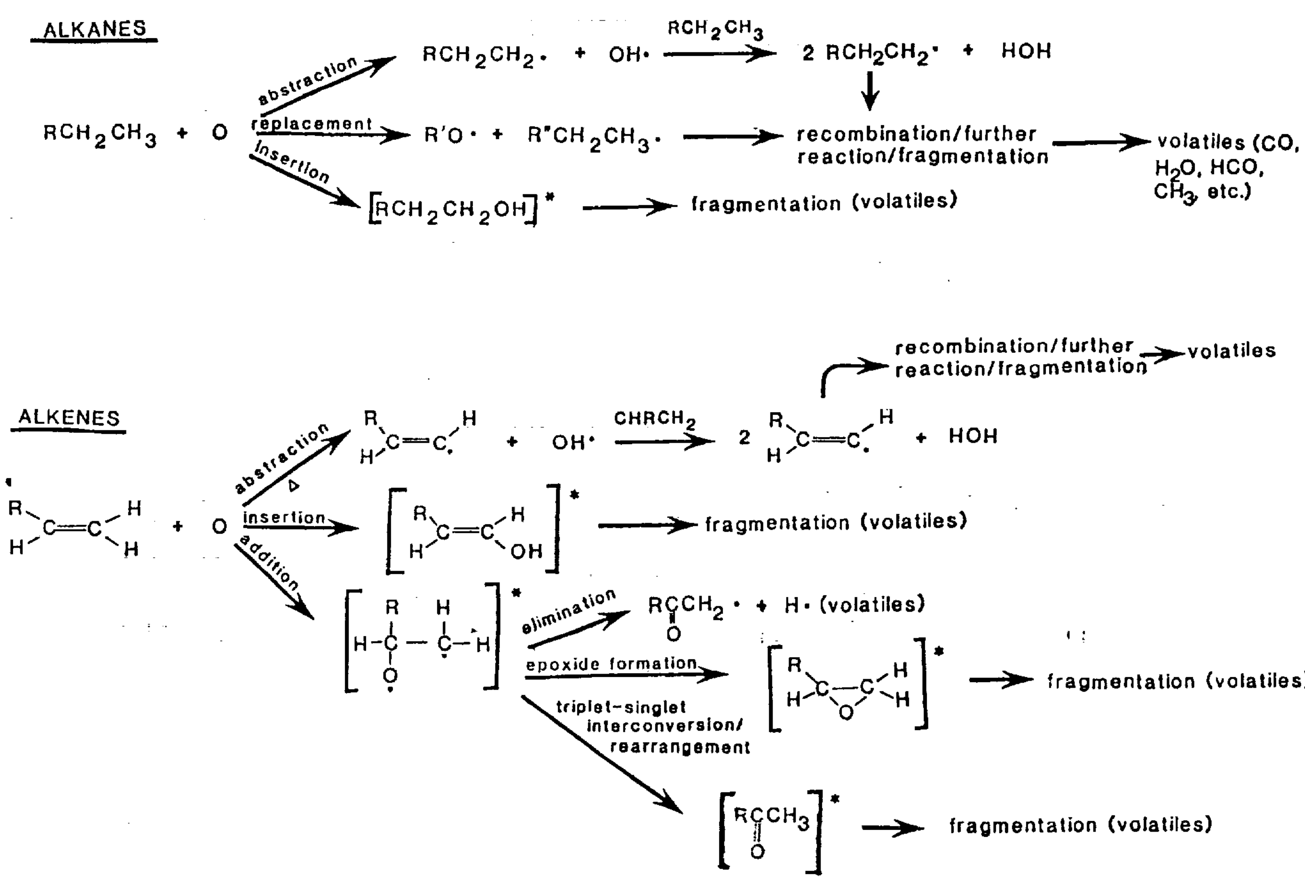
	Row \ Bay	A	B	C		D	E	F	Atomic Oxygen fluence, atoms/cm²
Trailing edge	1	A0175	S0001	Grapple		A0178	S0001	S0001	0
Trailing edge	2	A0178	S0001	A0015, A0187, M0006		A0189, A0172, S0001	A0178	P0004, P0006	6.5×10^{17}
Trailing edge	3	A0187	A0138	A0023, A0034, A0114, A0201		M0003, M0002	A0187, S1002	S0001	5.7×10^{17}
	4	A0178	A0054	S0001		M0003	S0001	A0178	0
	5	S0001	A0178	A0178	P0003, P0005	A0178	S0050, A0044, A0135	S0001	0
	6	S0001	S0001	A0178		A0201, S0001	A0023, S1006, S1003, M0002	A0038	3.9×10^{19}
Leading edge	7	A0175	A0178	S0001		A0178	S0001	S0001	4.0×10^{21}
Leading edge	8	A0171	S0001, A0056, A0147	A0178		M0003	A0187	M0004	8.3×10^{21}
Leading edge	9	S0069	S0010, A0134	A0023, A0034, A0114, A0201		M0003, M0002	S0014	A0076	1.0×10^{22}
	10	A0178	S1005	Grapple		A0054	A0178	S0001	9.7×10^{21}
	11	A0187	S0001	A0178		A0178	S0001	S0001	6.4×10^{21}
	12	S0001	A0201	S0109		A0023, A0019, A0180	A0038	S1001	1.4×10^{21}



ATOMIC OXYGEN SURFACE INTERACTION PROCESSES



ATOMIC OXYGEN REACTION MECHANISMS



ATOMIC OXYGEN EROSION YIELDS OF VARIOUS MATERIALS

MATERIAL	EROSION YIELD, 10^{-24} CM^3/ATOM
Kapton H polyimide	3.0
Mylar polyester	2.7 - 3.9
Polyethylene	3.3 - 3.7
Epoxy	1.7
Polycarbonate	2.9 - 6.0
Polystyrene	1.7
Polysulfone	2.4
Urethane (black, conductive)	0.3
Silver	10.5
Carbon	0.9 - 1.7
Chemglaze Z306 (flat, black)	0.35
FEP Teflon	0.037
Aluminum	0.0
Copper	0.0
Gold	0.0
Platinum	0.0
SiO_2	0.0

MATERIAL THICKNESS LOSS FROM OXIDATION BY ATOMIC OXYGEN

μm / mils

	ROW				EROSION YIELD
	9	8 & 10	7 & 11	6 & 12	cm^3/atom
Fluence, atoms/cm^2	1.05×10^{22}	9.08×10^{21}	5.25×10^{21}	4.1×10^{20}	
MATERIAL					
Polyethylene	347 / 13.6	300 / 11.8	173 / 6.8	13.6 / 0.54	3.3×10^{-24}
Kapton polyimide	315 / 12.4	272 / 10.7	158 / 6.2	12.4 / 0.49	3.0×10^{-24}
Epoxy	179 / 7.0	154 / 6.1	89 / 3.5	7.0 / 0.26	1.7×10^{-24}
Graphite	126 / 5.0	109 / 4.3	63 / 2.5	4.9 / 0.19	1.2×10^{-24}
FEP Teflon	3.9 / 0.15	3.4 / 0.13	1.9 / 0.08	0.15 / 0.01	3.7×10^{-26}

EROSION YIELDS OF VARIOUS MATERIALS EXPOSED TO ATOMIC OXYGEN IN LOW EARTH ORBIT

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
Aluminum (150 Å)	0.0	1
Aluminum-coated Kapton	0.01	2
Aluminum-coated Kapton	0.1	2
Al_2O_3	< 0.025	3
Al_2O_3 (700 Å) on Kapton H	< 0.02	4
Apiezon grease 2 μm	> 0.625	5
Aquadag E (graphite in an aqueous binder)	1.23	6
Carbon	1.2	7, 1, 8, 9
Carbon (various forms)	0.9 - 1.7	10
Carbon/Kapton 100XAC37	1.5	11
401-C10 (flat black)	0.30	12
Chromium (123 Å)	partially eroded	14
Chromium (125 Å) on Kapton H	0.006	15, 16
Copper (bulk)	0.0	17
Copper (1,000 Å) on sapphire	0.007	15, 16

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
Copper (1,000 Å)	0.0064	14
Diamond	0.021	17
Electrodag 402 (silver in a silicone binder)	0.057	6
Electrodag 106 (graphite in an epoxy binder)	1.17	6
Epoxy	1.7	10, 16
Fluoropolymers:		
FEP Kapton	0.03	18
Kapton F	< 0.05	6
Teflon, FEP	0.037	5
Teflon, FEP	< 0.05	10
Teflon, TFE	< 0.05	10, 6
Teflon, FEP and TFE	0.0 and 0.2	15, 19
Teflon, FEP and TFE	0.1	15
Teflon	0.109	19
Teflon	0.5	15
Teflon	0.03	15
Teflon	< 0.03	9

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
Gold (bulk)	0.0	17
Gold	appears resistant	20
Graphite Epoxy:		
1034 C	2.1	10
5208/T300	2.6	10
GSFC Green	0.0	1
HOS-875 (bare and preox)	0.0	1, 26
Indium Tin Oxide	0.002	15, 16
Indium Tin Oxide/Kapton (aluminized)	0.01	2
Iridium Film	0.0007	17
Lead	0.0	1, 26
Magnesium	0.0	1, 26
Magnesium Fluoride on glass	0.007	15, 16
Molybdenum (1,000 Å)	0.0056	4
Molybdenum (1,000 Å)	0.006	15, 16
Molybdenum	0.0	1, 26
Mylar	3.4	10
Mylar	2.3	15, 19

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
Mylar	3.9	15, 19, 9
Mylar	1.5 - 3.9	15
Mylar A	3.7	18
Mylar A	3.4	21, 6
Mylar A	3.6	6
Mylar D	3.0	6
Mylar D	2.9	21
Mylar with Antiox	heavily attacked	22
Nichrome (100 Å)	0.0	1
Nickel film	0.0	17
Nickel	0.0	8, 26
Niobium film	0.0	17, 1
Osmium	0.026	10
Osmium	heavily attacked	20
Osmium (bulk)	0.314	17
Parylene, 2.5 μm	eroded away	22
Platinum	0.0	1, 26
Platinum	appears resistant	20

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
Platinum film	0.0	17
Polybenzimidazole	1.5	10, 7
Polycarbonate	6.0	8
Polycarbonate resin	2.9	17
Polyester - 7% Polysilane/93% Polyimide	0.6	10
Polyester	heavily attacked	10, 22
Polyester with Antiox	heavily attacked	10, 22
Polyester (Pen-2,6)	2.9	23
Polyethylene	3.7	10, 21, 16, 15
Polyethylene	3.3	18, 6
Polyimides:		
BJPIPSX-9	0.28	23
BJPIPSX-9	0.071	24
BJPIPSX-11	0.56	23
BJPIPSX-11	0.15	24
BTDA-Benzidene	3.08	23
BTDA-DAF	2.82	23
BTDA-DAF	0.8	24

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
BTDA-mm-DDSO2	2.29	23
BTDA-mm-MDA	3.12	23
BTDA-pp-DABP	2.91	23
BTDA-pp-ODA	3.97	23
I-DAB	1.80	23
Kapton (black)	1.4 - 2.2	15, 12
Kapton (TV blanket)	2.0	15
Kapton (TV blanket)	2.04	19
Kapton (OSS - 1 blanket)	2.55	15
Kapton (OSS - 1 blanket)	2.5	15
Kapton H	3.0	10, 15, 19, 4, 6, 9
Kapton H	2.4	15, 19
Kapton H	2.7	15, 18
Kapton H	1.5 - 2.8	15
Kapton H	2.0	18
Kapton H	3.1	18
Kapton (uncoated)	0.1, 0.06	2
ODPA-mm-DABP	3.53	23

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
PEN-2.6	2.90	23
PMDA-pp-DABP	3.82	23
PMDA-pp-MDA	3.17	23, 24
PMDA-pp-ODA	4.66	23
Polymethylmethacrylate	3.1	16
7% Polysilane/93% Polyimide	0.6	10
25% Polysiloxane, 75% Polyimide	0.3	10
25% Polysiloxane-Polyimide	0.3	9
Polystyrene	1.7	10, 16, 9
Polysulfone	2.4	10, 16
Polyvinylidene Fluoride	0.6	9
Pyrone:		
PMDA-DAB	2.5	23
S-13-GLO, white	0.0	12
SiO_2 (650 Å) on Kapton H	< 0.0008	4
SiO_2 (650 Å) with ≤ 4% PTFE	< 0.0008	4
SiOx/Kapton (aluminized)	0.01	2

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
Silicones:		
DC1-2577	0.055	21
DC1-2755-coated Kapton	0.05	15
DC1-2775-coated Kapton	< 0.5	15
DCG-1104	0.0515	20
Grease 60 μm	intact but oxidized	25
RTV-560	0.443	21
RTV-615 (black, conductive)	0.0	20
RTV-615 (clear)	0.0625	5
RTV-670	0.0	1
RTV-S695	1.48	11
RTV-3145	0.128	1
T-650-coated Kapton	< 0.5	15
Siloxane Polyimide (25% Sx)	0.3	7
Siloxane Polyimide (7% Sx)	0.6	7
Silver	10.5	5
Tantalum	appears resistant	20
Tedlar	3.2	10

MATERIAL	EROSION YIELD, x 10^{-24} cm^3/ATOM	REFERENCE
Tedlar (clear)	1.3 and 3.2	15
Tedlar (clear)	3.2	18, 6
Tedlar (white)	0.4 and 0.6	15
Tedlar (white)	0.05	15
TiO_2, (1,000 Å)	0.0067	5
Trophet 30 (bare and preox)	0.0	1, 26
Tungsten	0.0	8, 26
Tungsten Carbide	0.0	8
YB-71 (ZOT)	0.0	7
Z302 (glossy black)	3.9	26

EROSION YIELD TABLE
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20. Goddard Space Flight Center

21. Johnson Space Center

22. Washington University

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26. Whitaker, A. F., Little, S. A., Harwell, R. J., Griner, D. B., and DeHaye, R. F. NASA Marshall Space Flight Center - "Orbital Atomic Oxygen Effects on Thermal Control and Optical Materials: STS-8 Results." AIAA 23rd Aerospace Sciences Meeting, January 14-17, 1985.

EFFECT OF LEO ATOMIC OXYGEN ON OPTICAL PROPERTIES OF MATERIALS

Material	Change in Optical Properties due to A/O			Reference
	Solar Absorptance	Emittance	Reflectance	
Ag/FEP	0.006	0.0	-	I
Al/Al_2O_3	-0.006	0.0	-	I
$AlMgF_2$	-	-	0.0	B
Al_2O_3	0.0	-	0.0	E
Al_2O_3/Al(He)	-0.005	0.0	-	I
Al_2O_3/Al(Le)	-0.006	0.0	-	I
Aluminized FEP Teflon, second surface mirror (0.025 mm thick)	0.05	-0.19	-	O
Al Kapton	0.048	0.018	-	K
Al Kapton	-0.062	-0.007	-	K
Aluminized Kapton, second surface mirror, uncoated (0.052 mm thick)	-0.23	-0.59	-	O
Aluminum (150 Å)	0.0	0.0	0.0	B
Aluminum (chromic acid oxidized)	0.0	0.0	0.0	F
Black, carbon-filled PTFE impregnated fiberglass (0.127 mm thick)	-0.16	-0.05	-	O

Material	Change in Optical Properties due to A/O Solar Absorptance	Emittance	Reflectance	Reference
Black Cr on Cr on Mo	-	-	0.20*	N
Black Ir on Mo	-	-	-0.75	N
Black Rh on Mo (matte)	-	-	-0.25	N
Black Rh on Mo (specular)	-	-	-0.50	N
Bostic 463-14	0.01	0.0	-	J
Chemglaze A276 (w/modifiers)	-0.006 to 0.016	0.02	-	A
Chemglaze A276 (white)	-0.005	0.03	-0.039	B, C
Chemglaze Z004	0.01	0.0	-	J
Chemglaze Z302 (glossy, black)	0.011	-	-0.01	D
Chromium (123 Å)	0.0	0.0	0.0	E
FEP Teflon with silver undercoat	0.006	0.0	-	
GE-PD-224	0.0	0.0	-	J
GSFC (green)	-0.002	-	-	L
Indium Tin Oxide coated Kapton H with aluminized backing	0.006	0.004	-	K
ITO ring	0.006	0.004	-	K
ITO (S) Sheldahl, black/Kapton (sputtered)	0.01	0.0	-	J

Material	Change in Optical Properties due to A/O Solar Absorptance	Emittance	Reflectance	References
ITO (VD) Sheldahl, black/Kapton (vacuum deposited)	0.0	0.0	-	J
Ir foil on Al	-	-	0.0	N
KAT glass	-	-	-0.05 to 0.1**	N
Kapton with aluminized backing	0.048	0.018	-	K
Kapton H (aluminized)	0.041	-	-0.051	
Mo (polished)	-	-	0.0	N
Nickel	0.005	0.0	-	I
Ni/SiO_2	-0.004	0.0	-	I
Polyurethane A-276	0.023	-	0.01	I
Polyurethane A276 glossy white	-0.002	-	0.2	L
Polyurethane A276 with 0.5-1 mil OI 650 overcoat	0.002	-	-0.3	L
Rh foil on Al	-	-	0.0	N
S13 - GLO	-0.005	0.0	-	I
SiO_2 (650 A on Kapton H)	0.0	0.0	0.0	E
SiO_x ring	0.039	-0.002	-	K
Silicate MS-74	0.01	0.0	-	H, A

Material	Change in Optical Properties due to A/O Solar Absorptance	Emittance	Reflectance	Reference
Silicone (black, conductive)	0.0	-0.005	-	A
Silicone RTV-602/Z302	-0.004	-	-	
Silicone RTV-650+TiO_2	0.001	-0.01	-	A
Silicone RTV-670	-0.004	-	0.001	B
Silicone S1023	-0.022	-0.02	-	G
Siloxane coating, RTV 602/ 0 on aluminized Kapton, second surface mirror substrate (0.008 mm thick coating) (0.052 mm thick Kapton)	0.0	0.0	-	O
Ti/"tiodized" alloy	-	-	-0.25***	N
Ti/"tiodized" CP	-	-	-0.40****	N
Urethane (black, conductive)	0.042	0.55	-	A
Urethane inhib A-276	0.0	0.01	-	A
YB-71	0.004	0.0	-	I
Z302 glossy black	0.043	-	-4.3	L
Z302 with MN41-1104-0 overcoat	-0.002	-	-	M
Z302 with OI 651 overcoat	0.0	-	-	M
Z302 with OI 650 overcoat	-0.001	-	0.1	L
Z302 with RTV-602 overcoat	-0.004	-	-	L

Material	Change in Optical Properties due to A/O Solar Absorptance	Emittance	Reflectance	Reference
Z302 with RTV-670 overcoat	-0.004	-	0.4	L
Z306	0.022	0.0	-	I
Z306 (flat black)	0.028	-	-	L
Z853, glossy yellow with MN41-1104-0 overcoat	0.011	-	-	M
Z853, yellow	-0.034	-	-	L
401 - C10 flat black	0.005	-	-	L

NOTE:

* More reflective as a result of the exposed Mo substrate.
** Low absolute reflectance (-0.5 to 1%)
*** Contrast in different spectra between STS-8 and control. Possible aging effects on controls.
**** Aging effects similar in STS-8 and control. No exposure effect.

EFFECT OF LEO ATOMIC OXYGEN ON
OPTICAL PROPERTIES OF MATERIALS

REFERENCES

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B. NASA Marshall Space Flight Center

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G. Martin Marietta

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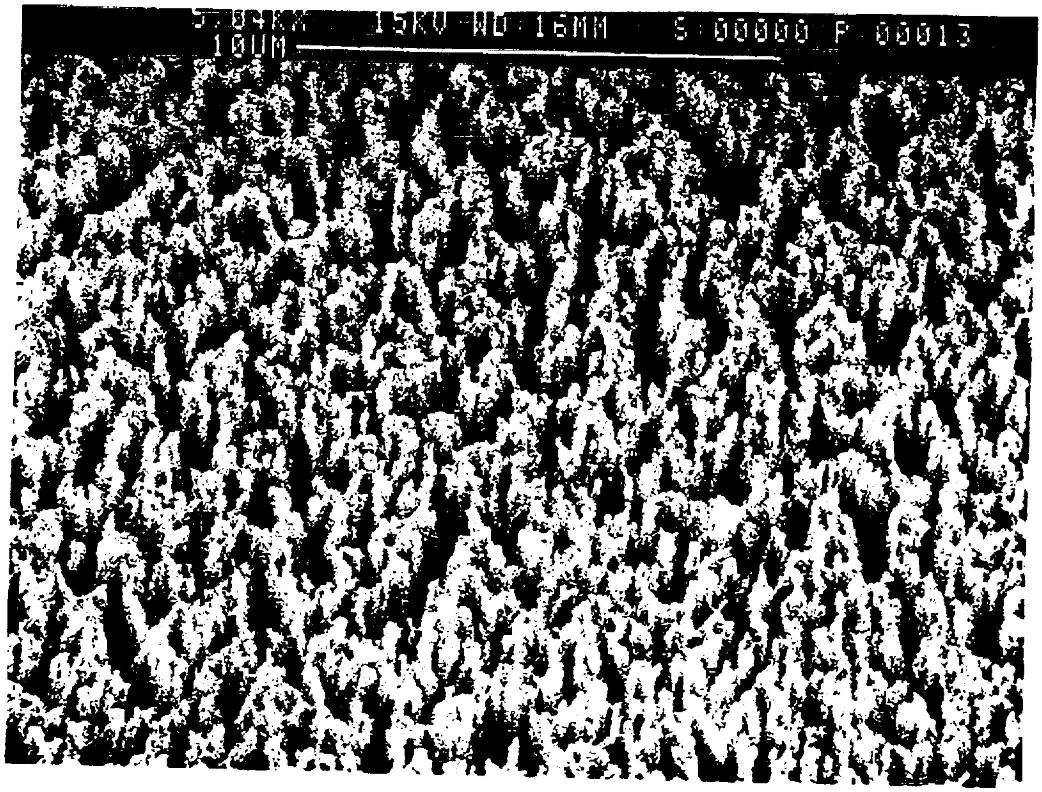
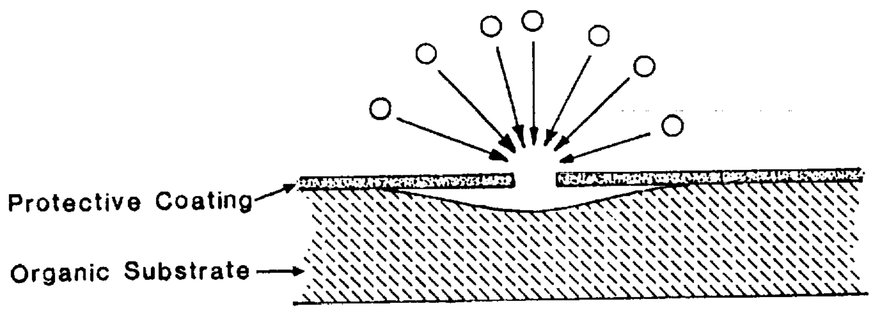
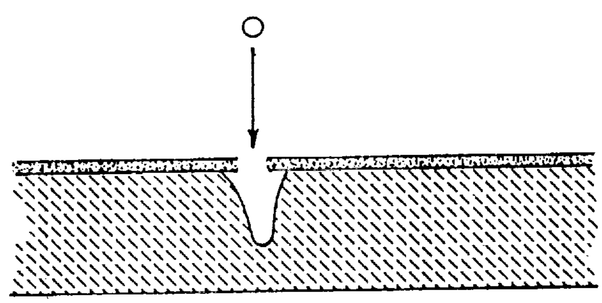
ATOMIC OXYGEN TEXTURED FEP TEFLON BY DIRECTED BEAM EXPOSURE AT UNIVERSITY OF TORONTO.



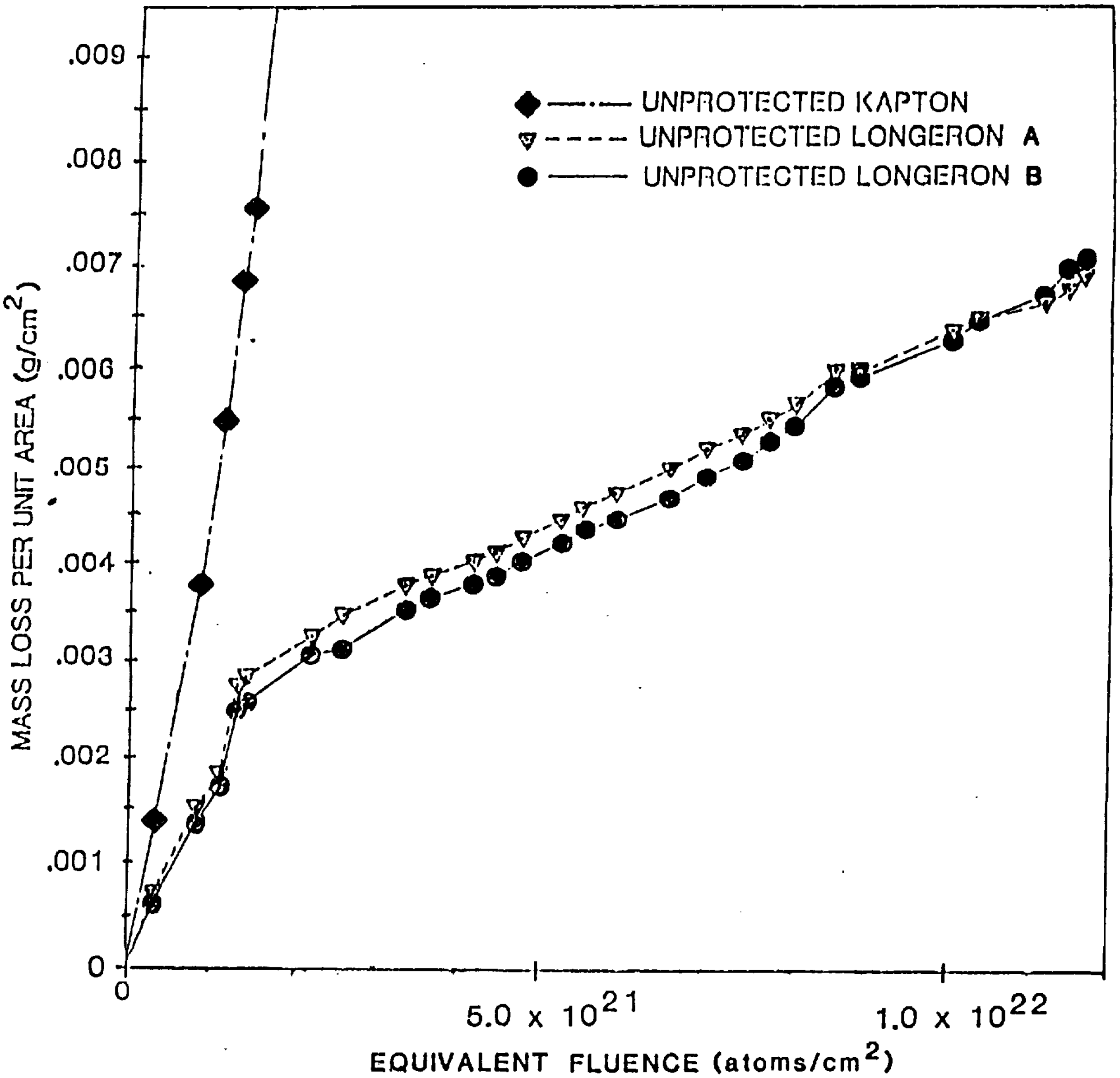
ORIGINAL PAGE IS
OF POOR QUALITY



ATOMIC OXYGEN IN PLASMA ASHERS.

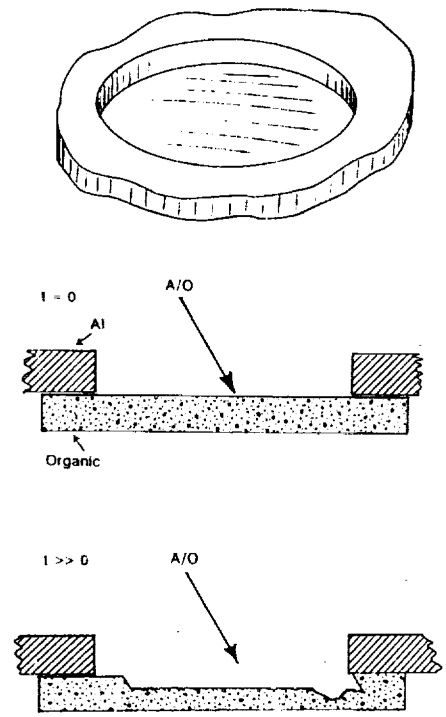


ATOMIC OXYGEN EXPOSURE BY DIRECTED BEAMS.

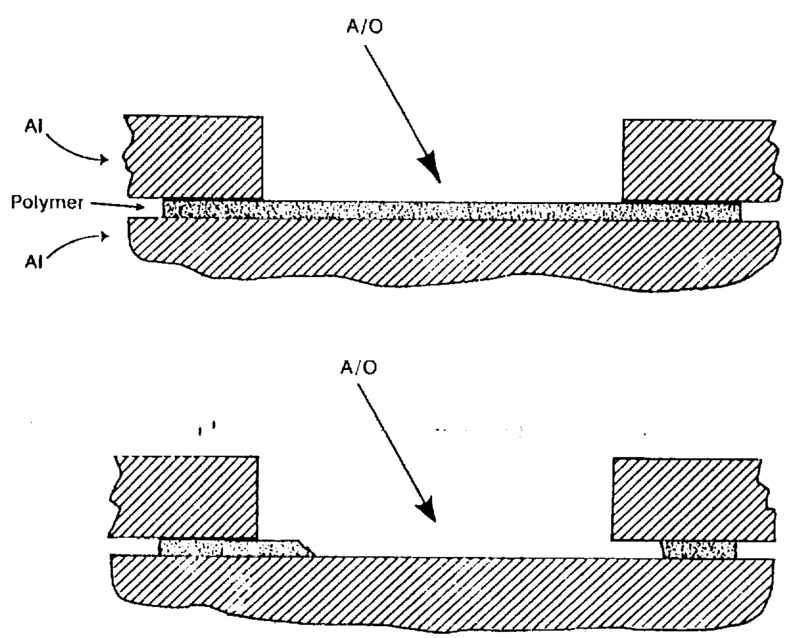


MASS LOSS OF FIBERGLASS EPOXY COMPOSITES AND KAPTON AS A FUNCTION OF EFFECTIVE ATOMIC OXYGEN FLUENCE (KAPTON BASED).

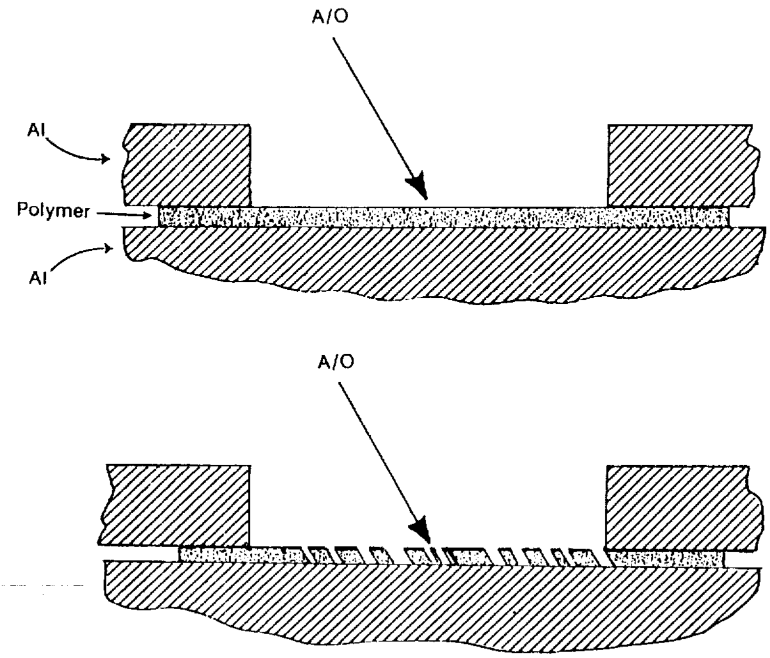
ANTICIPATED SURFACE PROFILE FOR THICK ORGANIC LDEF SAMPLES.



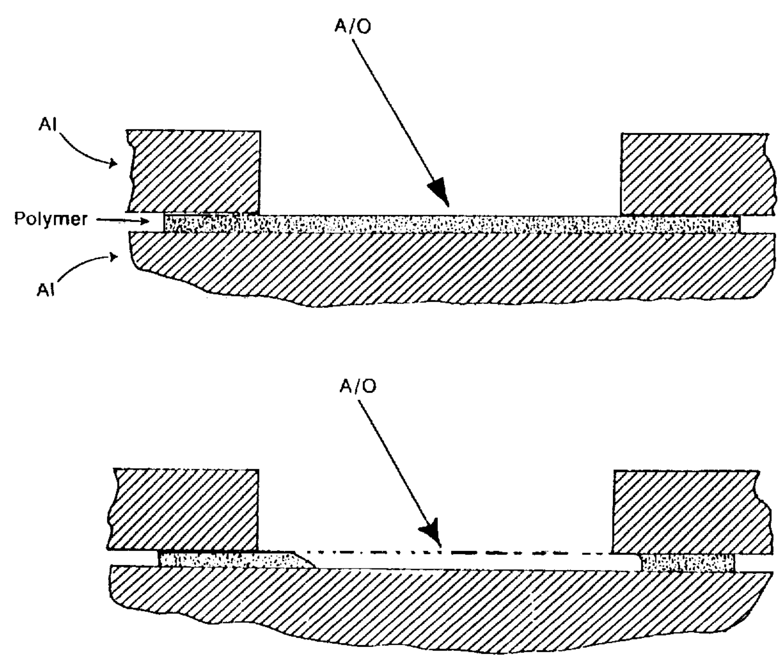
THIN POLYMER FILMS (<5 mils)



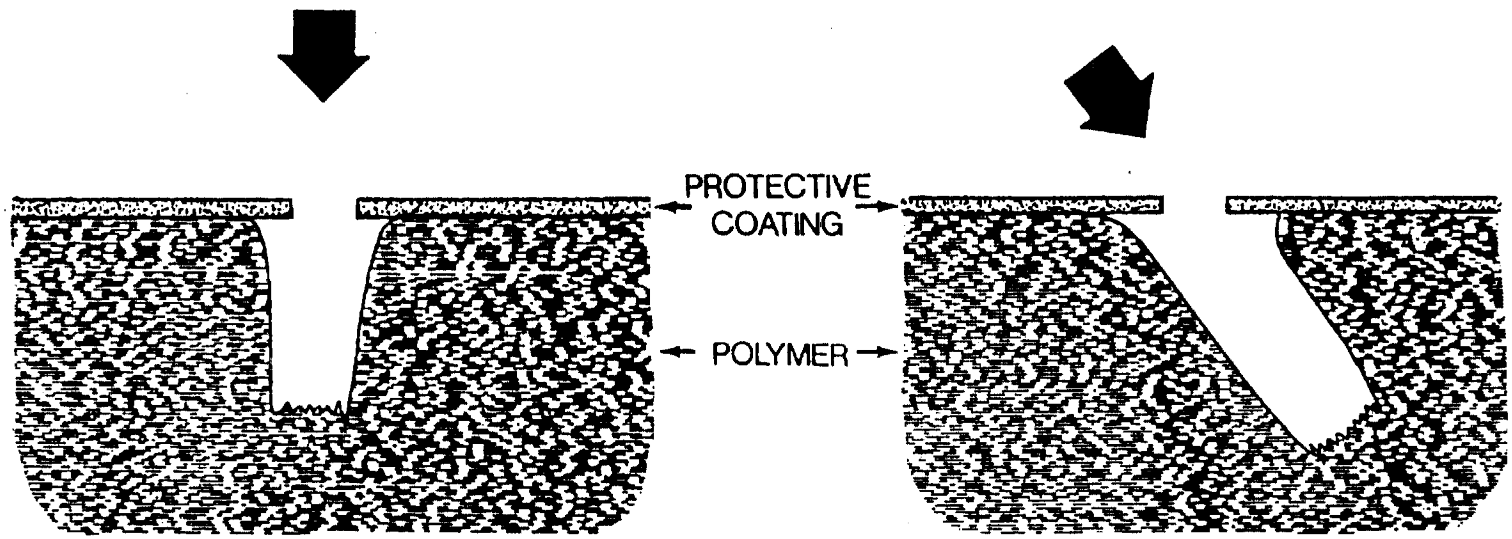
THIN POLYMER FILMS (<5 mils)
WITH ATOMIC OXYGEN PROTECTIVE COATINGS



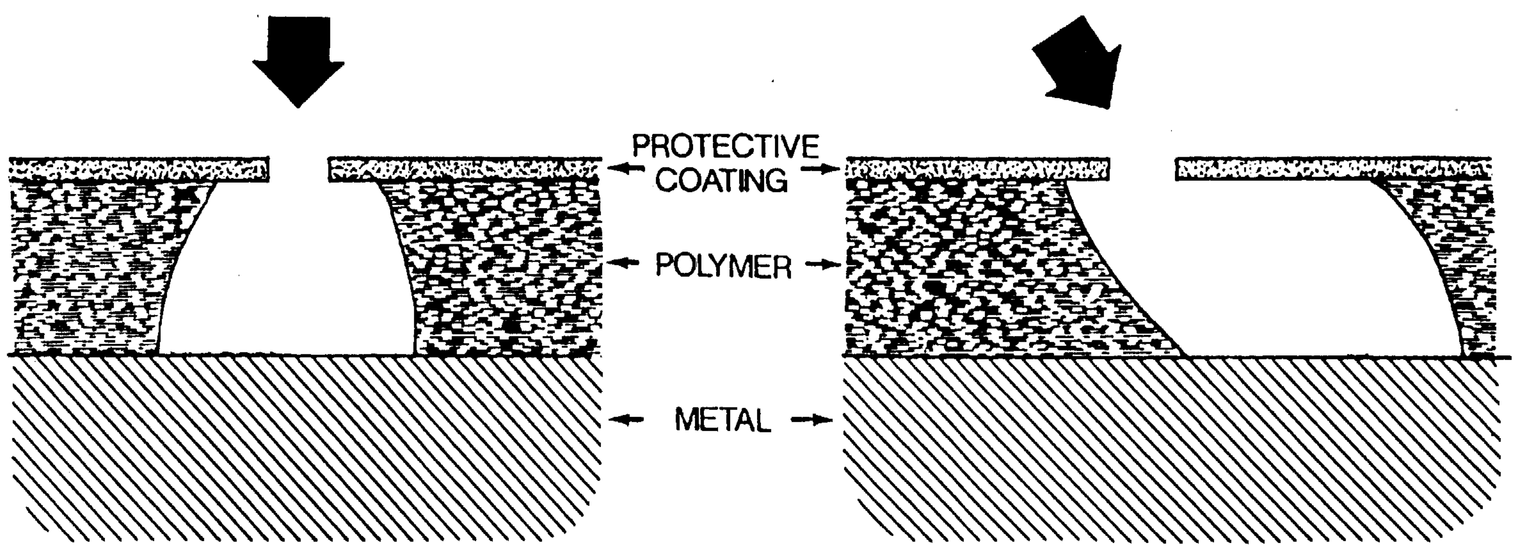
THIN POLYMER FILMS (<5 MILS)
WITH ATOMIC OXYGEN PROTECTIVE COATINGS



ANTICIPATED LDEF SURFACE PROFILES FOR PROTECTED THICK POLYMERS.



ANTICIPATED UNDERCUTTING CAUSED BY SCATTERING FROM BACK SIDE METALLICATION AT DEFECT SITES.



NASA
LONG DURATION EXPOSURE FACILITY

MATERIALS SPECIAL INVESTIGATION GROUP MATERIALS ANALYSIS

GARY PIPPIN

BOEING AEROSPACE AND ELECTRONICS CO.
MSIG SUPPORT

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

MSIG KSC WORKSHOP - FEB 1990

LONG DURATION EXPOSURE FACILITY MATERIALS DATA ANALYSIS

MSIG KSC WORKSHOP - FEB 1990

- NAS 18224

  Task 12, Materials

  Task 15, Systems

- Boeing contract with tasks in support of MSIG and SSIG activities Through NASA LaRC

BOEING MATERIALS TEAM AT KSC DURING DEINTEGRATION PROCESS

Dr. Gary Pippin-Environmental Effects on Materials

Syl Hill-Adhesives, Composites

Roger Bourassa-TCC, Composites, Lubricants, Environmental Effects Modeling

Dr. Johnny Golden-TCC, Paints, Al Anodizing

Russ Crutcher-Particular and Molecular Analysis, Contamination Control

Harry Dursch-Tech Leader Boeing Tasks for SSIG

Bob Roper-Composites, Adhesives, Program Support

GOALS:

TO BE ABLE TO PREDICT THE PERIOD OF TIME A GIVEN MATERIAL WILL SURVIVE IN LEO

TO BE ABLE TO ESTIMATE THE ENGINEERING PERFORMANCE LIFETIME IN LEO OF SPECIFIC MATERIALS

TO UNDERSTAND THE DEGRADATION MECHANISMS IN ORDER TO PRODUCE MATERIALS MORE INHERENTLY RESISTANT TO THE LEO ENVIRONMENT

MSIG KSC WORKSHOP - FEB 1990

Tasks:

- Make Quantitative measurements of the effects of the low earth orbit environment on materials.
- Report results for inclusion into LDEF materials data base

SPECIMEN/SYSTEM ENVIRONMENTAL EXPOSURE

SPECIMEN EXPOSURE DEPENDENT ON LOCATION

12 Sides + 2 ends

Modules with/without lids

"Shadow" effects
- Depth of tray
- Oscillation of spacecraft

"Edge" effects
- Side, front of specimens

Secondary scattering

MSIG KSC WORKSHOP - FEB 1990

Unique Specimens

- One time opportunity
- Procedures selected to maximize information value
- Careful documentation of each step

HARDWARE CONDITION WILL DRIVE INVESTIGATION

COMPARISON- OPTICAL IMAGE SUBTRACTION

QUALITATIVE-TRENDS

QUANTITATIVE-NUMERICAL VALUE

SPECIFIC ITEMS

SILVER BACKED TEFLON BLANKETS
ALUMINUM PLATES WITH A-276 & Z-306
COPPER GROUNDING STRIPS
COMPOSITES
KAPTON(POLYIMIDES)
"TEFLONS"- MANY VARIETIES
PIECES OF OTHER THERMAL CONTROL BLANKETS
LEXAN, PAINTS, ADHESIVES

FLUORINATED MATERIALS

PAINTS

- A276
- Z306
- S13
  - YELLOW PAINT ON TRUNNIONS

ALUMINUM, STEEL

KAPTON

POLYCARBONATE(LEXAN)

COMPOSITES

COMPLETE SET ALUMINUM PLATES, TCC DISKS, BOLTS, WASHERS

- AT LEAST ONE FROM EACH TRAY LOCATION (TWO PREFERRED)

PHOTODOCUMENT ORIENTATION BEFORE REMOVAL

VARIETY OF MATERIALS WITH COMMON LOCATION DISTRIBUTION

DETAILED OPTICAL AND SURFACE CHARACTERIZATION

SURVEY CONDITION OF TEFLON MATERIALS ON LDEF

- DIMENSIONAL CHANGES WHERE POSSIBLE

SURFACE TEXTURE
COLOR-OPTICALS

OUTGASSING, CHEMICAL IDENTITY

IR SPECTRA

COPPER GROUNDING STRIPS

INTACT

WITH PIECE OF THERMAL CONTROL BLANKET ADHESIVELY ATTACHED

COPPER GROUNDING STRIPS
STRUCTURE TO AO178 TRAY

EXPERIMENTAL MEASURE OF ATOMIC OXYGEN FLUX TO EACH ORIENTATION

CONTOUR OF EACH STRIP SHOWS VARIATION
- MEASURE THICKNESS, DENSITY, OXIDE SPECIES, OPTICALS

PRESERVE ORIENTATION OF EACH STRIP

OPTICAL PROPERTIES

SURFACE CHEMISTRY
- FUNCTIONAL GROUPS
- ELEMENTAL ANALYSIS-
  - OXIDATION STATE
- MICROCRACKING
- TEXTURE
- RECESSION, THICKNESS

BULK PROPERTIES
- MECHANICAL
- THERMAL

OUTGASSING

Properties of Interest-Composites

Non-Experimental Materials

Property	Test	Purpose
Mechanical Properties	Tensile strength,modulus Compression strength, modulus Shear strength	Determine end-of-life structural capability by comparing with specification requirements & historical data
CTE	Quartz tube or laser dilatometer	Determine effects on dimensional stability
Depth effects & microstructure	Chemical/analytical, microscopy	Determine degradation vs depth, extent that UV, AO are self-limiting & thermal cycling effects

Experimental Materials

Property	Test	Purpose
Depth effects & microstructure	Chemical/analytical. microscopy	Determine degradation vs depth, extent that UV, AO are self-limiting & thermal cycling effects
CTE	Laser dilatometer	Determine effects of exposure & one-surface degradation

LDEF Thermal Control Coatings

- Engineering Properties
  - Thermal Vacuum Stability
  - Optical Characteristics
  - Adhesion
  - Abrasion Resistance
- Basic Properties
  - Chemical Changes
    - Molecular Weight
    - Dehydration
    - Oxidation State
  - Morphological Changes
    - Crystallinity or Phase Changes
    - Defects

THERMAL EMITTANCE
CORRECT TO HEMISPHERICAL

SOLAR ABSORPTANCE

SURFACE TEXTURE-SEM

SURFACE CHEMISTRY
AUGER
REFLECTANCE, IR
ESCA

Physical/Chemical Changes

- Outgassing
- Average molecular weight distributions
- Pyrolysis GC

Examine Surface of Metals For Oxidation

- Aluminum

  Depth - XPS

- Chrome - Plating on trunnions
- Steel - bolts

Insulation Materials

- Optical ---- Surface properties
- Thermal conductivity
- Specific heat
- Compressibility/resiliency
- Wettability/contact ----- surface roughness, actual area

If PI requests and NASA approves, Boeing will conduct measurements on PI hardware/specimens

- Test equipment not available/planned for by PI
- Lab to Lab comparison
- Results back to PI to publish; also included in LDEF data base

Request to PI's

- **Schedule of availability of hardware/specimens**

- **Commitment from each PI regarding which specimens/hardware will be made available for MSIG analysis**

This list is an expression of the interests of the LDEF Special Investigation Groups (SIGs). These groups were established by NASA to maximize the scientific return from the LDEF experiments, in view of LDEF's extended space exposure. At this time, the materials noted above have merely been identified for consideration by the Project. The Principal Investigators'(PIs) cooperation will be solicited in this extended research . Either the PIs could provide samples for analysis to the SIGs, or the PIs could perform the additional research with guidance provided by the SIGs.

MATERIALS OF INTEREST TO MSIG

MSIG CONTACT: DR. H. GARY PIPPIN (206)393-3584

EXPERIMENT: STRUCTURE NASA

MATERIAL DESCRIPTION	SAMPLE	TESTS PLANNED
S13/LO, Disk Coatings		
Al & SS, Disk plates and fasteners		
Cr-Plated Steel, Trunion Pins		
Z306, Thermal Control Paint		
Cr-Plated Steel, Keel Pin		

QUESTIONS

NOTES

DATA BASE

- By Experiment
- By System
    - Quantitative Data From Measurements
    - "Lessons Learned" Text Summaries
    - Recommended Practices
    - Undesirable/Forbidden Practices
    - Relate To Space Environment

NASA
LONG DURATION EXPOSURE FACILITY

MSIG/MAPTIS DATA BASE

JOHN M. DAVIS

NASA - MARSHALL SPACE FLIGHT CENTER
MEMBER, MSIG

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

MATERIALS & PROCESSES TECHNICAL INFORMATION SYSTEM

- MATERIALS AND PROCESSES TECHNICAL INFORMATION SYSTEM (MAPTIS)

1. General Information
2. Materials Properties Database
   a. Metals Properties
   b. Nonmetals Properties
3. Material Selection Handbook Database
   a. Metals Selection
   b. Nonmetals Selection
   c. Many Other Selection Categories
4. Other Special Materials Databases
   a. Standards
   b. Foreign Alloy Cross Reference
   c. Materials Usage Agreements (MUA's)
   d. 'Where Used'
      1. MSFC Shuttle Elements
      2. Spacelab
      3. Hubble Space Telescope
      4. Space Station Freedom (future)
   e. Manufacturer Codes (H4 ID's)
   f. Other Selected Databases
      1. Atomic Oxygen
      2. Materials Test Data
      3. Materials Temperature Usage
      4. Long Duration Exposure Facility (LDEF)
      5. Many Others

MATERIALS & PROCESSES TECHNICAL INFORMATION SYSTEM

- MAPTIS GENERAL INFORMATION

1. MAPTIS is a collection of databases giving information about materials and processes.
2. Databases are relational databases written with the ORACLE Database Management System.
3. MAPTIS is accessible from anywhere by user with an account.
4. MAPTIS is constantly changing - with updates and improvements Ex. New Graphics Package will be added within one year.
5. New material information is added every day.

MATERIALS & PROCESSES TECHNICAL INFORMATION SYSTEM

METALS PROPERTIES DATABASE

- Alloy Information
  - Density
  - Poisson Ratio
  - Melting Range
  - Alternate Designation
  - UNS Designation
  - Category
- Composition Information
  - Elements
  - Average Percentage
  - Minimum/Maximum Composition
- Specification Data
  - Alloy
  - Condition
  - Form
  - Material Code (MSFC Assigned Easy Reference)
  - Specification Number
- Mechanical Properties
  - Elongation
  - Tensile Strength
  - Bearing Strength
  - Bearing Yield
  - Compressive Strength
  - Bend Radius
  - Fatigue Strength
  - Hardness
  - Hydrogen Embrittlement
- General Comments on Properties
  - Corrosion Resistance
  - Formability
  - Heat Treatment & Stress Relief by Plastic Stretching
  - Machineability
  - Surface Treatment
  - Weldability
- Much More...

MATERIALS & PROCESSES TECHNICAL INFORMATION SYSTEM

NONMETALS PROPERTIES DATABASE

- Identification Information
  - Designation
  - Manufacturer
  - Color
  - Description

- Chemical Classification
  - Composition
  - Category
  - Compound
  - Generic ID
  - Material Code
  - Process Method
  - Specifications (MIL Spec., etc)

- Component Parts Information
  - Designation
  - Description
  - Generic Type
  - Form
  - Mix Ratio

- Cure Information
  - Cure Cycle
  - Temperature
  - Time

- Material Properties
  - Use Temperature Range
  - Shelf Life
  - Compressive Strength
  - Shear Strength
  - Viscosity

- ETC.....................................

MATERIALS & PROCESSES TECHNICAL
INFORMATION SYSTEM

MATERIAL SELECTION HANDBOOK DATABASE

- Material Information
  - Material Code
  - Designation
  - Composition
  - Cure
  - Use Type
  - Specifications
  - Manufacturer
- Test Results and Data
  - Corrosions
  - Liquid Oxygen
  - Hydrazine
  - High Pressure Hydrogen
  - Low Pressure Hydrogen
  - Gasseous Oxygen
  - Nitrogen Tetraoxide
  - Flammability
  - Toxicity
  - TVS
- ETC........................

MATERIALS & PROCESSES TECHNICAL INFORMATION SYSTEM
MAPTIS MAIN MENU

1. Properties
2. Materials Selection Handbook
3. Standards
4. Foreign Alloy Cross Reference
5. Material Usage Agreement (MUA)
6. Where Used
7. Valve and Component
8. Manufacturer Codes
9. Resource Database

Enter choice:

PRINT ALL SKEWED SELECTION LIST DATA FOR ALL MATERIALS WHICH HAVE DESIGNATIONS LIKE %%RTV%102%%

*********** MAPTIS SELECTION LIST DATA FOR MTRL CODE:00128 ********* 31-JAN-90

MTRL CODE: 00128
DESIGNATION: RUBBER SILICONE RTV 102
COMPOSITION:
GENERIC ID: MIN USE TEMP: -10 f MAX USE TEMP: 350 f
USE TYPE: RUBBER

SPECIFICATION: MB0120-041

MANUFACTURER: GENERAL ELECTRIC

FLAMMABILITY DATA

TEST NUMBER	FL RT	C T	PCT OXY	PRESS psia	THICK inch	CMBST RTE	T Y	BURN LGTH inch	TOT BRN	F	F	SSTR THICK inch	SUBSTRATE MTRL	CONFIG	DRIP BRN	FLAME JETS	SPARKS	FUSN AMP	I G	GUA GE
W10558	A	U	025.9	014.3	0.008			01.40		A	A	0.003	ALUMINUM							
W16783	I	U	030.0	010.0	0.061	00.02	M	12.00	T	A	A				SMALL					
W10558	A	U	033.0	014.3	0.008			01.80		A	A	0.003	ALUMINUM							
W10558S	X	D	100.0	019.0	0.008	00.48		12.00	T	A	A	0.003	ALUMINUM							
W10558S	X	U	100.0	019.0	0.008	02.03		12.00	T	A	A	0.003	ALUMINUM							

FLUID SYSTEMS DATA

TEST NR	FLUID RTG	MEDIA
W11006	A	HYZE
W11006	A	MMH
W11006	X	N2O4

OXYGEN DATA

TEST NUMBER	OXY RTG	PRESS psia	IMPCT THRSH	TEMP f	THICK inch	TEST TYPE	REACT	NO. TES	SUBSTR THICK inch	SUBSTRATE MTRL	BATCH NUMBER	LOT NUMBER
OVERALL	B	40		70	0.007	PNEU	0	20				
OVERALL	I	40	72	70	0.007	MECH	0	20				

OXYGEN CURE DATA

TEST NUMBER	NO	PH	TIME hr	TEMP f	PRESS psia	CURE ADDITIONAL PREP
	3	1				G SEE TOX CURE

TOXICITY DATA

TEST NUMBER	SMP WGHT gram	ODOR	ODOR RTG	TEST BASIS	GAS NAME	MICRO GM	TOX RTG	OVR RTG
W10558	00021.07	1.0	A	MICROGRM/GRM	UNIDENTIFIED COMPONENT	0000000.60	V	V
W10558	00021.07	1.0		MICROGRM/GRM	TERT-BUTYL ALCOHOL	0000020.00	K	
W10558	00021.07	1.0		MICROGRM/GRM	1-BUTENE	0000000.10	K	
W10558	00021.07	1.0		MICROGRM/GRM	CARBON MONOXIDE	0000000.20	K	

TOXICITY CURE DATA

TEST NUMBER	NO	PH	TIME hr	TEMP f	PRESS psia	CURE ADDITIONAL PREP
W10558	1	1	24.00	70		
W10558	1	2	24.00	150		

THERMAL VACUUM STABILITY DATA

TEST NUMBER	TVS RTG	PRESS torr	TEMP C	TML	CVCM	WVR
SRI11803	X	1.0E-6	125	5.45	1.63	.00

DESIGNATION: RTV-102
MANUFACTURER: ALLIED RESINS CORP
DESCRIPTION: READY TO USE ADHESIVE/SEALANT USES-SEALING, AEROSPACE (EXTREME TEMPERATURE)
CATEGORY:
COMPOUND:
GENERIC ID: ABDRXXXX
MATERIAL CODE: 00128
PROCESS METHOD:
COLOR: WHITE

COMMENT:

COMPOSITION:

PART DESIGNATION	PART DESCRIPTION	GENERIC TYPE	FORM	PARTS BY WGT	PARTS BY VOL	FILLER PCT	THICK (in)
RTV 102 PART A	ONE PART CURE						

CURE:

MATERIAL SPECIFICATIONS:

MATERIAL SPECIFICATION: MIL-A-46106

PROPERTIES:

PROPERTY	CODE	VALUE	UNIT	RATING	TEMP (F)	TIME (hrs)	PRESS (psi)	FREQ (KHZ)	THICK (in)	PCT OXY	OTHER NAME
VALUE	UNIT	SUBSTRATE	SUPPLEMENT								
SPEC/TEST											
DENSITY		.03852	LB/CU IN								
DIELECTRIC CONSTANT		2.8						.06			
DIELECTRIC STRENGTH	SHORT TIME	500	VOLTS /MIL						.075		
DISSIPATION FACTOR		.0026						.06			
ELONGATION		400	PCT								
HARDNESS		30									

TEST METHOD- SHORE A

MOLD SHRINKAGE	1	PCT	
SHELF LIFE	525600	MIN	
SPECIFIC GRAVITY	1.07		
TENSILE STRENGTH	350	PSI	
THERMAL CONDUCTIVITY COEF	.12	BTU-IN/HR SQ FT DEG F	200
THERMAL EXPANSION > Tg COEF	.00015	IN/IN /DEG F	
VISCOSITY		SOFT THIXOTROPIC PASTE	
VOLUME RESISTIVITY	3000000000	OHM-CM	

RESISTANCE CHARACTERISTICS:

PRINT ALL DATA FOR MATERIALS WHICH HAVE MATERIAL CODES LIKE 10233%

*************** MATERIALS AND PROCESSES TECHNICAL INFORMATION SYSTEM ** 31-JAN-90

MATERIAL CODE	DESIGNATION	THICKNESS inch	OPER TEMP MIN f	OPER TEMP MAX f	CURE
10233	CRES 304L BAR ANNEALED				

SPECIFICATION: MB0160-037

SUPPORT DATA: Z N204 + HDZE 10078

PROPERTY DATA

PROP CODE	RTG	PRESSURE psia	THRESH HOLD	PNEU IMPACT	MECH IMPACT	DECM	IMPACT	SCC	CORR	TEMP f
CORR	A									
GOX	A	3300		A						
HDZE	A									
HIH2	A					A			A	
LOH2	A									
LOX	A				A					
N204	A									
SCC	A					A			A	

ORIGINAL PAGE IS OF POOR QUALITY

GENERAL DATA FOR FE 304L

ALLOY	ALLOY TYPE	DENSITY	DENSITY UNIT	POISSON RATIO	MELTING RANGE DEG-F
FE 304L	FE 0.050C 19.0CR 10.0NI 2.00MN				2550 - 2650

ALT-DESIGNATION	UNS-DESIGNATION	CATEGORY
LOW CARBON 18-8S STAINLESS STEELS	J92620	FEA

COMPOSITION DATA FOR ALLOY: FE 304L

ELEMENT	NOMPCT	MAXPCT	MINPCT	COM#
C		.05		10
CR	19	21	18	10
CU		.5		10
MN		2	1	10
MO		.5		10
NI	10	11	8	10
P		.04		10
S		.03		10
SI		1.5	.75	10
C		.03		80
CR	19	21	18	80
MN		1.5		80
NI	10	11	8	80
P		.04		80
S		.04		80
SI		2		80
C		.08		81
CR	19	21	18	81
MN		1.5		81
NI	10	11	8	81
P		.04		81
S		.04		81
SI		2		81

COMPOSITION PROPERTY COMMENTS FOR: FE 304L CONDITION: FORM:

COMMENT NUMBER	COMMENTS
10	AMS 5370 SPECIFIED 1.0 PERCENT MAXIMUM ONLY FOR SI. AMS 5371 GIVES 0.04 PERCENT FOR S.
80	CASTING COMPOSITION TYPE CF3.
81	CASTING COMPOSITION TYPE CF8.

SPECIFICATION DATA:

ALLOY	CONDITION	FORM	MATERIAL CODE	SPECIFICATION NUMBER
FE 304L	A	BAR		AMS 5647
FE 304L	A	BAR		QQ-S-763
FE 304L	A	NOT SPECIFIED		
FE 304L	A	PLATE		AMS 5511A
FE 304L	A	PLATE		MIL-S-4043
FE 304L	A	SHEET		AMS 5511A
FE 304L	A	SHEET		MIL-S-4043
FE 304L	A	STRIP		AMS 5511A
FE 304L	A	STRIP		MIL-S-4043
FE 304L	A1	SHEET		AMS 5511A
FE 304L	A1	SHEET		MIL-S-4043
FE 304L	A2	SHEET		AMS 5511A
FE 304L	A2	SHEET		MIL-S-4043
FE 304L	A3	SHEET		AMS 5511A
FE 304L	A3	SHEET		MIL-S-4043
FE 304L	A4	SHEET		AMS 5511A
FE 304L	A4	SHEET		MIL-S-4043
FE 304L	CR	SHEET		
FE 304L	NULL	FORGING		AMS 5647
FE 304L	NULL	FORGING		QQ-S-763
FE 304L	NULL	NOT SPECIFIED		
FE 304L	NULL	TUBE		AMS 5647
FE 304L	NULL	TUBE		QQ-S-763

**** PROPERTY VALUES FOR ALL THE FORMS AND CONDITIONS WERE ONLY THOSE THAT WERE AVAILABLE IN THE RECOMMENDED REFERENCES.

** THE CONDITION CODES FOR STEELS, WHEN NOT AVAILABLE, WERE CREATED SOLELY FOR USE IN THIS DATABASE.

ABBREVIATIONS THAT MAY BE USED IN THE FOLLOWING TABLES

ABBREVIATION	MEANING
AVG	AVERAGE
AX	AXIAL
CRF	CIRCUMFERENTIAL
DRWN	DRAWN
E/D	RATIO OF EDGE DISTANCE TO HOLE DIAMETER
FIO	FOR INFORMATION ONLY
GMS	GRAMS
GPS	GRAMS PER SQUARE INCH
HLA, HLB, etc...	FOR EACH ALLOY, CONDITION AND FORM, THE VALUE GIVEN IS AN AVERAGE OF AT LEAST TWO TESTS ON A UNIQUE HEAT AND LOG. DESIGNATIONS ARE ARBITRARILY ASSIGNED BY THIS DATABASE SOLELY FOR COMPARISON PURPOSES.
HV	DENOTES THE HIGHEST VALUE FOR THE CROSS SECTION OR THICKNESS THAT GIVES THE CORRESPONDING PROPERTY VALUE.
HYDRL	HYDRAULIC
IACS	INTERNATIONAL ANNEALED COPPER STANDARD
KSQTI	KSI SQUARE ROOT OF INCH
LV	DENOTES THE LOWEST VALUE FOR THE CROSS SECTION OR THICKNESS THAT GIVES THE CORRESPONDING PROPERTY VALUE.
MAX	MAXIMUM
MIN	MINIMUM
MPCH	MILLIGRAMS/SQ.CM/HOUR
MPY	MILS PER YEAR
NDA	NO DATA AVAILABLE
NOM	NOMINAL
SEAMLSS	SEAMLESS
SMLSS	SEAMLESS
STO	SINGLE TEST THICKNESS ONLY
TOLER	TOLERANCE
TYP	AVERAGE FOR ALL SIZES, THICKNESSES, FORMS AND METHOD OF MANUFACTURE.

BASIS DEFINITIONS

BASIS	DEFINITION

A	AT LEAST 99 PERCENT OF THE POPULATION OF VALUES IS EXPECTED TO EQUAL OR EXCEED THE "A" BASIS MECHANICAL PROPERTY ALLOWABLE, WITH A CONFIDENCE OF 95 PERCENT.
B	AT LEAST 90 PERCENT OF THE POPULATION OF VALUES IS EXPECTED TO EQUAL OR EXCEED THE "B" BASIS MECHANICAL PROPERTY ALLOWABLE, WITH A CONFIDENCE OF 95 PERCENT.
C	THIS TYPICAL PROPERTY VALUE IS AN AVERAGE VALUE, NO STATISTICAL ASSURANCE BEING ASSOCIATED WITH IT. HOWEVER, THESE TYPICAL PROPERTIES HAVE BEEN BASED ON CONSISTENT RESULTS OF TESTS ON THREE OR MORE LOTS OF MATERIAL AND ARE USEFUL IN DESIGN, SINCE THERE ARE WELL KNOWN METHODS FOR REDUCING THEM TO MINIMUM VALUES. THE MANNER IN WHICH THESE PROPERTY VALUES ARE TO BE USED WILL BE SPECIFIED IN THE DETAILED STRUCTURAL REQUIREMENTS OF THE PROCURING OR CERTIFICATION AGENCY AND ARE THUS BEYOND THE SCOPE OF THIS DATABASE.
D	THIS TYPICAL PROPERTY VALUE IS AN AVERAGE VALUE, NO STATISTICAL ASSURANCE BEING ASSOCIATED WITH IT. HOWEVER, THESE TYPICAL PROPERTIES HAVE BEEN BASED ON CONSISTENT RESULTS OF TESTS ON THREE OR MORE LOTS OF MATERIAL AND ARE USEFUL IN DESIGN.
E	FOR INFORMATION ONLY.
S	THE S BASIS MECHANICAL PROPERTY ALLOWABLE IS THE MINIMUM VALUE SPECIFIED BY THE APPROPRIATE FEDERAL, MILITARY, SAE AEROSPACE OR ASTM SPECIFICATION FOR THE MATERIAL. THE STATISTICAL ASSURANCE ASSOCIATED WITH THIS VALUE IS NOT KNOWN.

REFERENCES THAT MAY BE USED IN THE FOLLOWING TABLES

REF	BOOK
1	AEROSPACE STRUCTURAL METALS HANDBOOK
2	MIL HANDBOOK 5
3	AMERICAN SOCIETY FOR METALS, METALS HDBK, 9TH EDT. VOL. 1
5	AMERICAN SOCIETY FOR METALS, METALS HDBK, 9TH EDT. VOL. 3
6	STRUCTURAL ALLOYS HANDBOOK

MECHANICAL PROPERTY DATA FOR: FE 304L CONDITION: A FORM: SHEET

PROPERTY NAME	PROP VALUE	PROP UNIT	PROP QUAL	EXP TIME HOURS	EXP TEMP DEG-F	TEST TIME HOURS	TEST TEMP DEG-F	DIR	B A S	CR SE QU	CROS SECT MIN SQR-INCH	CROS SECT MAX SQR-INCH	TEST THICK INCH	THICK MIN INCH	THICK MAX INCH	E/D	STRS CONC	CYCL	R VAL	CREEP PCT	RUP	COM	REF
BEARING ULTIMATE STRENGTH - DRY PIN VALUES	150.0	KSI	MIN				75	NDA	S				NDA	NDA	NDA	2.0						NONE	2
BEARING YIELD STRENGTH - DRY PIN VALUES	50.0	KSI	MIN				75	NDA	S				NDA	NDA	NDA	2.0						NONE	2
COMPRESSIVE ELASTIC MODULUS	28000.0	KSI	AVG				75	NDA	C				NDA	NDA	NDA							NONE	2
COMPRESSIVE YIELD STRENGTH	27.0	KSI	MIN				75	L	S				NDA	NDA	NDA							NONE	2
	27.0	KSI	MIN				75	LT	S				NDA	NDA	NDA							NONE	2
ELONGATION	40.0	%	MIN				75	LT	S				NDA	LV	0.015							NONE	2
	40.0	%	MIN				NDA	NDA	C				NDA	NDA	NDA							NONE	1
	45.0	%	MIN				75	LT	S				NDA	0.016	0.030							NONE	2
	50.0	%	MIN				75	LT	S				NDA	0.031	HV							NONE	2
SHEAR RIGIDITY MODULUS	12500.0	KSI	AVG				75	NDA	C				NDA	NDA	NDA							NONE	
SHEAR STRENGTH	50.0	KSI	MIN				75	NDA	S				NDA	NDA	NDA							NONE	2
TENSILE ELASTIC MODULUS	29000.0	KSI	AVG	NDA	NDA		75	NDA	C				NDA	NDA	NDA							NONE	2
TENSILE YIELD STRENGTH	30.0	KSI	MIN	NDA	NDA		75	L	S				NDA	NDA	NDA							NONE	2
	30.0	KSI	MIN	NDA	NDA		75	LT	S				NDA	NDA	NDA							NONE	2
ULTIMATE TENSILE STRENGTH	75.0	KSI	MIN	NDA	NDA		75	L	S				NDA	NDA	NDA							NONE	2

MECHANICAL PROPERTY DATA FOR: FE 304L   CONDITION: A   FORM: SHEET

PROPERTY NAME	PROP VALUE	PROP UNIT	PROP QUAL	EXP TIME HOURS	EXP TEMP DEG-F	TEST TIME HOURS	TEST TEMP DEG-F	DIR	BAS	CR SE QU	CROS SECT MIN SQR-INCH	CROS SECT MAX SQR-INCH	TEST THICK INCH	THICK MIN INCH	THICK MAX INCH	E/D	STRS CONC	CYCL	R VAL	CREEP PCT	RUP	COM#	REF
ULTIMATE TENSILE STRENGTH	75.0	KSI	MIN	NDA	NDA		75	LT	S				NDA	NDA	NDA							NONE	2
	100.0	KSI	MAX	NDA	NDA		NDA	NDA	C				NDA	NDA	NDA							NONE	1

NO MAGNETIC RECORDS FOUND FOR: FE 304L   A   SHEET

CORROSION/STRESS CORROSION DATA FOR: FE 304L   CONDITION: A1   FORM: SHEET

PROPERTY NAME	PROPERTY VALUE	PROP UNIT	PROP QUAL	DIR	TEST THICK INCH	THICK MIN INCH	THICK MAX INCH	TEST TEMP DEG-F	EXP TEMP	EXP TIME HOURS	TEST ENVIRONMENT	EXP STRESS (KSI)	PCT TNSL YLD	PIT DEPTH AVG	FAIL	INTER-GRAN CORR	COM#	REF
CORROSION RATE	8.3	MPCH			0.015						NITRIC-DICHROMATE						NONE	1

NO H2 EMBRITTLEMENT RECORDS FOUND FOR: FE 304L   A1   SHEET

NO MECHANICAL RECORDS FOUND FOR: FE 304L   A2   SHEET

NO MAGNETIC RECORDS FOUND FOR: FE 304L   A2   SHEET

CORROSION/STRESS CORROSION DATA FOR: FE 304L   CONDITION: A2   FORM: SHEET

PROPERTY NAME	PROPERTY VALUE	PROP UNIT	PROP QUAL	DIR	TEST THICK INCH	THICK MIN INCH	THICK MAX INCH	TEST TEMP DEG-F	EXP TEMP	EXP TIME HOURS	TEST ENVIRONMENT	EXP STRESS (KSI)	PCT TNSL YLD	PIT DEPTH AVG	FAIL	INTER-GRAN CORR	COM#	REF
CORROSION RATE	7.7	MPCH			0.015						NITRIC-DICHROMATE						NONE	1

NO H2 EMBRITTLEMENT RECORDS FOUND FOR: FE 304L   A2   SHEET

NO MECHANICAL RECORDS FOUND FOR: FE 304L   A3   SHEET

NO MAGNETIC RECORDS FOUND FOR: FE 304L   A3   SHEET

CORROSION/STRESS CORROSION DATA FOR: FE 304L   CONDITION: A3   FORM: SHEET

PROPERTY NAME	PROPERTY VALUE	PROP UNIT	PROP QUAL	DIR	TEST THICK INCH	THICK MIN INCH	THICK MAX INCH	TEST TEMP DEG-F	EXP TEMP	EXP TIME HOURS	TEST ENVIRONMENT	EXP STRESS (KSI)	PCT TNSL YLD	PIT DEPTH AVG	FAIL	INTER-GRAN CORR	COM#	REF
CORROSION RATE	3.3	MPCH			0.015						NITRIC-DICHROMATE						NONE	1

NO H2 EMBRITTLEMENT RECORDS FOUND FOR: FE 304L   A3   SHEET

NO MECHANICAL RECORDS FOUND FOR: FE 304L   A4   SHEET

NO MAGNETIC RECORDS FOUND FOR: FE 304L   A4   SHEET

CORROSION/STRESS CORROSION DATA FOR: FE 304L CONDITION: A4 FORM: SHEET

PROPERTY NAME	PROPERTY VALUE	PROP UNIT	PROP QUAL	DIR	TEST THICK INCH	THICK MIN INCH	THICK MAX INCH	TEST TEMP DEG-F	EXP TEMP	EXP TIME HOURS	TEST ENVIRONMENT	EXP STRESS (KSI	PCT TNSL YLD	PIT DEPTH AVG	FAIL	INTER-GRAN CORR	COMM	REF
CORROSION RATE	8.9	MPCH			0.015						NITRIC-DICHROMATE						NONE	1

NO H2 EMBRITTLEMENT RECORDS FOUND FOR: FE 304L A4 SHEET

MECHANICAL PROPERTY DATA FOR: FE 304L CONDITION: CR FORM: SHEET

PROPERTY NAME	PROP VALUE	PROP UNIT	PROP QUAL	EXP TIME HOURS	EXP TEMP DEG-F	TEST TIME HOURS	TEST TEMP DEG-F	DIR	BAS	CR SE QU	CROS SECT MIN SQR-INCH	CROS SECT MAX SQR-INCH	TEST THICK INCH	THICK MIN INCH	THICK MAX INCH	E/L	STRS CONC	CYCL	R VAL	CREEP PCT	RUP	COMM	REF
TENSILE YIELD STRENGTH	158.0	KSI	NDA	NDA	NDA		78	NDA	C				0.012	NDA	NDA							NONE	1
	186.0	KSI	NDA	NDA	NDA		-100	NDA	C				0.012	NDA	NDA							NONE	1
	187.0	KSI	NDA	NDA	NDA		-320	NDA	C				0.012	NDA	NDA							NONE	1
	231.0	KSI	NDA	NDA	NDA		-423	NDA	C				0.012	NDA	NDA							NONE	1
ULTIMATE TENSILE STRENGTH	176.0	KSI	NDA	NDA	NDA		78	NDA	C				0.012	NDA	NDA							NONE	1
	198.0	KSI	NDA	NDA	NDA		-100	NDA	C				0.012	NDA	NDA							NONE	1
	251.0	KSI	NDA	NDA	NDA		-320	NDA	C				0.012	NDA	NDA							NONE	1
	279.0	KSI	NDA	NDA	NDA		-423	NDA	C				0.012	NDA	NDA							NONE	1

NO MAGNETIC RECORDS FOUND FOR: FE 304L CR SHEET

GENERAL COMMENTS FOR ALLOY: FE 304L

PROPERTY NAME	COMMENTS
CORROSION RESISTANCE	GENERAL CORROSION RESISTANCE OF THIS STEEL TO VARIOUS ATMOSPHERES, MOST ACIDS, HOT PETROLEUM PRODUCTS AND STEAM AND COMBUSTION GASES IS VERY GOOD. INTERGRANULAR CORROSION IN TYPE 304L WHEN SUBJECTED TO A NITRIC-DICHROMATE SOLUTION IS ASSOCIATED WITH THE PRESENCE OF CONTINUOUS GRAIN BOUNDARY PATHS OF EITHER SECOND PHASE OR SOLUTE-SEGREGATED REGIONS. THE SUSCEPTIBILITY OF THESE TYPES TO INTERGRANULAR CORROSION MAY BE SUBSTANTIALLY REDUCED BY SUITABLE HEAT TREATMENTS. TYPE 304L WILL BECOME SENSITIZED ONLY AFTER PROLONGED HEATING IN THIS TEMPERATURE RANGE, BUT ITS USE OVER 800 F IS NOT RECOMMENDED BECAUSE OF ITS RELATIVELY LOW STRENGTH. COMPLETE IMMUNITY FROM INTERGRANULAR CORROSION IS OBTAINED ONLY IN THE STABILIZED TYPES 321 AND 347. DEEP OCEAN BEHAVIOR OF TYPE 304L VARIES, BUT LOCAL ATTACK OFTEN TAKES PLACE. IT IS SUSCEPTIBLE TO STRESS CORROSION IN HOT DILUTE CHLORIDE SOLUTIONS. THE PRESENCE OF OXYGEN IN THE SOLUTION INCREASES THE TENDENCY TO STRESS CORROSION. MAKING THE STEELS ANODIC ACCELERATES STRESS CRACKING, WHILE CATHODIC CURRENTS PREVENT IT. THE BEST CORROSION RESISTANCE COMES FROM A CLEAN SURFACE FREE OF ALL ORGANIC AND METALLIC CONTAMINANTS. SUCH SURFACES CAN BE OBTAINED BY A THOROUGH DECREASING TREATMENT AND A NITRIC ACID RINSE. NITRIDING SIGNIFICANTLY INCREASED THE RESISTANCE TO STRESS CORROSION CRACKING. OXIDATION RESISTANCE OF THIS STEEL IS GOOD UP TO 1700 F FOR CONTINUOUS SERVICE AND UP TO 1600 F FOR INTERMITTENT SERVICE. THE PRESENCE OF HIGH PRESSURE HYDROGEN DURING LOADING TO FAILURE LEADS TO A MARKED REDUCTION IN THE TENSILE STRENGTH AND DUCTILITY OF TYPE 304L AT ROOM TEMPERATURE. THIS REDUCTION IN STRENGTH IS DEPENDENT UPON THE STATE OF STRESS AT THE ROOT OF THE NOTCH, INCREASING BOTH WITH INCREASING NOTCH SEVERITY AND WITH INCREASING HYDROGEN PRESSURE.
FORMABILITY	THIS STEEL HAS EXCELLENT FORMABILITY IN THE ANNEALED CONDITION, ALTHOUGH OTHER STRAIGHT 18-8 GRADES MAY BE PREFERRED FOR CERTAIN OPERATIONS. IT HAS A LOW YIELD STRENGTH AND HIGH STRAIN HARDENING CAPACITY AND REQUIRES CONSIDERABLY MORE POWER THAN CARBON STEELS. SEVERE FORMING OPERATIONS MAY REQUIRE INTERMEDIATE ANNEALS AND A FINAL ANNEAL IMMEDIATELY AFTER FORMING SHOULD BE APPLIED TO PREVENT STRESS CRACKING. STARTING FORGING TEMPERATURE 2300 F MAXIMUM, FINISHING TEMPERATURE 1500 F MINIMUM. SEVERE REDUCTIONS BELOW 1700 F SHOULD BE AVOIDED. THE CASTING CHARACTERISTICS OF THIS ALLOY ARE EXCELLENT. MANY OF THE CASTERS USE THIS COMPOSITION AS A BASE FOR MAKING COMPARISONS OF CASTING CHARACTERISTICS.
GENERAL	TYPE 304L IS A LOW CARBON MEMBER OF THE STRAIGHT 18-8 AUSTENITIC STAINLESS STEEL FAMILY, WITH 0.03 PERCENT MAXIMUM CARBON. IT HAS PROPERTIES SIMILAR TO THOSE OF TYPE 302 BUT THEIR CORROSION RESISTANCE IS SLIGHTLY HIGHER BECAUSE OF THE LOWER CARBON AND THE INCREASED CHROMIUM AND NICKEL CONTENTS. THE SUSCEPTIBILITY OF THIS STEEL TO INTERGRANULAR CORROSION DECREASES CONSIDERABLY WITH DECREASING CARBON CONTENT, ALTHOUGH LONG EXPOSURE TO ELEVATED TEMPERATURES MAY EVEN SENSITIZE TYPE 304L. TYPE 304L IS AVAILABLE IN ALL COMMON WROUGHT FORMS AND ALSO AS CASTINGS UNDER THE DESIGNATIONS OF CF-8 AMD CF-3, RESPECTIVELY. THE WROUGHT FORMS POSSESS VERY GOOD FORMABILITY AND THE STEELS CAN BE READILY WELDED BY ALL COMMON METHODS.
HEAT TREATMENT	A CONDITION HEAT TREATMENT. ANNEAL AT 1800 DEG F FOR 30 MINUTES TO 1 HOUR PER INCH THICKNESS, 2 HOURS MINIMUM FOR PLATE, AIR COOL OR QUENCH DEPENDING ON SECTION SIZE. COOLING TO 800 DEG F MAXIMUM SHOULD BE WITHIN 3 MINUTES. A1 CONDITION HEAT TREATMENT. ANNEAL AT 1920 DEG F FOR 2 HOURS WATER QUENCH. A2 CONDITION HEAT TREATMENT. ANNEAL AT 1920 DEG F FOR 2 HOURS WATER QUENCH AND HEAT TO 1650 DEG F FOR 2 HOURS WATER QUENCH.

GENERAL COMMENTS FOR ALLOY: FE 304L

PROPERTY NAME	COMMENTS
HEAT TREATMENT	A3 CONDITION HEAT TREATMENT. ANNEAL AT 1920 DEG F FOR 2 HOURS WATER QUENCH AND HEAT TO 1470 DEG F FOR 2 HOURS WATER QUENCH. A4 CONDITION HEAT TREATMENT. ANNEAL AT 1920 DEG F FOR 2 HOURS WATER QUENCH AND HEAT TO 1110 DEG F FOR 2 HOURS WATER QUENCH. CR CONDITION IS 50 PERCENT COLD ROLLED.
MACHINABILITY	BECAUSE OF ITS HIGH STRAIN HARDENING, MACHINING OF AUSTENITIC STAINLESS STEELS REQUIRES POSITIVE FEEDS, CORRECTLY CONTOURED AND SHARP TOOLS AND AN AMPLE SUPPLY OF COOLANT. WHILE COMPARISON WITH OTHER MATERIAL VARIES WITH THE OPERATION. SPECIAL MEASURES, SUCH AS CHIP CURLERS, ARE REQUIRED TO HANDLE THE VERY LONG CHIPS FORMED BY THIS STEEL.
SURFACE TREATMENT	CLEANING PRIOR TO HEATING AND WELDING SHOULD INCLUDE THOROUGH REMOVAL OF CARBONACEOUS MATERIAL AND OF ANY PICKUP OF ZINC OR LEAD FROM DIES. CONTAMINATION FROM THESE SOURCES MAY REDUCE THE CORROSION RESISTANCE, CAUSE EMBRITTLEMENT AND SUSCEPTIBILITY OF INTERGRANULAR ATTACK DURING SERVICE OR PROCESSING.
WELDABILITY	THIS STEEL CAN BE WELDED READILY BY ANY OF THE COMMON WELDING METHODS. FUSION WELDING OF SHEET UP TO 0.125 INCH THICK IS GENERALLY DONE BY THE INERT GAS TUNGSTEN ARC (TIG) METHOD. THE SHIELDED METAL ARC WELDING PROCESS IS PREFERRED FOR SHEET OVER 0.125 INCH THICK AND OTHER PRODUCTS. TYPE 308 FILLER ROD AND ELECTRODES ARE USED. TYPE 304L WILL BECOME SUSCEPTIBLE TO INTERGRANULAR CORROSION ONLY IF SUBJECTED TO HEATING AT ABOUT 1200 F FOR A LONG TIME.

NASA
LONG DURATION EXPOSURE FACILITY

MATERIALS SPECIMEN PRESERVATION AND CONTAMINATION AVOIDANCE

RUSSELL CRUTCHER

BOEING AEROSPACE AND ELECTRONICS CO.
MSIG SUPPORT

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

CONTAMINATION ANALYSIS

CONTAMINATION CONTROL, AND

MATERIALS SPECIMEN HANDLING

WHY

- Ground contamination control effects Orbital performance

- Orbit generated cross contamination effects Orbital performance

QUESTIONS ANSWERED: WHAT ARE -

- Effects of Ground Contaminants
- Effectiveness of Ground Cleaning Activities
- Molecular Effects of Non-Approved Materials
- Contaminating Effects of Atomic Oxygen
- Cleaning Effects of Atomic Oxygen
- Contaminating Effects of Micrometeorites and Debris

ENVIRONMENTS

- Prelaunch and Launch
- Orbital
- Re-entry and Edwards Operations
- Ferry Flight Operations
- Orbital Processing Facility
- O&C Operations
- SAEF-II
- P.I. Laboratory Clean Room

OTHER QUESTIONS: WHERE ARE -

- Effects of Reentry on Payload
- Effects of Ferry Flight on Payload
- Effects of Terrestrial Environment upon Orbit Activated Materials

EXOLUTION

- Recovering prelaunch through Orbital data
- Identifying recovery generated debris
- Identifying recovery generated artifacts
- Identifying recent terrestrial debris

TOOLS

- Tapelift
- Witness plates
- Airborne particle counts
- Volumetric air samples
- Temperature and relative humidity data
- Swabs (NVR)
- Direct surface IR for NVR analysis
- Optical Values
- Photographic Documentation

MATERIALS CONTAMINATION CONTROL

SOURCE APPORTIONMENT

- Reference samples
- Analytical characterization
- Assemblage analysis

CONTAMINANT ANALYSIS

REFERENCE SAMPLES

- Photographs of trays
- Fines from known environments
  - Edwards
  - Debris from Shuttle Bay
  - Kennedy Space Center
- Tapelifts from known environments
- Plasticizers from tray materials
- Films from known sources
- Identification tables for knowns

TAPE LIFT SAMPLES- ALL SLIDES IN KIT 01

KIT-01	SLIDE-01	BLANKET ABOVE PURGE DUCT INITIAL SAMPLING STARBOARD.
KIT-01	SLIDE-02	BLANKET ABOVE PURGE DUCT INITIAL SAMPLING PORT.
KIT-01	SLIDE-03	BLANKET BELOW PURGE DUCT INITIAL SAMPLING PORT*
KIT-01	SLIDE-04	SLIDE-01 RESAMPLING AFTER DRYDEN PLB OPERATIONS
KIT-01	SLIDE-05	SLIDE-02 RESAMPLING AFTER DRYDEN PLB OPERATIONS
KIT-01	SLIDE-06	SLIDE-03 RESAMPLING AFTER DRYDEN PLB OPERATIONS
KIT-01	SLIDE-07	BLANKET STARBOARD SIDE NEAR ADAPTER PLATE INITIAL SAMPLING PRE-FERRY FLIGHT^^^
KIT-01	SLIDE-08	STARBOARD BLANKET CENTRAL SQUARE ONE AWAY FROM PSA LOCKER INITIAL SAMPLING PRE-FERRY FLIGHT
KIT-02	SLIDE-09	PORT SIDE BLANKET NEAR OPTICAL TARGET INITIAL SAMPLING PRE-FERRY FLIGHT
KIT-02	SLIDE-01	SLIDE-08 RESAMPLE AFTER LIFTING OPS AT OPF
KIT-02	SLIDE-08	SLIDE-09 RESAMPLE AFTER LIFTING OPS AT OPF
KIT-02	SLIDE-02	SAMPLE NEAR AFT PSA BLANKET AFTER LIFTING OPS AT OPF^^^

*SAMPLE INVALID- TOUCHED PURGE DUCT ON WAY UP.

^^^NOT RESAMPLED

ALL DRYDEN OPERATION SAMPLES ARE ON XO 576 BULKHEAD

ALL PRE AND POST FERRY OPERATIONS WERE PERFORMED ON BAY ONE SURFACES.

LDEF
TAPELIFT KIT #9
2-1-90

Tapelifts taken prior to LDEF arrival in SAEF II

SLIDE #	AREA SAMPLE
1	Laminar flow bence work surface
2	Tile floor, middle area
3	Concrete floor, middle area
4	Floor of 8' platform
5	Equipment locker, W. wall, S. room
6	Tray hoist
7	Stairs of 12' stamd
8	Tone alarm "push-to-talk" mike boxes, E. wall
9	Krypton vent pipe, S. wall
10	LN2 tanks for GeLi detectors
11	Floor tile in front of observation window, E. wall
12	Video camera and stand near air shower
13	Forklift, battery operated
14	Floor in front of airlock door, N. wall
15	Top of blue box, W. wall, 12" X 18" X 36" approx
16	Top of ladder platform, W. wall
17	Top of check-out unit, W. wall
18	Floor in front of radiation detectors (GeLi)
19	Floor, 10' in front of observation window
20	Floor, W. side, LDEF outline
21	Sole of clean room shoe after SAEF II tapelifts

LDEF
TAPELIFT KIT #10
2-9-90

Tapelifts taken in SAEF II DURING IMAX FILMING

SLIDE #	AREA SAMPLE
1	Floor, just inside airlock door, W. wall
2	Floor, E. wall near observation window
3	Floor, W. area near air return
4	LATS, between LDEF rows D & E, E. side
5	LATS, LDEF row D, W. side
6	Floor, edge of LATS, W. side
7	Laminar flow bench work surface (bench has been turned off)
8	M&D work station, table top, at door, w. wall
9	Concrete floor, E. wall, near phone
10	Sole of Tom See's clean room shoe, during SAEF II work
11	Work table top, W. wall, near emergency exit
12	Work table, IMAX camera stuff, NW. corner
13	Video camera and stand near air shower
14	Fiber on LDEF equipment box #175B, near air shower
15	Floor of 8' platform by LDEF boxes, NW. corner

CONTAMINANT ANALYSIS

ANALYSIS

- Begins with sample selection
- Synergism - Key to cost effectiveness
- Samples are cheaper than analysis

MATERIALS CONTAMINATION CONTROL

ANALYTICAL CHARACTERIZATION

- Optical crystallographic data
  - Color
  - Crystal type
  - Refractive indices (real and estimated imaginary)
  - "Texture"
- Morphological data
  - Shape type
  - Size
- Elemental data

CONTAMINANT ANALYSIS (Proposed)

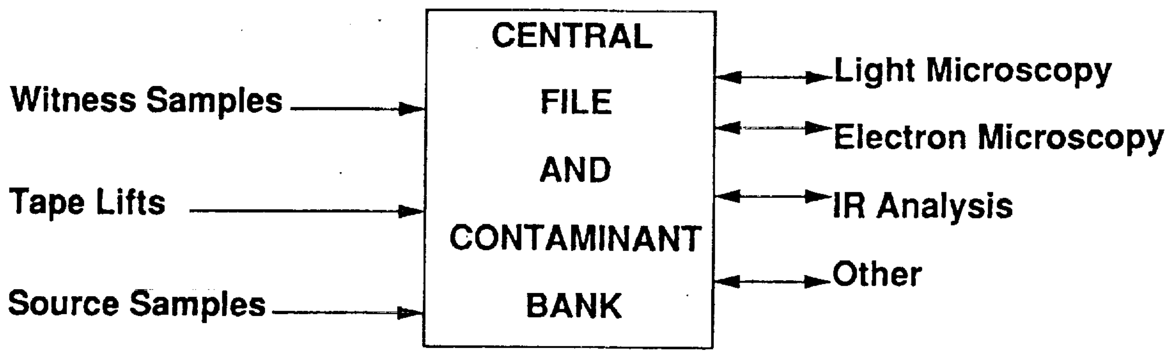
- IR image mapping of LDEF
- Selected "Swab" samples - IR and other
- Selected interface film thickness measurements
- Direct surface IR - ATR
- Selected control areas

CONTAMINANT ANALYSIS

- LDEF Preflight Photos
- Astronauts Flight Photos
- KSC Team
  - Macro Documentary
  - Surface Texture Study
  - Debris Distribution Study
  - "Shadow" Study
  - Discoloration Study
- JSC Team
  - Microvideo
  - Macrovideo
- SDIO Optical Surfaces and Contaminants Study
- IMAX Documentary
- Thermal (IR) Video

CONTAMINATE SOURCE APPORTIONMENT

APPROACH



CONTAMINATE SOURCE APPORTIONMENT

Concept

Terrestrial with Orbital Artifacts

Terrestrial without Artifacts

Extraterrestrial Impact and Surface Collection

CONTAMINATION CONTROL

- Minimize Dilution
- Minimize Cost
- Minimize Loss of Data

MATERIALS CONTAMINATION CONTROL

ISSUES

- Avoidance
- Monitoring
- Source apportionment
- Criteria for relief

MATERIALS CONTAMINATION CONTROL

AVOIDANCE

- Collection protocol
- Specimen isolation
- Specimen contamination monitoring
- Specimen inventory control
- People Control

MATERIALS CONTAMINATION CONTROL

MONITORING

- Environments
- Surfaces
- Kits to PIs

CONTAMINATION CONTROL

At Kennedy Space Center

1. Witness Plates
2. Selected Area Tape Lifts
3. Environmental Monitoring
4. Limited Exposure (Cover)
5. Packaging to Ship
6. Electrostatics

CONTAMINATION CONTROL

At Boeing

1. Clean Room Preparation of Samples
   Class 100,000 to Class 10 available
2. Clear View or Close-up Video to Outside
3. Intercom between Clean Room and Outside
4. Sample Collection and Preliminary Analysis Station

CONTAMINATION CONTROL

At P.I. Laboratories

1. Witness Plates
2. Selected Area Tape Lifts

MATERIALS CONTAMINATION CONTROL

Environments

- **Controlled**
  - Records available for facility
  - Exposure log for hardware (time out of container)
  - Surface samples (tapelifts)
- **Uncontrolled**
  - Exposure log for hardware (time out of container)
  - Surface samples (tapelifts)

CONTAMINATION CONTROL

SURFACES

- Tapelifts
  - Samples collected regularly
  - Samples processed as required
  - Samples archived with hardware until processed
- NVR Witness Plate or Surface
  - Flushed or wiped at weekly intervals or longer

MATERIALS CONTAMINATION CONTROL

KITS TO PIs

- Low cost
  - Glass slides
  - 3 M magic tape
  - Acetone
  - Beaker
  - Mountant
  - Storage box
- Small storage volume
  - 7" x 10" x 1-1/4" per 100 samples
- Simple procedure
  - Apply tape and lift
  - Soak in acetone
  - Mount in medium
- Available for detailed analysis of single particles

CONTAMINATION CONTROL

- **Surface Analysis Complete**

- **Remaining Tests for Bulk Properties**

ISSUES

- Tray handling and specimen isolation
- Documentation of precise origin
- Packaging
- Sample control
- Short term storage
- Archival preservation of samples

MATERIALS SPECIMEN CONTROL

TRAY HANDLING

- Special cart for tray
- Holding fixtures for cover, etc.
- Always two persons
- Removed from container in clean room

SPECIMEN ISOLATION

- Class 10,000 clean room or better
- Two persons, one for documentation
- Specimens labelled and packaged in clean room

MATERIALS SPECIMEN CONTROL

DOCUMENTATION OF ORIGIN

Tray Identifier

Bay A-F
Row J-12
End G-H by nearest vertical row, horizontal row

Specimen Identifier

Level I, II, III, IV, V, etc.
Position 12-36 (short axis from bottom) - (long axis from left) (in inches)

MATERIALS SPECIMEN CONTROL

PACKAGING

- Container selection
- Prelabelled containers
  - At KSC
  - To PIs
- Contingency containers
- Tapelifts
- Vacuum collection

MATERIALS SPECIMEN CONTROL

CONTAINER SELECTION

- Bags (least expensive)
- Boxes (large or heavy object support)
- Vials (small delicate object support)

ACCESSORIES

Styrofoam cushions
Dry nitrogen purge
Exterior supports

MATERIALS SPECIMEN CONTROL

SAMPLE CONTROL

- Single storage facility (temperature controlled)
- Single custodian
- Log-in, log-out procedure
- Indexed file for all samples - hard copy and computer history

LDEF SPECIMEN BOEING ENTRY LOG

TRAY #:_______ MODULE: _______ EXPERIMENT: ______ REFERENCES: ________ PROCEDURE #: _______

ITEM #	SAMPLE ID. OR DESCRIPTION	PROC. SEC.

PREPARED BY: ____

Name Organization Laboratory Phone #

DATE: ________ TIME: ________ DURATION OF PART EXPOSURE: _______ SIGNATURE: ______________

RECEIVED BY: ____

Name Signature Date Time

LDEF SPECIMEN REQUEST FORM

TRAY #:_________ MODULE:__________ EXPERIMENT:_________ REFERENCES:____________ PROCEDURE #:___________

DATE AND TIME NEEDED:____

ITEM #	SAMPLE ID. OR DESCRIPTION

Requestor	Orgn.	M/S	Phone #	Date	Time

Project Approval (Print)	Signature	Date	Time

Released By (Print)	Signature	Date	Time

Received By (Print)	Signature	Date	Time

EVENT #	DATE	DESCRIPTION OF ACTIVITY--TIME OF EXPOSURE	INITIALS

Returned By (Print)	Signature	Date	Time

Received By (Frint)	Signature	Date	Time

ONE COPY WITH SPECIMENS   ONE COPY IN TRAY FILE   ONE COPY IN 'OUT FILE'

LDEF SPECIMEN DISPOSITION FORM

TRAY #:__________ MODULE:__________ EXPERIMENT:__________ REFERENCES:____________ PROCEDURE #:____________

Requestor	Organization/Agency	Phone #

DELIVERY ADDRESS:____

DISPOSITION:____

DATE AND TIME NEEDED:________________________________

ITEM #	SAMPLE ID. OR DESCRIPTION

Project Approval (Print)	Signature	Date	Time

Released By (Print)	Signature	Date	Time

MATERIALS SPECIMEN CONTROL

SHORT TERM STORAGE

- Samples bagged to preserve condition
- Stored in single dedicated room or locker
- Stored in controlled environment 72° ± 7°
- Single custodial responsibility

CONTAMINANT ANALYSIS

DATA TO BE PROVIDED

- Recovery to deintegration background
- Update reports
- Final report: Prelaunch to Deintegration

CONTAMINANT ANALYSIS

CURRENTLY NOT FUNDED

- Detailed NVR analysis

NASA
LONG DURATION EXPOSURE FACILITY

STORAGE AND ARCHIVAL OF EXTRATERRESTRIAL MATERIAL

MICHAEL E. ZOLENSKY

NASA - JOHNSON SPACE CENTER
MEMBER, M&DSIG

LDEF
MATERIALS DATA ANALYSIS
WORKSHOP

NASA - KENNEDY SPACE CENTER
FEBRUARY 13 & 14, 1990

PLANETARY MATERIALS CURATION

RESPONSIBILITY: THREE COLLECTIONS PLUS

LUNAR - APOLLO & LUNA
ANTARCTIC METEORITES
COSMIC DUST PARTICLES
RETURNED SPACECRAFT PARTS

PURPOSE:

PRESERVE & PROTECT SAMPLES
CHARACTERIZE SAMPLES - CLASSIFY, DOCUMENT, PUBLICIZE
PROVIDE APPROPRIATE SAMPLES FOR SCIENTIFIC RESEARCH
PROVIDE SUPPORT FOR COMPLEX SAMPLING & CONSORTIA STUDIES
PROVIDE MATERIAL & INFORMATION FOR PUBLIC DISPLAY & EDUCATION

SCOPE: LUNAR

79,200 SAMPLES & SUBSAMPLES
11,000 PETROGRAPHIC THIN SECTIONS
CURRENTLY STUDIED IN 48 US AND 20 FOREIGN LABORATORIES
ABOUT 70 REQUESTS & 800 SAMPLE ALLOCATIONS PER YEAR
RESPONSIBILITY FOR SAMPLES RETURNED AFTER STUDY
LUNAR SAMPLE NEWSLETTER MAILED TO 1100 RECIPIENTS

SCOPE: METEORITES

NEW METEORITES RECEIVED & CHARACTERIZED YEARLY (670 IN 89)
21,800 SAMPLES & SUBSAMPLES
4,060 PETROGRAPHIC THIN SECTIONS
STUDIED IN 133 US AND 66 FOREIGN LABORATORIES
ABOUT 80 REQUESTS AND 700 SAMPLE ALLOCATIONS PER YEAR
ANTARCTIC METEORITE NEWSLETTER MAILED TO 500 RECIPIENTS

SCOPE: COSMIC DUST

137 COLLECTION SURFACES; 1350 CHARACTERIZED PARTICLES
CURRENTLY STUDIED IN 11 US & 9 FOREIGN LABORATORIES
76 REQUESTS SINCE 1982
LARGE AREA COLLECTORS NOW IN USE
PERFORM SOLAR MAX & LDEF PARTICLE CHARACTERIZATION
COSMIC DUST CATALOGS & NEWSLETTERS MAILED TO 300 RECIPIENTS

SCOPE: RETURNED SPACECRAFT PARTS

SOLAR MAX PARTS (DUST ON THERMAL BLANKETS & LOUVERS)
SOLAR MAX DUST SAMPLES DISTRIBUTED TO 6 INVESTIGATORS
LDEF EXPERIMENTS (PROCESSING LABORATORY IS READY)

SECTION V *

PROCEDURES FOR MEASURING IMPACT FEATURES

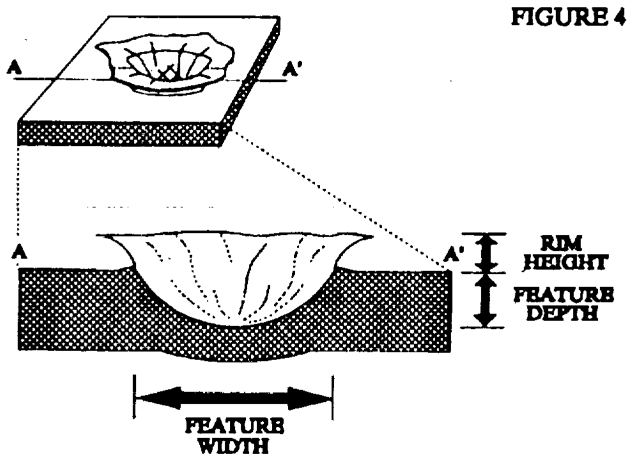
This section outlines the types of information and measurements, and the procedures for their acquisition for features of interest to the M&D SIG. Information acquired following the procedures outlined below will permit such data to be of significant use and compatible with similar data generated by the M&D SIG laboratories.

1.0 OPTICAL CHARACTERIZATION

1.1 **Minimum Characterization** -- Minimum characterization consists of acquiring a good quality color photograph of the feature(s) of interest at the earliest possible time.

1.2 **Detailed Characterization** -- Detailed characterization consists of acquiring various measurement on the feature(s) of interest, in addition to the color photography outlined in *Paragraph 1.1.* Feature measurement standards are available from the M&D SIG. Contact Michael E. Zolensky [(713) 483-5128] or Thomas H. See [(713) 483-5027] to request temporary loan of impact-feature standards.

FIGURE 4



1.2.1 Diameter -- Acquire the diameter measurement at the original target/material surface (see Figure 4). Measure and report the major and minor axes of elliptical features.

1.2.2 Depth -- Make the depth measurement from the original target/material surface (see Figure 4) to the bottom (lowest point) of the feature. When measuring the depth of an elliptical feature report the location of the deepest point within the feature; such data could then be utilized to provide directionality of the impactor. If a rim is present, provide a measurement of its height (if possible) from the original target/material surface (see Figure 4).

1.2.3 Halos -- Characterize halos by utilizing oblique lighting. Note halo type (*e.g.*, dark, bright, spalled, etc.) and width. If the feature is non-circular, characterize its variability. A color photograph of such features should be made when ever possible.

1.2.4 Impactor Residue -- Describe impactor residues in detail. Include color, location (*e.g.*, whether residue is within or around the impact feature, or both), size of individual grains or particles, as well as any unusual features of the material (*e.g.*, dendritic pattern, vesicularity, etc.).

*From the "Meteroid & Debris Special Investigation Group Operations Handbook," 1990.

2.0 CHEMICAL CHARACTERIZATION

The material of interest for chemical characterization is the impactor or impactor residues. Such materials will generally be molten in appearance and found adhering to the target/substrate. Contamination particles, on the other hand, generally should appear as discrete, loosely adhering particles or grains predominantly located outside an impact feature, although they may be found inside as well.

An issue of *extreme* importance to the M&D SIG is the amount, type, and composition of any post-recovery contaminants that may have come into contact with, or may now reside on the LDEF spacecraft and/or experiment trays due to recovery, ferrying operations associated with the flight of STS-32, and/or processing of the orbiter or LDEF spacecraft. Thus, the witness plates that fly on the STS-32 mission, those placed in the payload bay during the ferrying operation from Edwards AFB to KSC, those exposed in the Vertical Processing Facility (VPF) and the LDEF Assembly & Transportation System (LATS), as well as any other witness plates that may be utilized during the LDEF processing and deintegration activities will contain vital information to which the M&D SIG must have access. Ideally, the M&D SIG would like to analyze all or a portion of each witness plate. At an absolute minimum, the M&D SIG must obtain the results of the analyses performed on the various witness plates.

2.1 **Minimum Characterization** -- A minimum chemical characterization consists of *qualitative* analysis of the impactor residue and/or grains. Report the actual chemical constituents rather than simply referring to the materials as either "meteoritic" or "man-made debris".

2.2 **Detailed Characterization** -- Detailed chemical characterization consists of *quantitative* analysis of the impactor residue and/or grains. Extremely long counts may be necessary for small particles (*e.g.*, several thousand seconds at 20 kV) in order to minimize interference from the target/substrate materials. If possible, obtain a set of analytical standards from the M&D SIG by contacting Michael E. Zolensky [(713) 483-5128] or Thomas H. See [(713) 483-5027] to request temporary acquisition of these analytical standards.

2.2.1 Procedures -- Provide a detailed description of the analytical procedures employed in obtaining the analyses (*e.g.*, analytical instrument, count times, accelerating voltage, beam size, standards used with an analysis of each, detector crystals, etc.).

2.2.2 Composition -- Report the weighted average of the composition of the impactor residue(s).

2.2.3 Contamination -- If recognizable particles of contamination are present, report their composition.

Should a PI or institution decide to loan or donate any materials to the M&D SIG, or should questions arise as to techniques and/or procedures listed in this document, please contact the appropriate personnel at the Johnson Space Center in Houston, Texas, or the LDEF Project Office in Hampton, Virginia. A list of M&D SIG contacts can be found in *Section IX*.

SECTION VII *

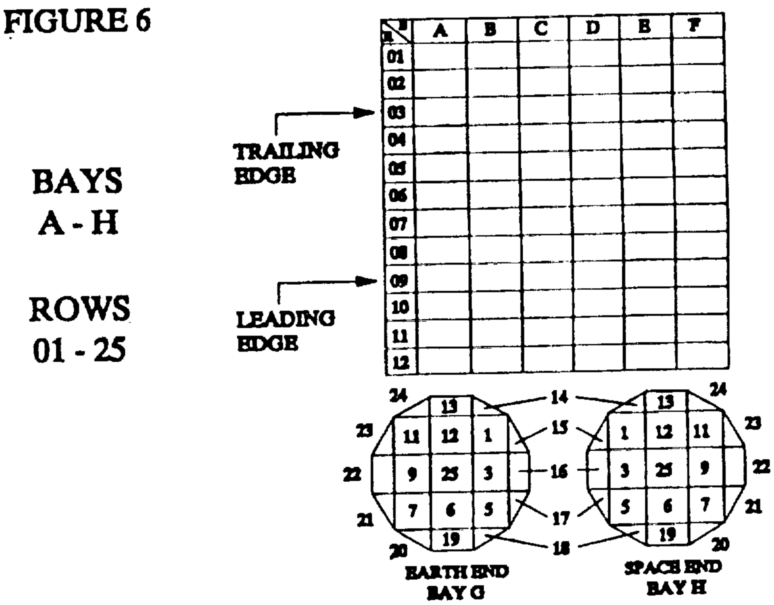
LDEF DATABASE

1.0 SAMPLE NUMBERING

The examination of the LDEF spacecraft for features of interest to the M&D SIG will consist of two phases. First, a preliminary examination will take place at KSC while the spacecraft is still intact and during the deintegration activities where features of about 1 mm in size or larger will be identified and documented. During the second phase, individual pieces will be transferred to JSC for microscopic examination in the Facility for the Optical Inspection of Large Surfaces (FOILS). During the secondary examination phase, features of much smaller size may be identified. For some features, the preliminary examination may be the only one possible.

In either case, the locations of the features on LDEF must be documented carefully so that their frequency, size, and distribution may be correlated with the orientation of the spacecraft, its direction of travel, and the type of surface on which the feature occurs.

FIGURE 6

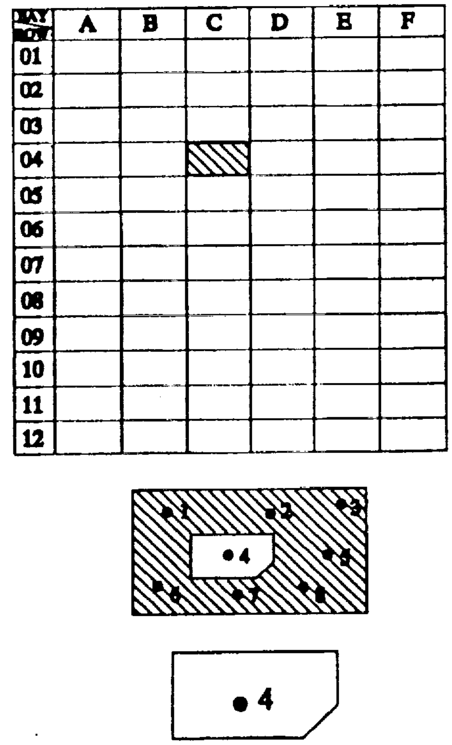


The LDEF spacecraft is a 14-faced (12 sides and two ends), open-grid structure on which a series of rectangular trays used for mounting experiment hardware are attached. All parts of the spacecraft, including experiment trays, framework, and hardware will be examined for the presence of features of interest. A numbering scheme for the satellite grid has been established, in which components are identified using "Bay" and "Row" numbers (Figure 6). The geometry of the two end pieces is more complex than that of the 12 sides, and the existing numbering scheme provides for identifying only the grids to which experiment trays are affixed. The current scheme may be expanded to include the end grids by assigning row numbers in a clockwise (Earth-facing end) or counter-clockwise (space-facing end) direction.

*From the "Meteroid & Debris Special Investigation Group Operations Handbook," 1990.

FIGURE 7

EXPERIMENT-TRAY LOCATION
BAY C, ROW 04



PRIMARY SURFACES

C04E00

FEATURES

• C04E00,1 - C04E00,8

CORES

LD-1

The examination and disassembly of LDEF will yield three different types of objects which need to be tracked and described.

1.1 Primary Surfaces -- *Primary surfaces* consist of all space-exposed hardware from the LDEF spacecraft. They may represent an entire experiment tray, a piece of hardware (*e.g.*, screw, clamp, etc.), or a piece of the spacecraft's structure (*e.g.*, frame, support beam, etc.).

The primary-surface ID will consist of four parts. The first two parts indicate the Bay (A-H) and Row (01-25) of the LDEF grid from which the primary surface was removed (see Figures 6 and 7), while the third part represents the spacecraft component. The following codes are proposed for the different components from the LDEF spacecraft:

E - Experiment Tray
B - Support Beam
F - Frame
C - Clamp
S - Screw
J - Joint

G - Grapple Pin

T - Trunion Pin

The fourth part of the primary-surface number represents the individual component number and may be a sequentially assigned number, or it may delineate a specific orientation, as will be the case for the experiment-tray clamps (see below).

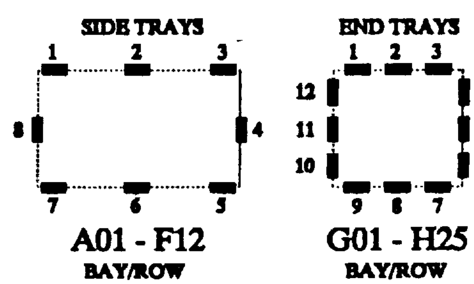
In the case that an entire experiment tray is designated to be a primary surface, the component number "00" will be assigned to it (*e.g.*, C04E00). Any pieces of hardware constituting the framework of the spacecraft will be assigned the bay and row numbers of the tray adjacent to them (*e.g.*, C04F00). If two trays share the same pieces of framework, as will be the case in most instances, the hardware to the left and bottom of the tray will be assigned the corresponding bay and row numbers.

All experiment trays are mounted to the LDEF spacecraft by clamps. A series of eight clamps affix the experiment trays on the 12 sides of LDEF, while experiments occupying the two ends are held in place by 12 clamps (Figure 8). In order to document an individual clamp's location around an experiment tray, the numbering scheme illustrated in Figure 8 will be utilized. Thus, if the M&D SIG were to obtain the clamp that occupies position 6 (Figure 8) on the experiment tray from C04 (Figure 7), that clamp would receive primary-surface number C04C06. Should clamps be acquired from configurations other than those depicted in Figure 8, a drawing will be made of the clamp configuration in order to illustrate the clamp's relationship with the experiment tray.

1.2 Features -- A *feature* is a hole, crater, or other type of impact structure which is identified on a primary surface. As features are identified, they are assigned a specific number. The numbering sequence for features begins with 1 for each primary surface. The primary-surface number plus the specific number constitute the feature number (*e.g.*, C04E00,8; Figure 7).

FIGURE 8

EXPERIMENT-TRAY CLAMP NUMBERING SCHEME



1.3 Cores -- A *core* is a piece which has been removed from a primary surface on which one or more features have been identified and numbered (*i.e.*, pieces removed from a primary surface which have no features identified are assigned component numbers; see **Primary Surfaces**, above). Core numbers are assigned sequentially as they are generated, regardless of the primary surface from which the core was removed. The core number consists of two parts: the "LD" prefix, which is the spacecraft identifier, and a sequential number beginning with 1 (*e.g.*, LD-1; Figure 7).

In summary, two distinct numbering systems are proposed for these objects in order to avoid ambiguity in their curation and among scientists. One system is for the *primary surfaces* and *features*, with features being a subset of the primary surfaces; the other is for the *cores*, or pieces which have been removed from primary surfaces.

Primary surfaces are the objects on which features are identified and from which cores are removed. Features are the objects which will be examined and described by the scientific community and in the FOILS laboratory; cores are the means by which they will be divided and transported. Once features have been identified on a surface, any piece removed, regardless of its size, will be assigned a core number. This procedure ensures that correlation between the primary-surface and feature number is maintained. Since the features will be the basic units of scientific interest, it is proposed that the LDEF grid number and component type be included in their identity so that the number will impart some information about a feature's location on LDEF. Cores will be numbered sequentially as they are produced, regardless of the primary surface from which they are removed.

2.0 DATA FILES

2.1 Primary-Surfaces File -- The *primary-surfaces file* will contain one record for each primary surface generated. For example, a primary-surface number will be assigned to each experiment tray, screw, clamp, or other spacecraft component which is removable as a separate unit; the shape of the component may be square, rectangular, round, oval, trapezoidal, or irregular. The orientation of the component, relative to the other components removed from the spacecraft, is recorded (the specific nomenclature for the orientation must be determined), as are the longest and shortest dimensions. The substrate is determined by the material of which the surface is made, or the material on the surface of the tray (*e.g.*, gold, aluminum, type of plastic). The location in this column refers to one of the various NASA centers (*e.g.*, LaRC, JSC, etc.). Fields for the original and current masses of the surface (grams) are included for accountability of the gold surfaces (Table 1).

2.2 Features File -- The *features file* will contain one record for each feature identified. If a feature is removed from the primary surface, the number of the core which contains the feature is recorded. The X,Y-coordinates of the feature, as determined by the scanning process are recorded as fixed units from the (0,0) reference point. Optical observations for each feature are recorded to the extent possible; not all features will be cored, and detailed descriptions regarding sizes, impact types, quantity of material, rims, and halos may not be feasible for all features.

2.3 Cores File -- The *cores file* will contain one record for each piece or core removed from a primary surface. The principal function of this file is to track the cores with regard to location and container. A field for the mass (grams) of the core is included for accountability of the gold surfaces (Table 1).

2.4 Allocation File -- The *allocation file* will contain one record for each distribution of a primary surface or core to a PI. The number of the material (primary surface or core), the name of the PI, and the date the material was allocated are recorded.

2.5 Images File -- The *images file* will contain one record for each image recorded during the preliminary examination of the LDEF spacecraft at KSC, as well as during subsequent processing at JSC. The image type may be a photograph, a digital image, or a video tape. The number will be the NASA photo number, or an assigned unique number or file name which identifies a video tape or digital-image file. Fields for feature number and core number are included (Table 1) so that cross-referencing with the other LDEF database files may be implemented; however, data will not be recorded in these fields unless such information applies directly to the photograph, image file, or video tape. A field for a more detailed description is also included.

2.6 Notes File -- The *notes file* will be used for recording comments about trays, primary surfaces, features, and cores. Separate fields for feature and core number are included (Table 1) for cross-referencing. Only those fields relevant to particular parts need be completed (for example, if a note is about a primary surface, only the bay, row, and component fields would be completed). Fields for the name of the person entering the note and the date are included.

2.7 Chemistry File -- The *chemistry file* will be used to record, for individual features, the elemental composition of projectile residues, surface materials, and possible contaminants. Fields for the feature number, element, the part analyzed, the analyst, and the date of the analysis are included (Table 1). Two separate fields are included for recording the amount of element present. One is for expressing the amount as the weight percent of the element, while the other is for expressing the amount in parts per million. Data in the field for the part analyzed is restricted to specific keywords, such as "IMPACTOR", "SURFACE", or "CONTAMINATION", so that records pertaining to each of these materials may be collected and sorted by element for calculation of elemental composition. The file may contain many records for some elements for a feature and none for others.

Table 1. LDEF Database File Interaction

PRIMARY SURFACE	FEATURES	CORES	ALLOCATION	IMAGES	NOTES	CHEMISTRY
				Image ID		
				Type		
				Number		
	Feature #			**Feature #**	**Feature #**	**Feature #**
Surface ID	**Surface ID**		**Surface ID**	**Surface ID**	**Surface ID**	**Surface ID**
Bay	**Bay**		**Bay**	**Bay**	**Bay**	**Bay**
Row	**Row**		**Row**	**Row**	**Row**	**Row**
Component	**Component**		**Component**	**Component**	**Component**	**Component**
Compon. #	**Compon. #**		**Compon. #**	**Compon. #**	**Compon. #**	**Compon. #**
	Specific #			**Specific #**	**Specific #**	**Specific #**
	Core #	**Core #**	**Core #**	**Core #**	**Core #**	
Shape	Coordinates	Location	Location (PI)	Description	Entry By	Element
Orientation	X	Container	Date Allocated	Date	Date	Element %
Long Axis	Y	Mass			Note (may	Element ppm
Short Axis	Dimensions				contain	Part Analyzed
Substrate	Long Axis				counting	Analyst
Location	Short Axis				statistics)	Date
Original Mass	Crater Depth					
Current Mass	Impact Type					
Origin	Rim					
	Type					
	Relief					
	Shape					
	Material Qty.					
	Halo Type					

3.0 SOFTWARE REQUIREMENTS

The following are the requirements which should be considered in order to implement the proposed database system:

3.1 Multi-User Access -- Although the number of persons accessing the database will be limited initially, more than one person should be able to access the database at one time for both updating and reporting purposes. Record-locking should be used in the event that several people attempt to access the same record for writing at the same time.

3.2 Menus -- Access to the database should be configured so that updating the files and generating reports is accomplished through menus, which permit the user to have little to no knowledge of how the database software actually operates.

3.3 Multi-File Access -- The proposed design divides the data into a number of different files, with redundancy only in the identifiers for the different types of objects. The database software must have the capability of synthesizing information from one or more of these files into a single report (for example, one requirement might be to list all the features in the custody of a PI, even though locations of samples are recorded for core numbers only).

3.4 Graphics -- The data must be able to be selected and sorted to produce a variety of plots for data recording, analysis, and presentation. For example, a plot of the features on a primary surface based on the X,Y-coordinates recorded by the FOILS scanner provides a means for correlating core and feature numbers. Plots of size distribution versus frequency of impact were requirements resulting from studies of the Solar Maximum spacecraft; similar plots will be necessary for LDEF.

3.5 Weight Balancing -- If weight accountability for gold surfaces is a requirement, the software must be capable of prohibiting entry of updates for these surfaces until masses of the primary surface and cores removed from that surface total the same before and after the transaction.

3.6 Expandability -- In order to meet new requirements as they are identified, the database must be capable of being expanded or adapted, either by means of additional data files or by reformatting of existing ones.

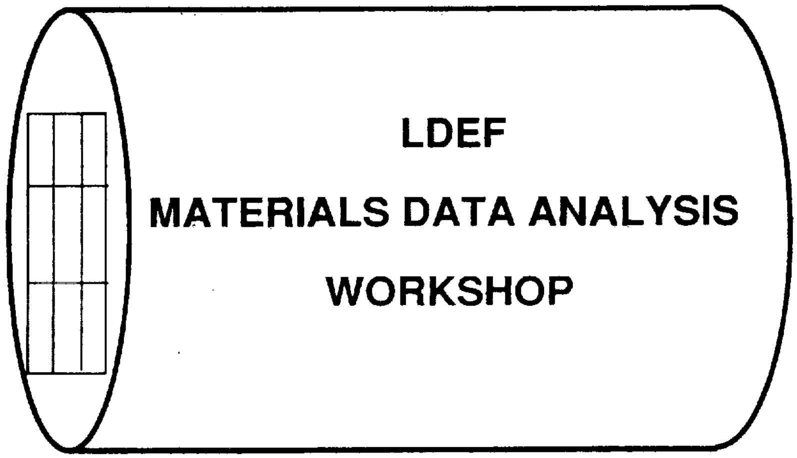
3.7 Commonality -- The data must be usable by different types of computers and applications (e.g., main-frames, PC's, MAC's).

3.8 Access -- The database will be accessible *via* SPAN. Details on the procedures for gaining access to the LDEF M&D SIG database can be obtained by contacting C.B. Dardano, T.H. See, or M.E. Zolensky, at JSC.

Should a PI or institution decide to loan or donate any materials to the M&D SIG, or should questions arise as to techniques and/or procedures listed in this document, please contact the appropriate personnel at the Johnson Space Center in Houston, Texas, or the LDEF Project Office in Hampton, Virginia. A list of M&D SIG contacts can be found in *Section IX*.

LONG DURATION EXPOSURE FACILITY

WORKSHOP AGENDA



LDEF

MATERIALS DATA ANALYSIS

WORKSHOP

NASA - KENNEDY SPACE CENTER
BUILDING M7-351, TRAINING AUDITORIUM

FEBRUARY 13 & 14, 1990

LDEF
MATERIALS DATA ANALYSIS WORKSHOP

NASA - KENNEDY SPACE CENTER
BUILDING M7-351, AUDITORIUM

FEBRUARY 13 & 14, 1990

CO-CHAIRMAN: MR. BLAND A STEIN, CHAIRMAN LDEF MSIG, NASA-LARC

CO-CHAIRMAN: DR. PHILIP R. YOUNG, NASA-LARC

AGENDA

FEBRUARY 13, 1990

8:00 A.M. Registration

Session 1 - **LDEF Data Analysis Responsibilities and Plans**

8:30 A.M.	Workshop Introduction	B. Stein, Workshop Co-Chairman
8:45 A.M.	NASA Headquarters Perspective	R. Hayduk, LDEF Coordinator, NASA Headquarters
8:55 A.M.	LDEF Data Analysis Project Office Overview	D. Tenney, Chief, Materials Division, NASA-LaRC
9:15 A.M.	LDEF Project Operations	B. Lightner, LDEF Manager
9:30 A.M.	Supporting Data Group Plans:	
	- Environments	W. Kinard, LDEF Chief Scientist
	- Orbit and Orientation	W. Kinard, LDEF Chief Scientist

February 13, 1990

Session 1 - **LDEF Data Analysis Responsibilities and Plans (continued)**

10:00 A.M.	Special Investigation Group Plans: - Meteoroid and Debris SIG	 W. Kinard, Chairman, M&DSIG
10:50 A.M.	Storage and Archival of Extraterrestrial Material	M. Zolensky, NASA-JSC
11:00 A.M.	Supporting Data Group Plans (Continued): - Spacecraft Thermal	 W. Berrios, NASA-LaRC
11:45 A.M.	**Lunch**	
1:00 P.M.	Special Investigation Group Plans (continued): - Systems SIG - Materials SIG - Induced Radiation SIG	 J. Mason, Chairman, SSIG B. Stein, Chairman, MSIG T. Parnell, Chairman, IRSIG
4:00 P.M.	Overview of Principal Investigator Plans	J. Jones, LDEF Science Manager
4:40 P.M.	SDIO Overview	W. Ward, WRDC/MLBT

February 14, 1990

Session 2 - **Materials Data Analysis Methodology Discussions**

8:30 A.M.	Overview	B. Stein, NASA-LaRC
8:45 A.M.	Discussion Topics and Leaders: - Polymeric Materials Characterization - Surface Chemistry - Atomic Oxygen	 P. Young, NASA-LaRC J. Wightman, Virginia Tech B. Banks, NASA-LeRC
11:45 A.M.	**Lunch**	

February 14, 1990

Session 3 - Materials Analysis, Data Base, and Specimen Preservation

1:00 P.M.	MSIG Materials Analysis	G. Pippin, Boeing Aerospace
1:40 P.M.	MSIG/MAPTIS Data Base	J. Davis, NASA-MSFC
2:20 P.M.	Materials Specimen Preservation and Contamination Avoidance	R. Crutcher, Boeing Aerospace
3:20 P.M.	General Discussion	All participants
4:00 P.M.	**Adjourn**	

LDEF MATERIALS DATA ANALYSIS WORKSHOP ATTENDANCE

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FRAYSSE, DIDIER	MATRA		TOULOUSE, FRANCE		A0138-8	61-39-61-39
FREDERICK, A. ROBB	GL - PHP		HUNSCOM AFB, MA	01731	M0002	617-377-3211
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STRAW, DAVID C.	W.J. SCHAFER ASSOCIATES	1901 N. FT. MYER	ARLINGTON, VA	22209	M0003/M0006	703-558-7900
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Report Documentation Page

1. Report No. NASA CP-10046	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle LDEF Materials Data Analysis Workshop		5. Report Date July 1990
		6. Performing Organization Code
7. Author(s) Bland A. Stein and Philip R. Young, Compilers		8. Performing Organization Report No.
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665-5225		10. Work Unit No. 506-48-71-01
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546-0001		13. Type of Report and Period Covered Conference Publication
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The 5-year, 10-month flight of the Long Duration Exposure Facility (LDEF) greatly enhanced the potential value of most LDEF materials, compared to the original 1-year flight plan. NASA recognized this potential by forming the LDEF Space Environmental Effects on Materials Special Investigation Group in early 1989 to address the expanded opportunities available in the LDEF structure and on experimental trays, so that the value of all LDEF materials to current and future space missions would be assessed and documented. The LDEF Materials Data Analysis Workshop served as one step toward the realization of that responsibility and ran concurrently with activities surrounding the successful return of the spacecraft to the NASA Kennedy Space Center. This document is a compilation of visual aids utilized by speakers at the workshop.

Session 1 summarized current information on analysis responsibilities and plans and was aimed at updating the workshop attendees: the LDEF Advisory Committee, Principle Investigators, Special Investigation Group Members, and others involved in LDEF analyses or management. Sessions 2 and 3 addressed materials data analysis methodology, specimen preparation, shipment and archival, and initial plans for the LDEF Materials Data Base. A complementary objective of the workshop was to stimulate interest and awareness of opportunities to vastly expand the overall data base by considering the entire spacecraft as a materials experiment.

17. Key Words (Suggested by Authors(s)) Long Duration Exposure Facility (LDEF) Space environmental effects/exposure Enviromental effects on materials	18. Distribution Statement Unclassified—Unlimited Subject Category 23

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 295	22. Price A13

NASA FORM 1626 OCT 86 NASA-Langley, 1990

For sale by the National Technical Information Service, Springfield, Virginia 22161-2171