

“The Space Shuttle Columbia Preservation Project – The Debris Loan Process”

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Columbia Preservation Project

- Purpose:
 - Provide a process for loan of Columbia debris to qualified researchers and technical educators
 - Aid in advanced spacecraft design and flight safety development
 - Advance the study of hypersonic re-entry to enhance ground safety.
 - Train and instruct accident investigators
 - Establish an enduring legacy for Space Shuttle Columbia and her crew.



Columbia Recovery Office

- The Columbia Recovery Office was formed at JSC at the conclusion of recovery operations on May 1st
- In October the SFOC contract was changed to incorporate the Columbia Recovery Office and Preservation, subsequently the CRO was transferred to USA/KSC on October 6th
- Using (866) 446-6603, this is the same phone number used throughout the recovery, anyone can call about debris
 - Phone rings in OSB 6th floor, USA GO Program Office
 - Information is taken and input into Shuttle Interagency Debris Database (SIDDs). Name, contact #s, location
 - Any available pictures or information is forwarded to PH/GO for determination of Orbiter hardware or not
 - If designated hardware and within 25 miles of the current known debris path Weston (EPA contractor that participated in recovery) will recovery and transport to NASA Palestine Balloon facility. Subsequently items are shipped to KSC
 - Otherwise the person is directed to transport item to local authority and contact NASA where we give Fed Ex shipping number and send to KSC
 - Once at KSC item is inventoried into Reconstruction/Preservation database and placed on 16th floor of VAB

Debris Check-in Process

Receiving Materials (CRO/Weston)

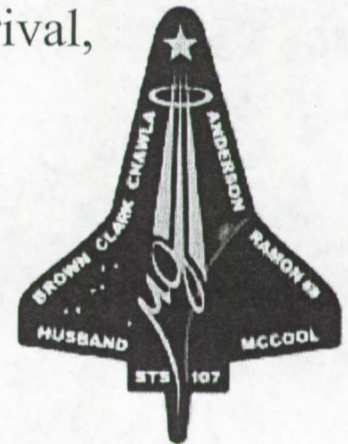
- Toxic Vapor Checks are performed on all items before processing

Quality Receiving

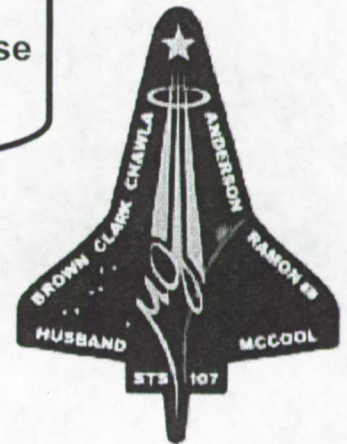
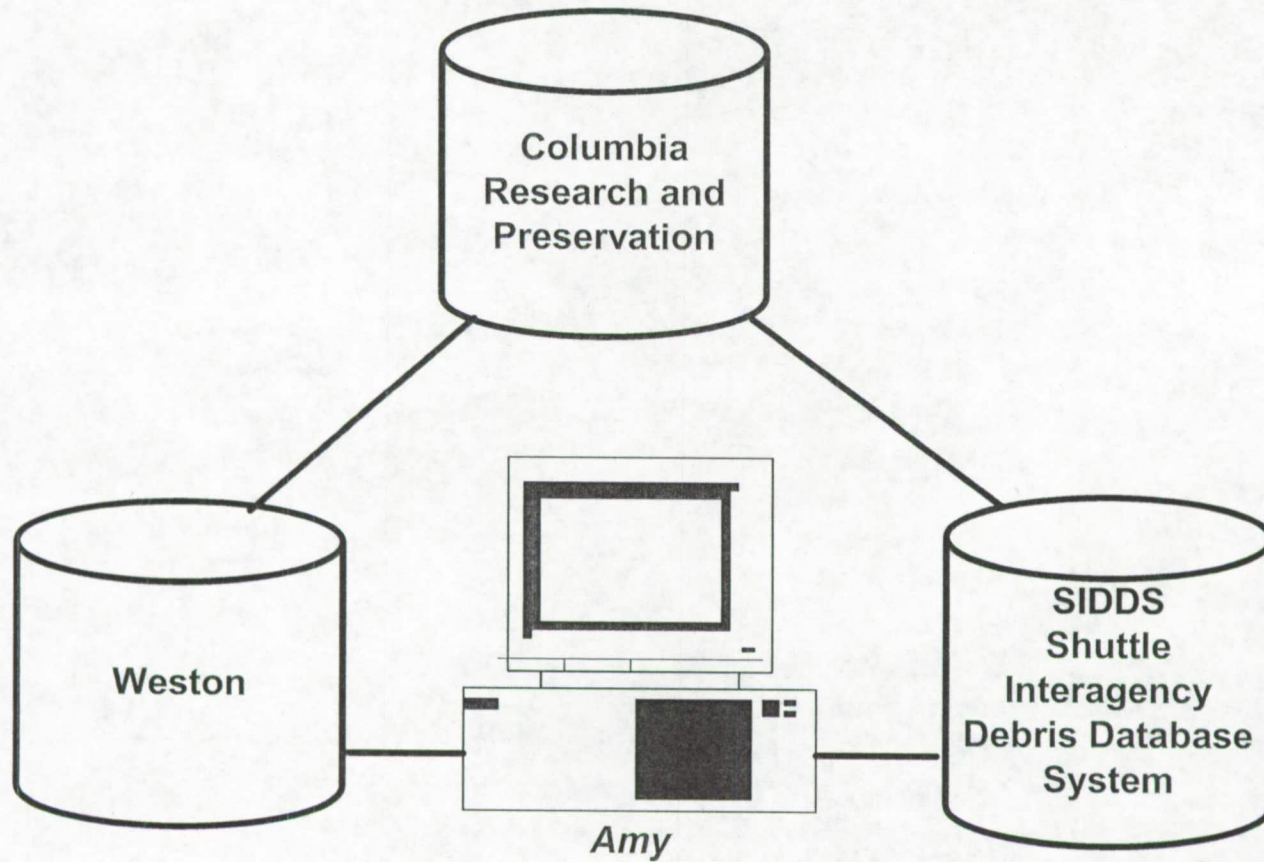
- Debris items are:
 - ✦ Photographed bar-coded and tagged
 - ✦ Entered into CRDS. Multiple items are separated into parent/child relationships
 - ✦ Data records include item description, time and date of arrival, longitude/latitude and date and time of recovered area.

Movement of Debris

- Handler assign items to locations for storage according to size, weight, and system identification



Database Interface



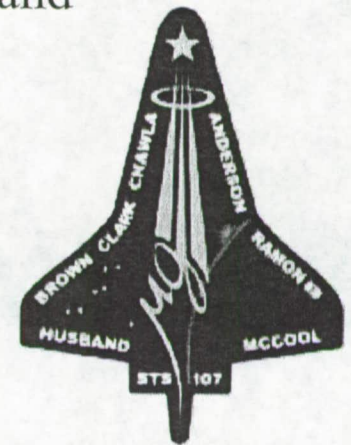
Coordination of Debris Requests

Internal to Space Shuttle Program

- Requestor fill out Debris Loan Request and contacts Columbia Research and Preservation Office for validation and approval.
- Forward to following for release approval
 - ✚ Space Shuttle Orbiter Project Office (OPO) Manager (JSC/MV)
 - ✚ Flight Crew Operations Directorate (FCOD)/ Astronaut Office if crew module debris is involved.
 - ✚ Space Shuttle Deputy Program Manager at KSC (MK)
 - ✚ Columbia Research and Preservation Office for database entry and coordination for shipping

Shipping of Material

- Coordinated with USA logistics.
 - ✚ Generate DD1149
 - ✚ Tracking number entered into CRDS

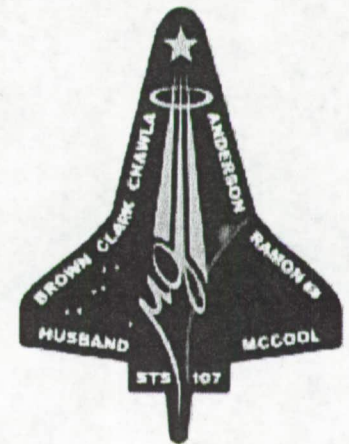


Coordination of Debris Requests

External to Space Shuttle Program

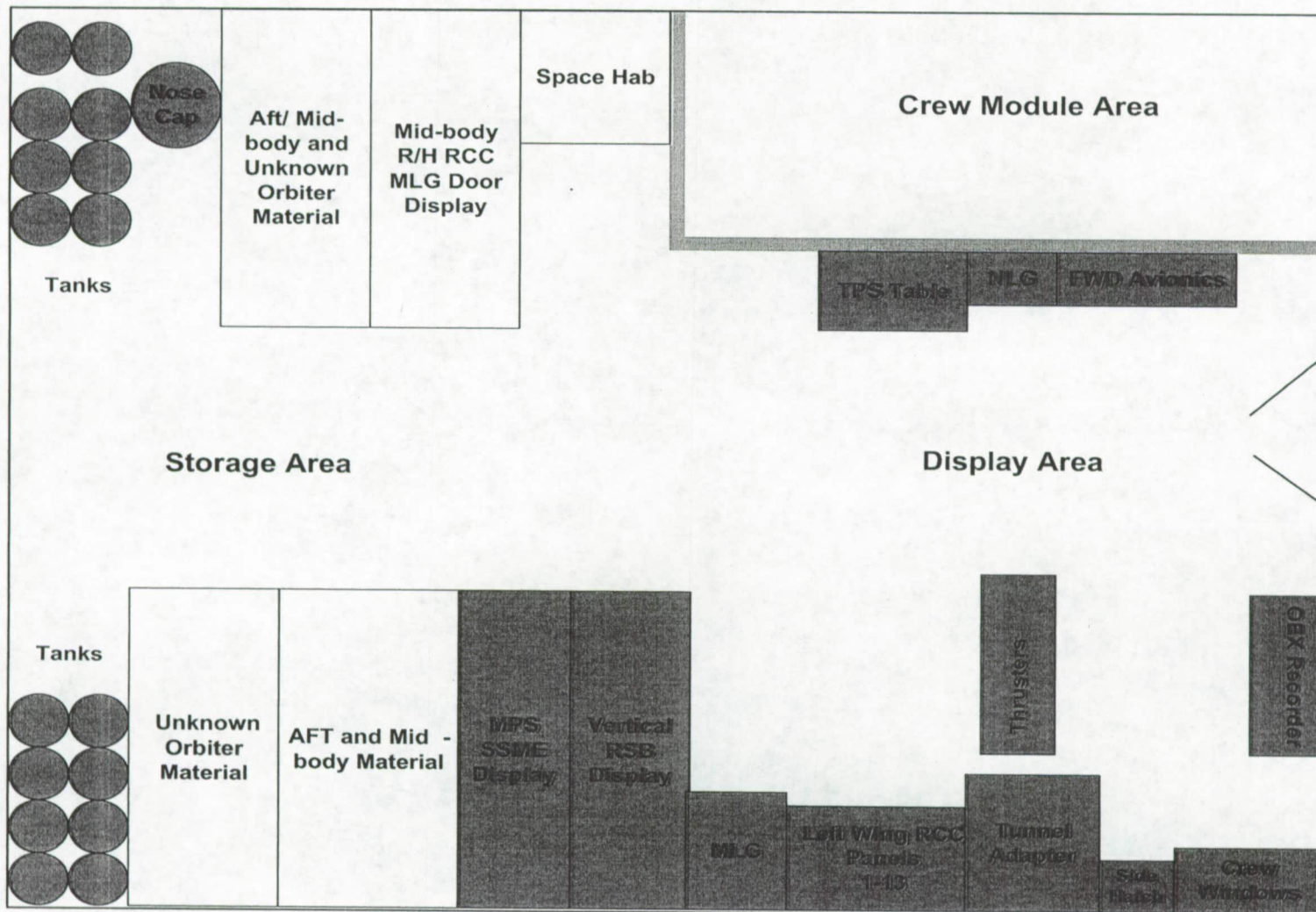
➤ The NASA Review and Approval Committee will consist of the following individuals for concurrence:

- ✦ Designated NASA Approval Authority (Space Shuttle Program Manager)
- ✦ Technical Expert (Subsystem Manager)
- ✦ NASA expert in research process.
- ✦ NASA Legal
- ✦ NASA Education (education-related request)
- ✦ FCOD/Astronaut Office



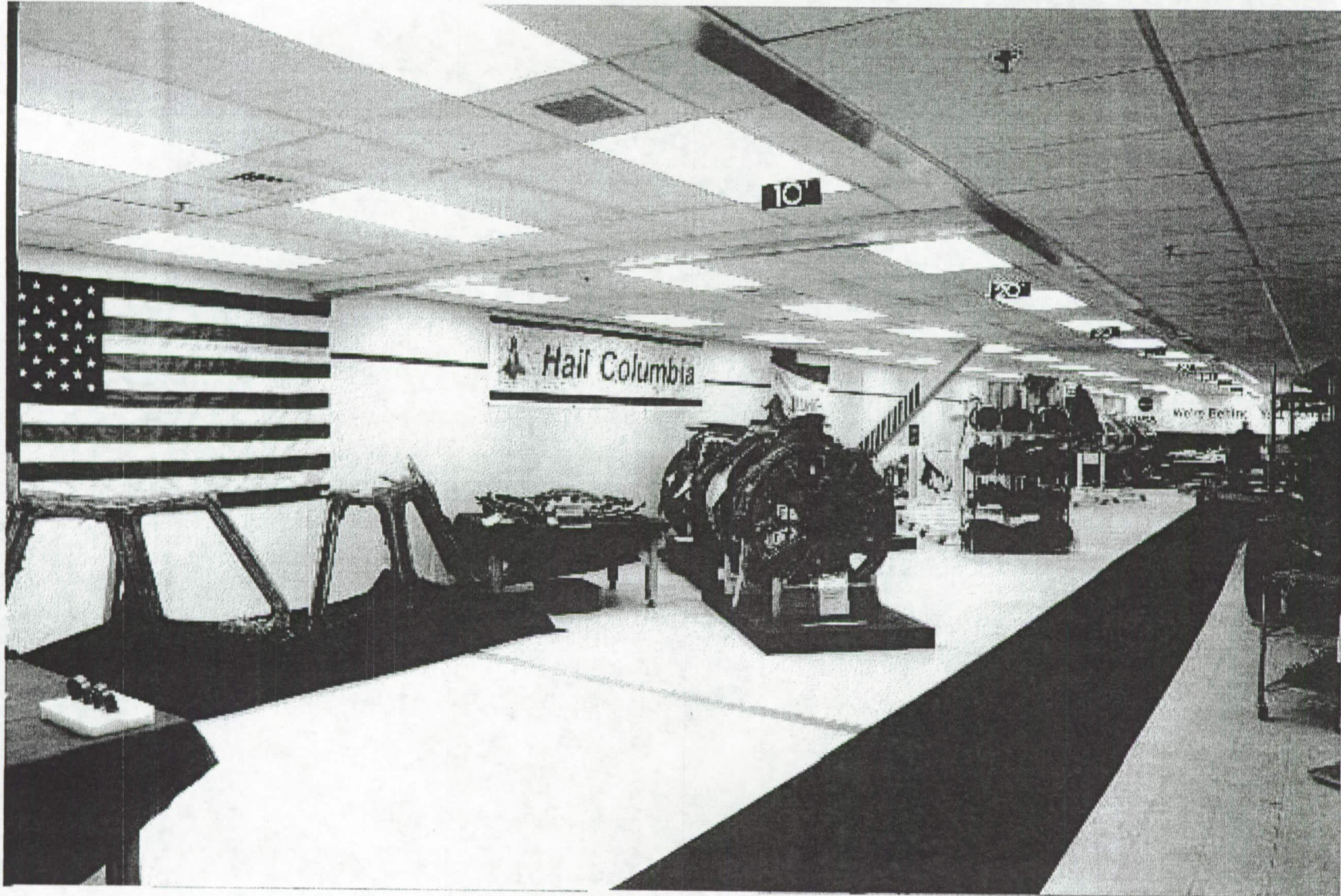


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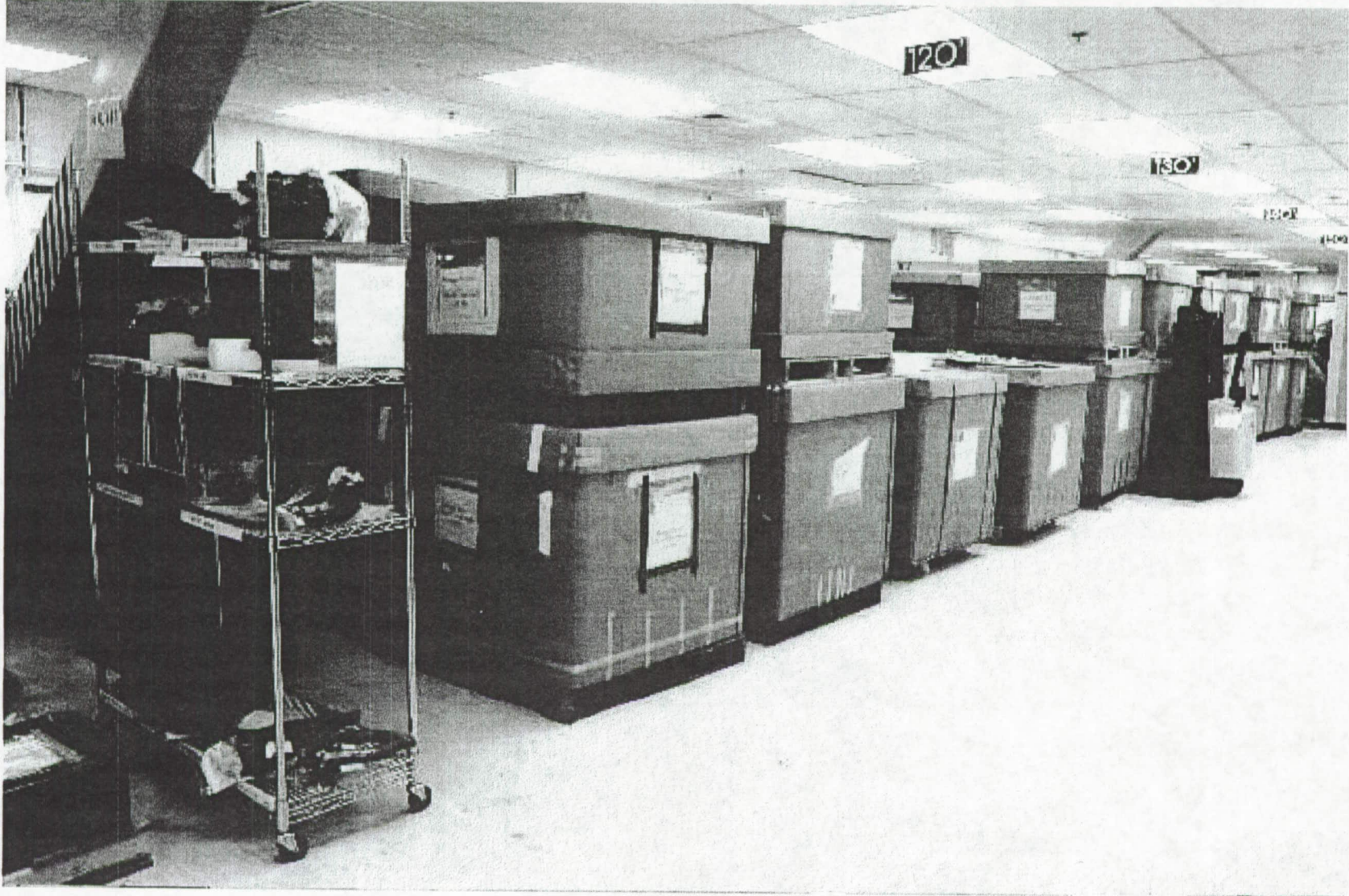


Columbia Preservation Project



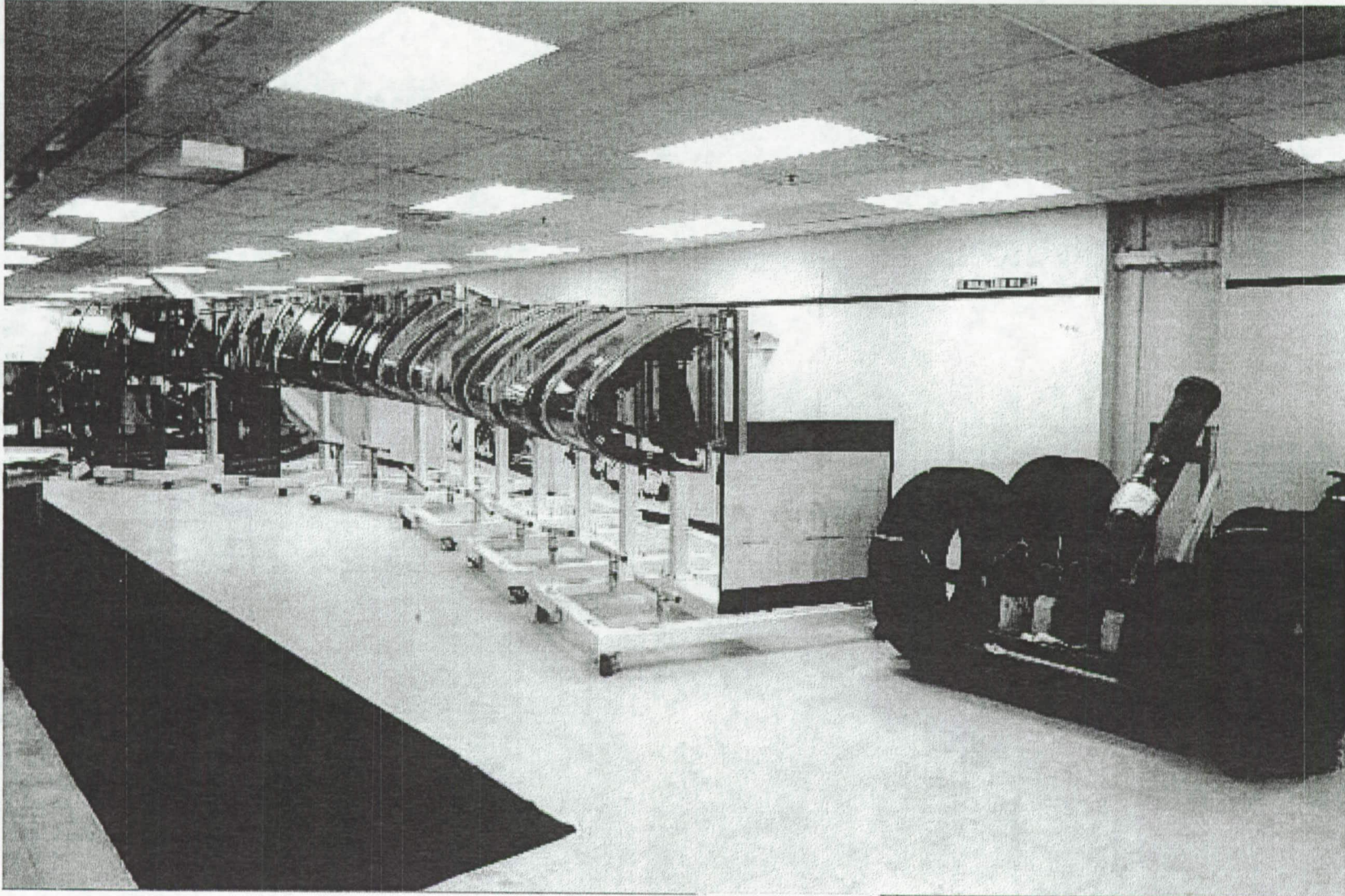


Columbia Preservation Project



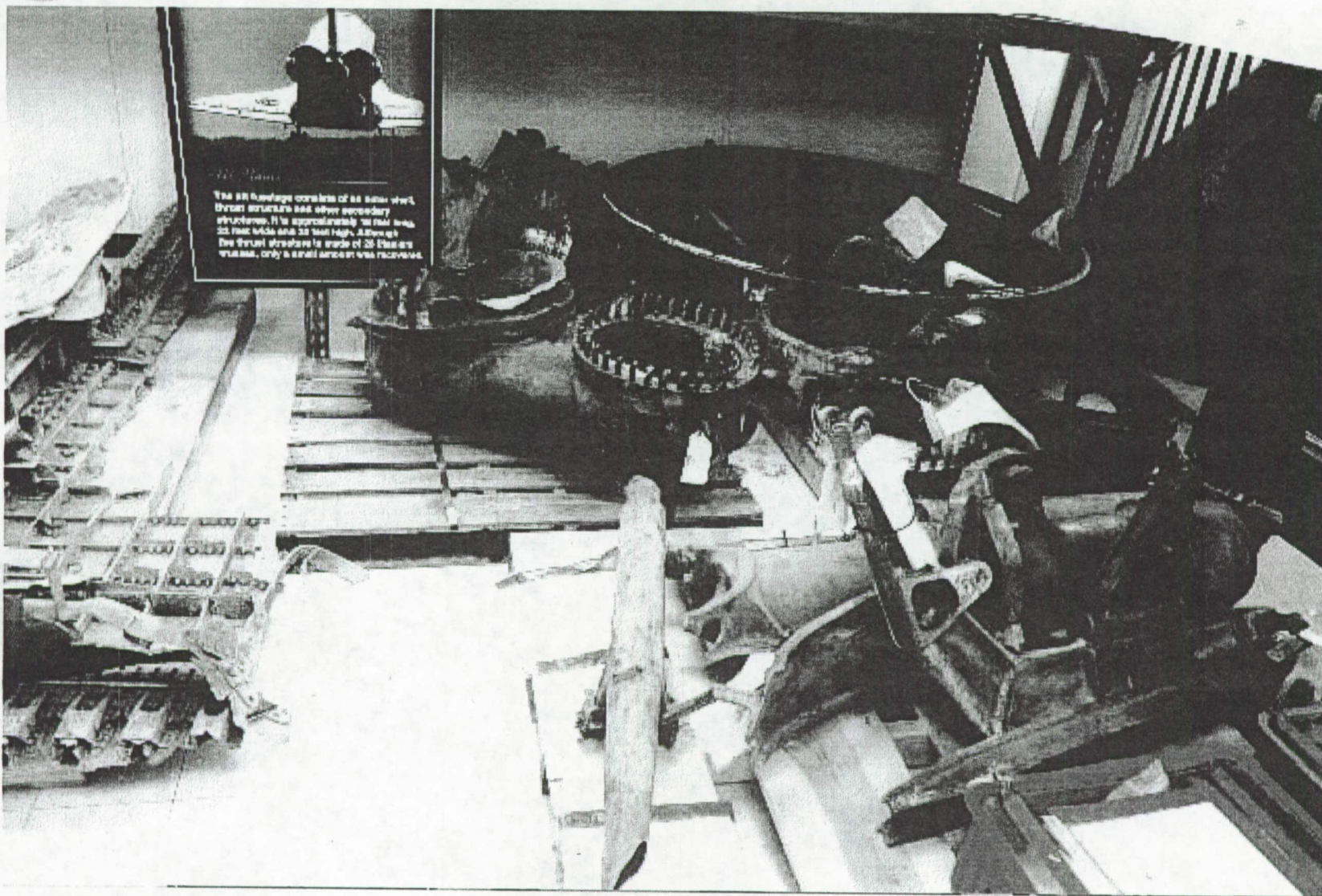


Columbia Preservation Project



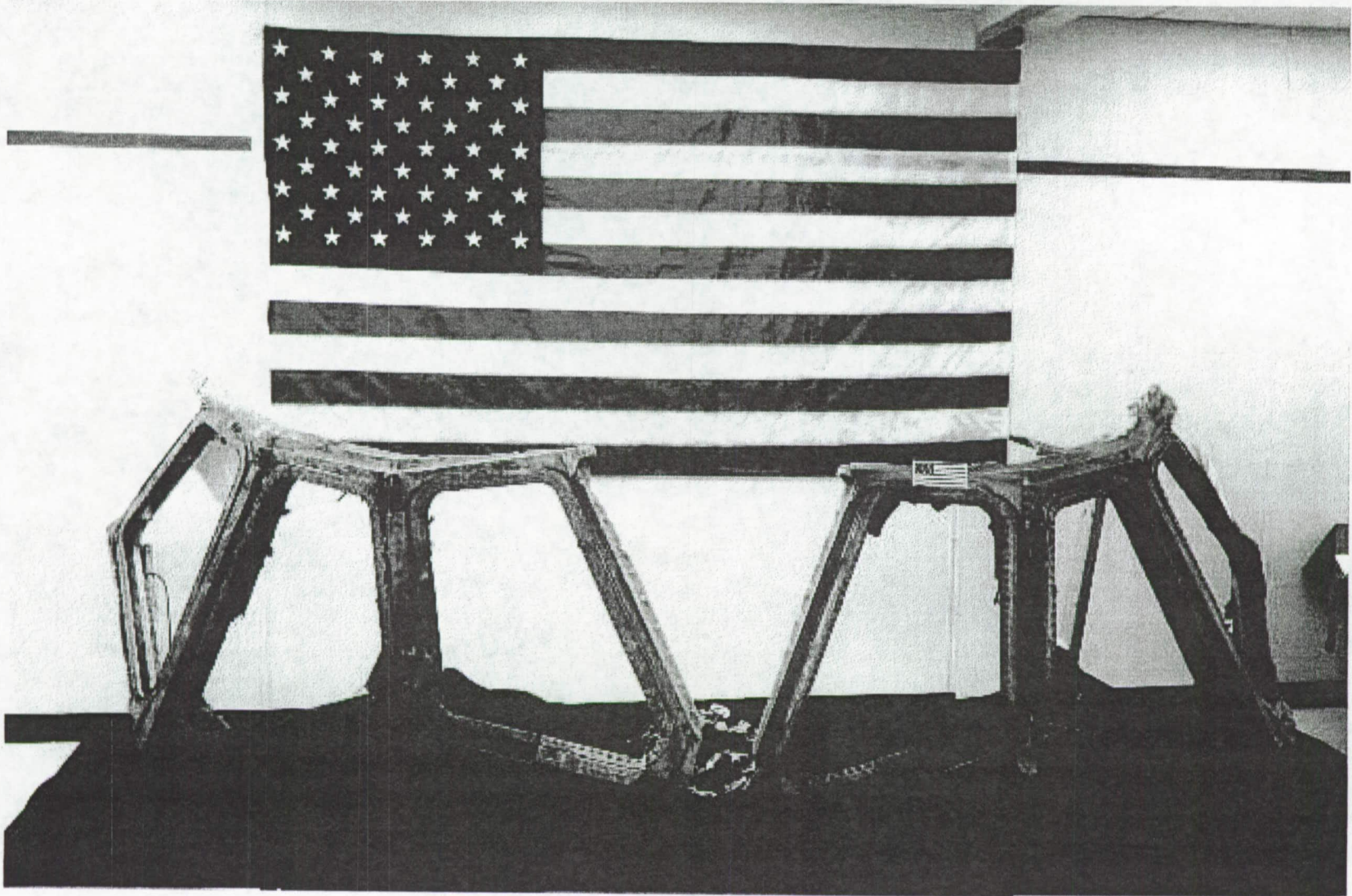


Columbia Preservation Project





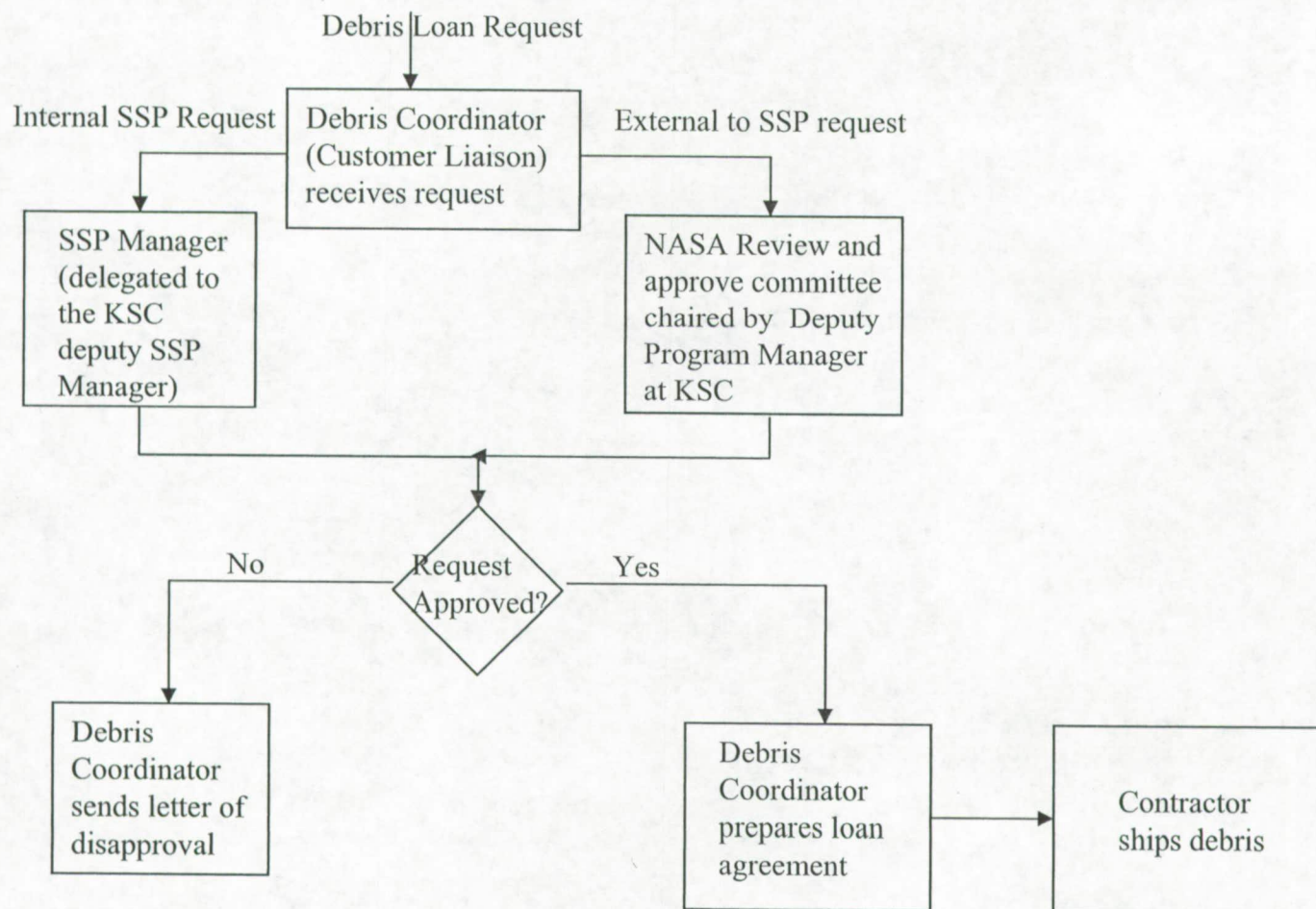
Columbia Preservation Project





Columbia Preservation Project

Columbia Debris Loan Process





LEHIGH
UNIVERSITY



*The Columbia Debris Failure Analysis
Program at
Lehigh University*

*R. M. Deacon
A. R. Marder*

AeroMat 2005

Mat 338 – Failure Analysis Reports

- Capstone senior level materials science and engineering course
- Requires students to draw on knowledge learned in previous 3½ years
- Discuss mechanisms and identification of various failure modes in lectures
- Hands on demonstrations of actual failures in laboratory session
- Culminates in independent failure analysis project

Why Study Columbia Debris?

- *Excellent example of real life failure*
 - Complex materials experienced severe loads and temperatures during hypersonic re-entry
 - Unknown sample history / background
 - Little data on loads and conditions at failure
 - Sample contamination issues
- *Opportunity to turn tragic event into an educational learning tool*

The Process

1. Assignment of debris
2. Observations and planning
3. Submission of cut plans
4. Sectioning and metallography
5. Light optical microscopy
6. Scanning electron microscopy / EDS

Emphasized throughout –

DOCUMENTATION and SECURITY

Sample Cut Plan

I. Defect Description

Defect #0291 is a subsurface piece of the Columbia reactor. Figure 1 shows photographic images (a) of the top surface of the defect (Fig. 1(a)) and of the bottom surface of the defect (Fig. 1(b)).

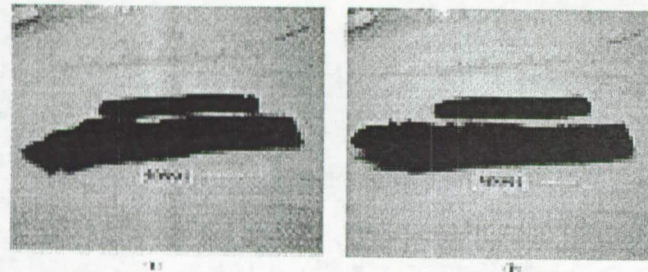


Figure 1. Photographic images of defect #0291, a rectangular aluminum defect.

II. Cut Plan

Four different sections are to be prepared from defect #0291 for future analysis. Figure 2 shows the locations that are to be made in the upper portion of defect #0291 and 2 lower sections to be prepared in the lower portion of defect #0291. In preparation, however, the different material layers of the defect are investigated. A

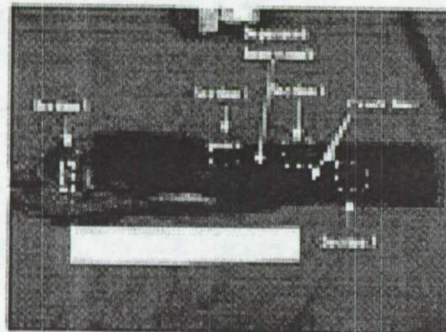


Figure 2. Locations to be cut from defect #0291. Three different cross-sections will be prepared from the defect for microscopic analysis.

microstructural analysis of the surface interface between these pieces will help in determining the underlying causes for the type of material behavior. This analysis will be performed using a photomicroscope (POM) technique. In preparation of this analysis, using scanning electron microscopy (SEM), will be performed in order to locate the failed surface interface. This procedure that will provide a large area of repeated image analysis, as shown in Figure 3, is shown in Figure 3. This procedure will be used from the area point of the defect, which is located in Section 1. This procedure of the region may help in determining the region of failure and, perhaps, the cause of failure for the subsurface defect. Section 2, which is a section of the defect, is made by using a diamond saw that will cut through the compound for the failure of the failed surface interface, as shown in Figure 3. This procedure will allow the failure to be found. In addition, a cross-sectional view of the region will allow for a microstructural analysis of the material layers of the defect.

Photographic and scanning electron images of each of the prepared cross-sections are to be prepared during the cutting process on the basis of Figure 3. Figure 3 shows a close-up view of the cut of the defect material to be made using a diamond saw. The diamond saw will be used to cut the defect material. The diamond saw will cut the top and bottom layers of the defect. The diamond saw will cut the top and bottom layers of the defect and the diamond saw will cut the diamond saw compound that is used to cut the defect. One should notice that there seems to be a large layer of material between the top and bottom layers of the defect. This layer of material, which is an interface between the top and bottom layers of the defect, is to be carefully analyzed using POM and SEM/EDS in order to determine the cause of the separation between the layers of the defect.

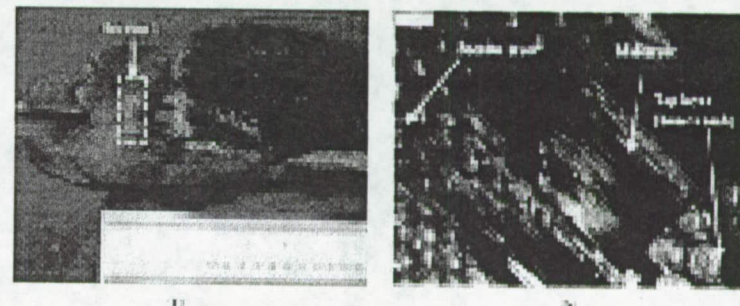
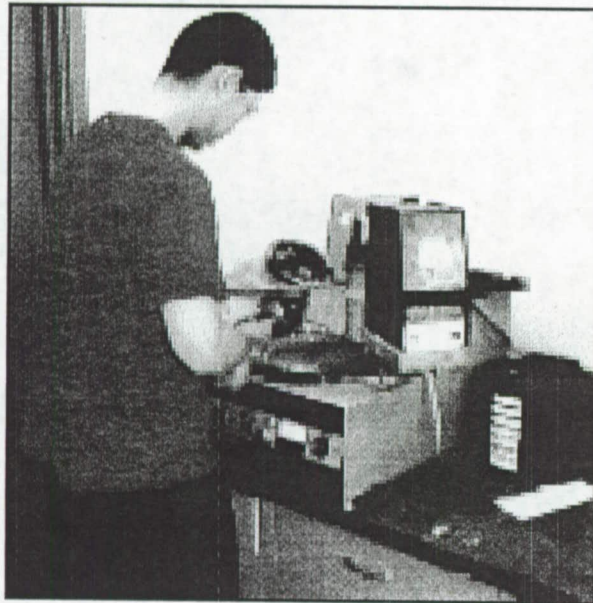


Figure 3. The top of defect #0291 (a) and the bottom of defect #0291 (b). The diamond saw is used to cut the defect material and to cut the diamond saw compound that is used to cut the defect. The diamond saw will cut the top and bottom layers of the defect.

A photomicrograph image of each of the four different sections is shown in Figure 4. This image shows the region of the defect that was cut and shows the failure of the subsurface interface of the defect. The diamond saw of the defect will be

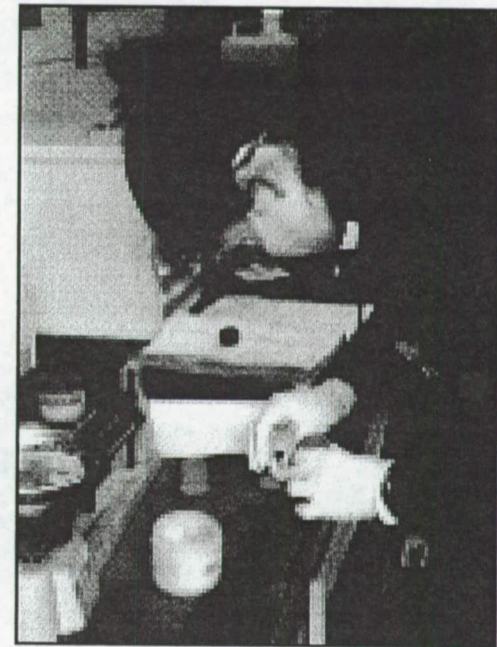
Sample Preparation



*Polishing Aluminum
Samples*

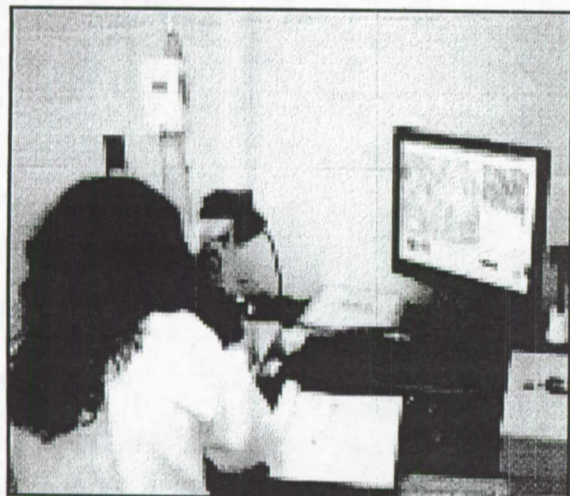


*Epoxy
Impregnation*

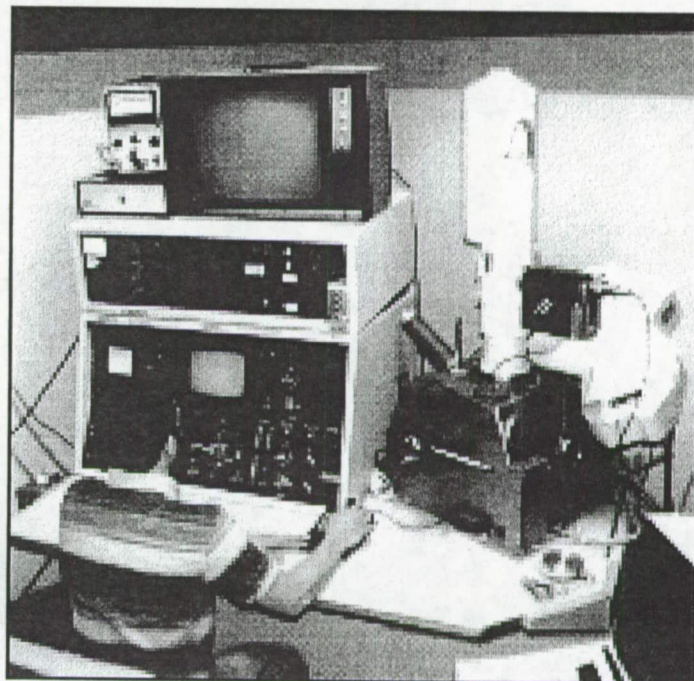


*Mounting Tile
Sections*

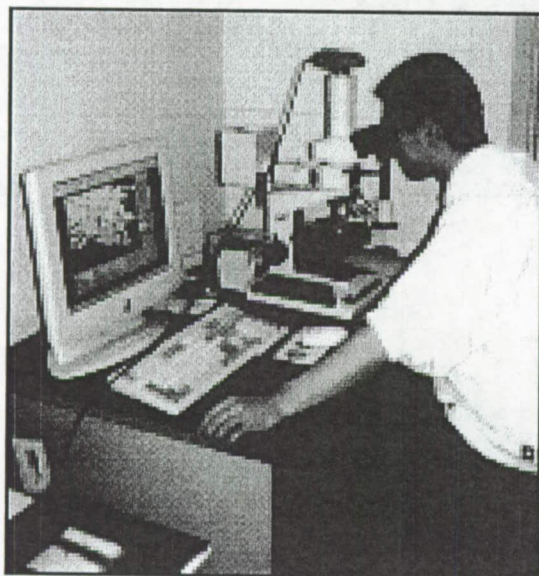
Image Analysis, LOM, SEM



*Digital Image
Analysis*



*Dedicated
Undergraduate
Scanning Electron
Microscope*



*Digital Image
Archiving
System*

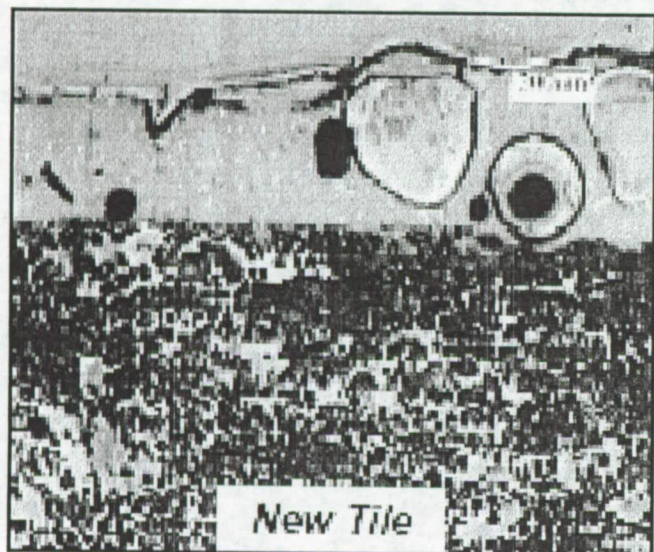
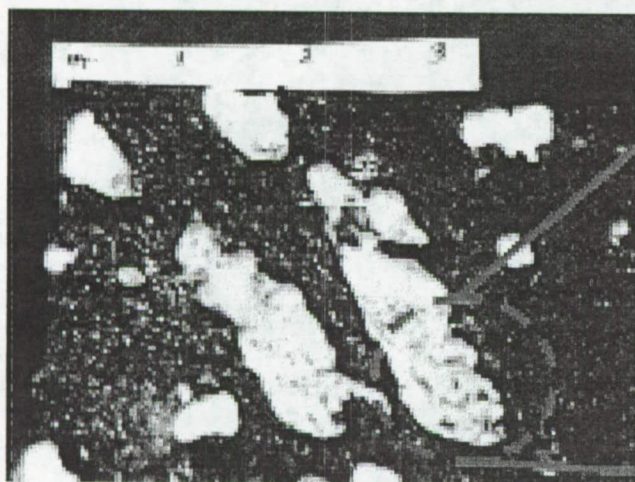
Media Coverage

- *Associated Press*
- *Fox Philadelphia*
- *CBS Harrisburg*
- *Lehigh Valley Tempo*
- *The Morning Call*

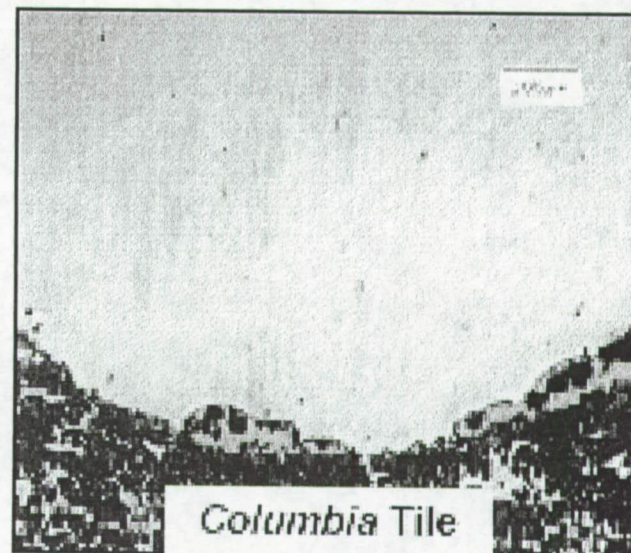


*Professional
development experience*

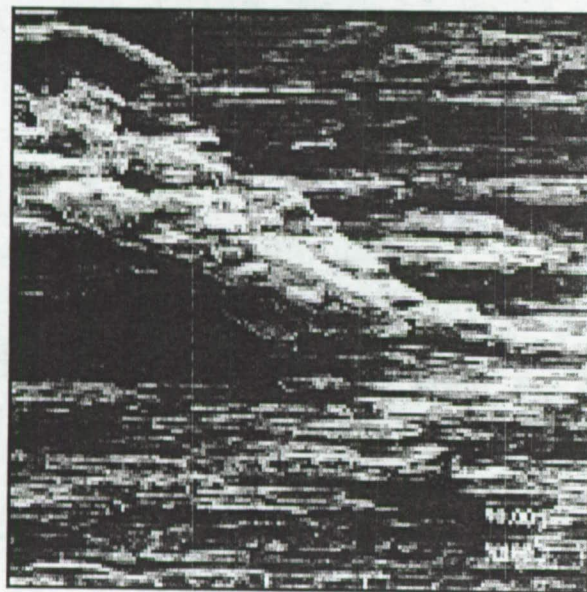
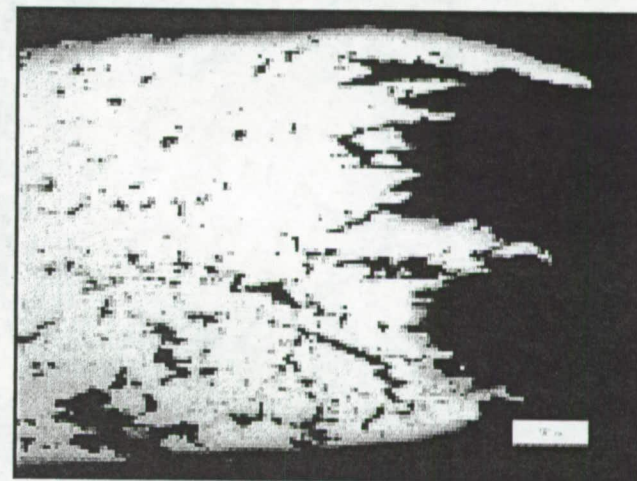
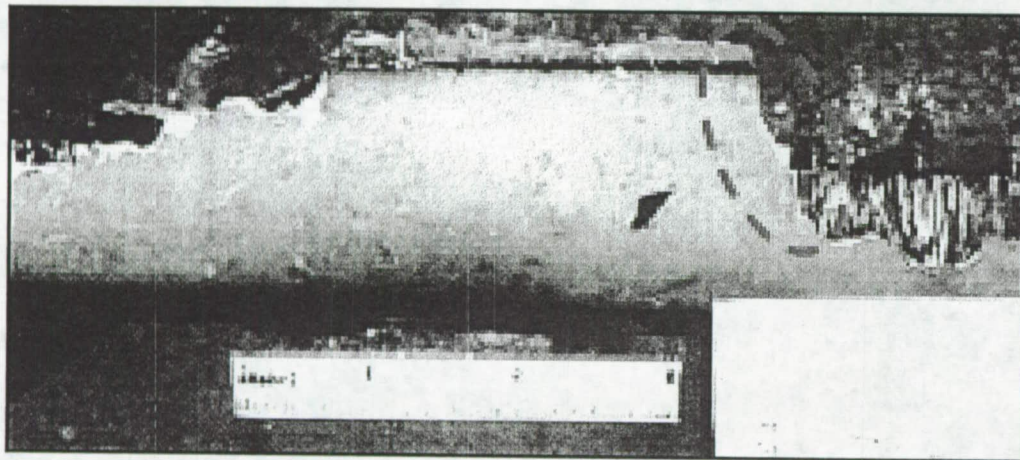
Analysis of Columbia Tile: Slumping of RCG Layer



*Comparison of
RCG Layer on
New and
Recovered
Columbia
Tiles*

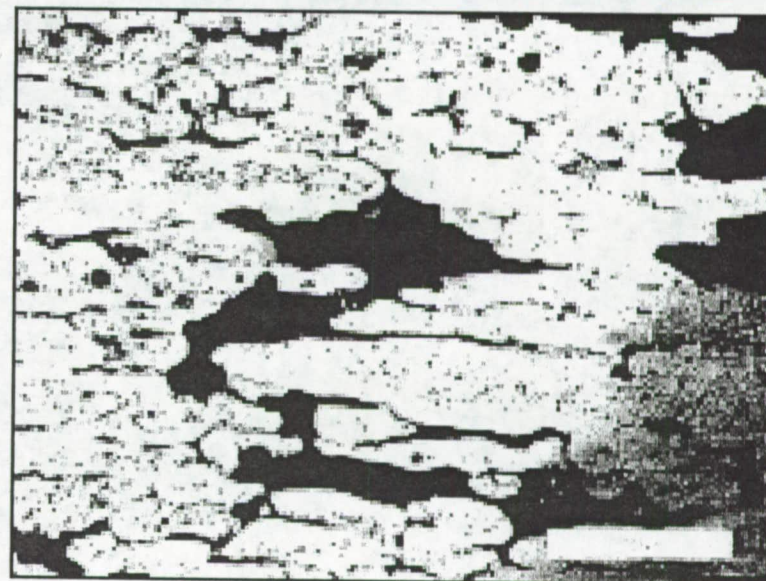


Analysis of Al Upper Spar Fitting: Void Formation and Intergranular Fracture

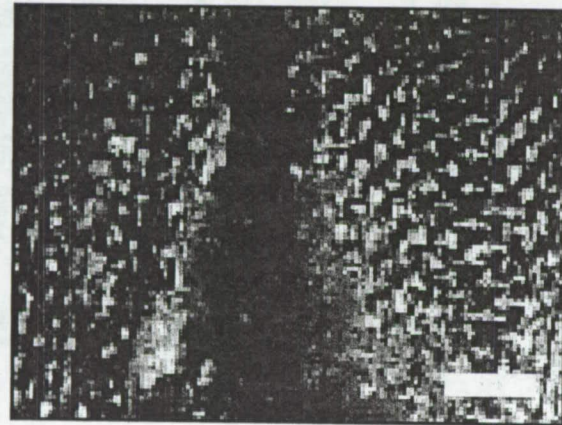
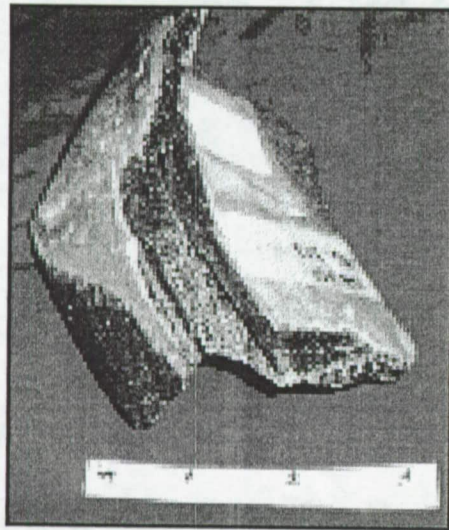


*Void
Formation*

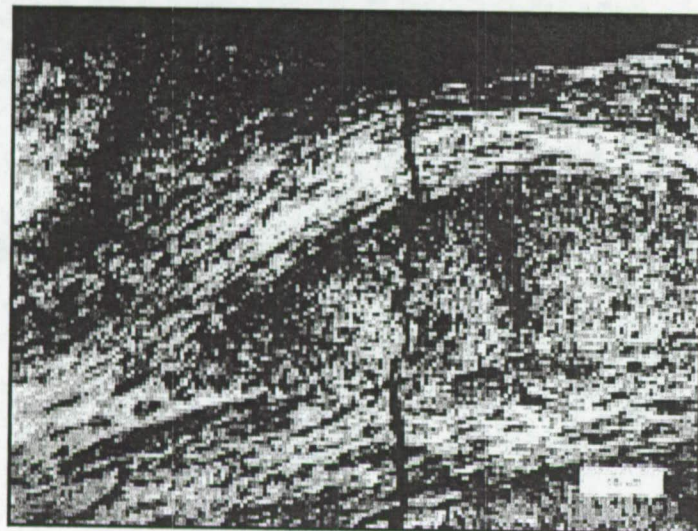
*Intergranular
Fracture*



Analysis of RCC T-Seal: SiC Erosion and Cracking

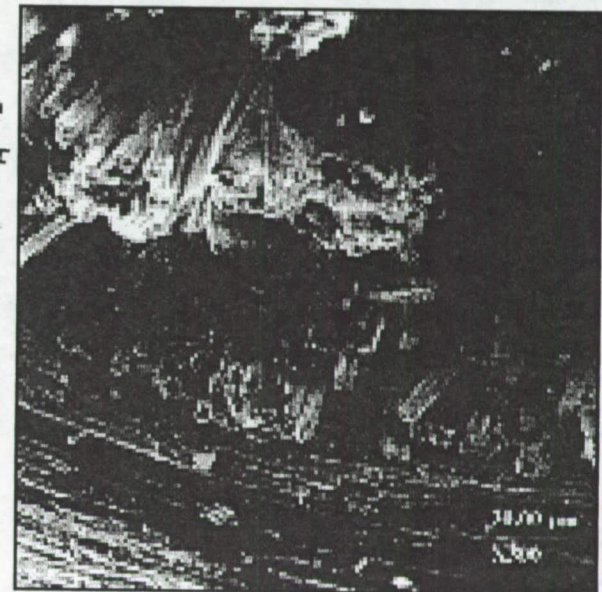


*Erosion
of SiC
Layer*



*Cracks
through
SiC layers*

*Brittle
fracture of
fibers*



Conclusions

- Excellent project for failure analysis class
- Students experience
 - Real life failure analysis
 - Working in secure environment
 - Interactions with the media
- Student analysis of debris adds to NASA knowledge base
- Program should be continued in the future