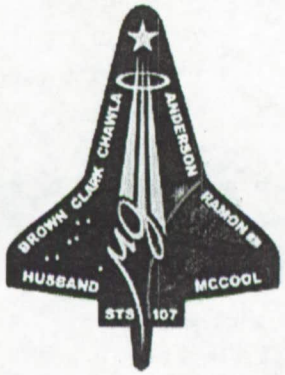


"The Space Shuttle Columbia Preservation Project – The Debris Loan Process"

Scott Thurston, NASA Kennedy Space Center
Jim Comer, United Space Alliance
Dr. Arnold Marder, Lehigh University
Ryan Deacon, Lehigh University

June 8, 2005

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)

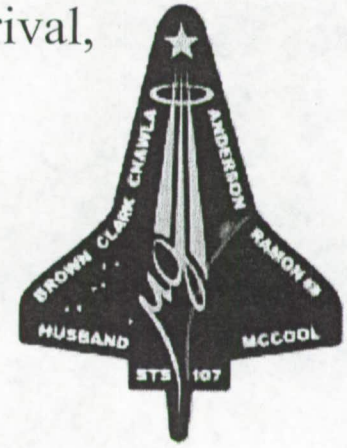
- Toxic Vapor Checks are performed on all items before processing

Quality Receiving

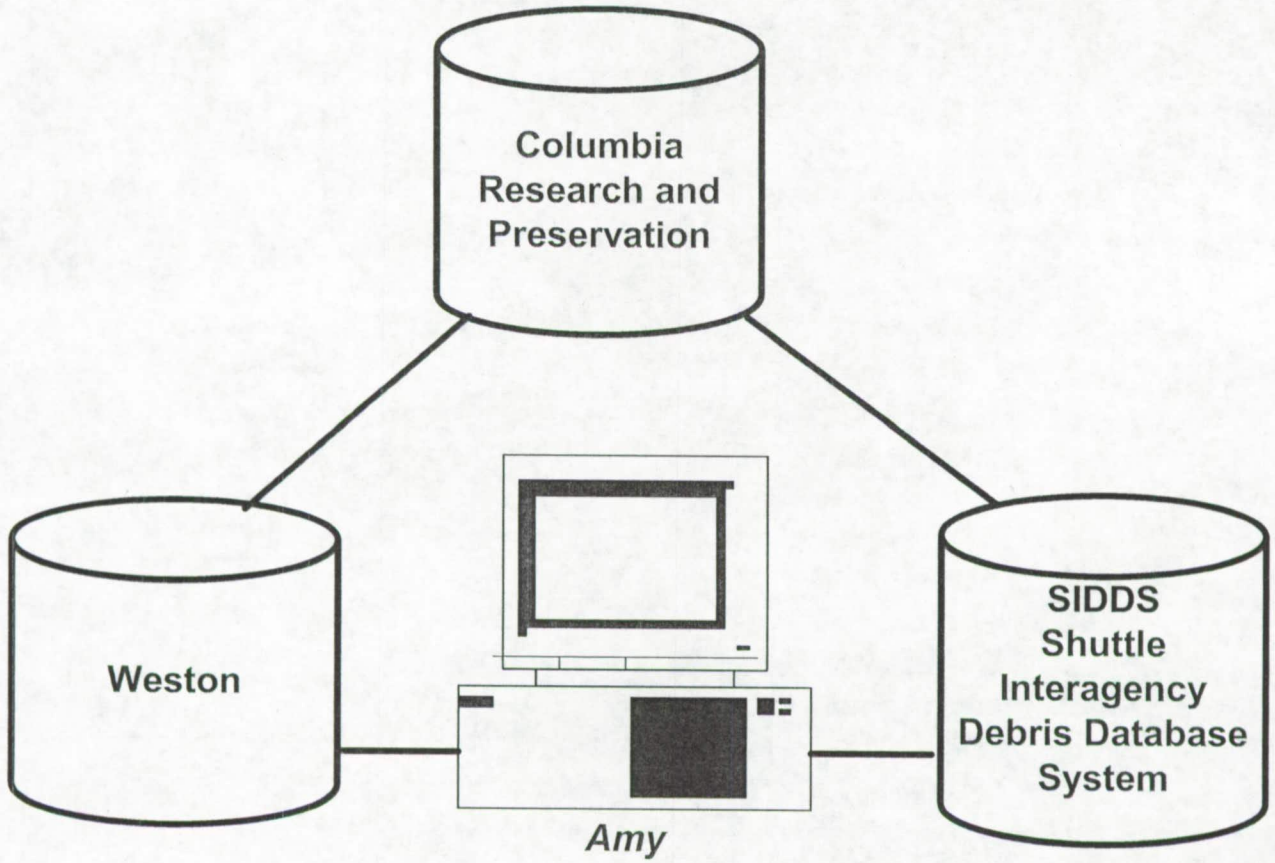
- Debris items are:
  - Photographed bar-coded and tagged
  - Entered into CRDS. Multiple items a separated into parent/child relationships
  - Data records include item description, time and date of arrival, longitude/latitude and date and time of recovered area.

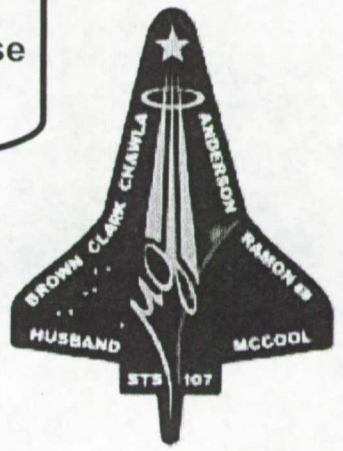
Movement of Debris

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



Database Interface





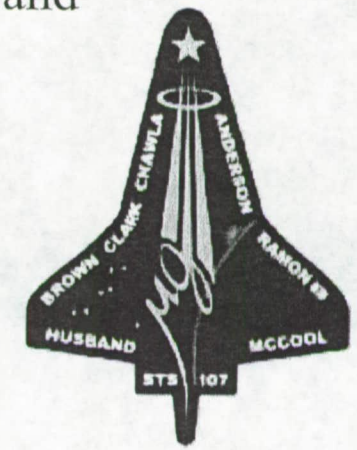
Coordination of Debris Requests

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

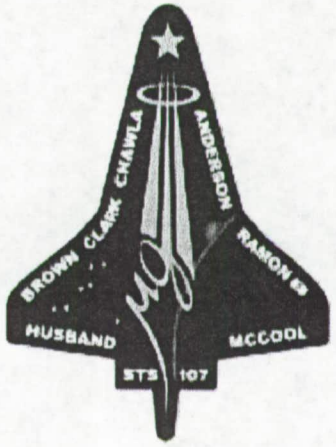


Coordination of Debris Requests

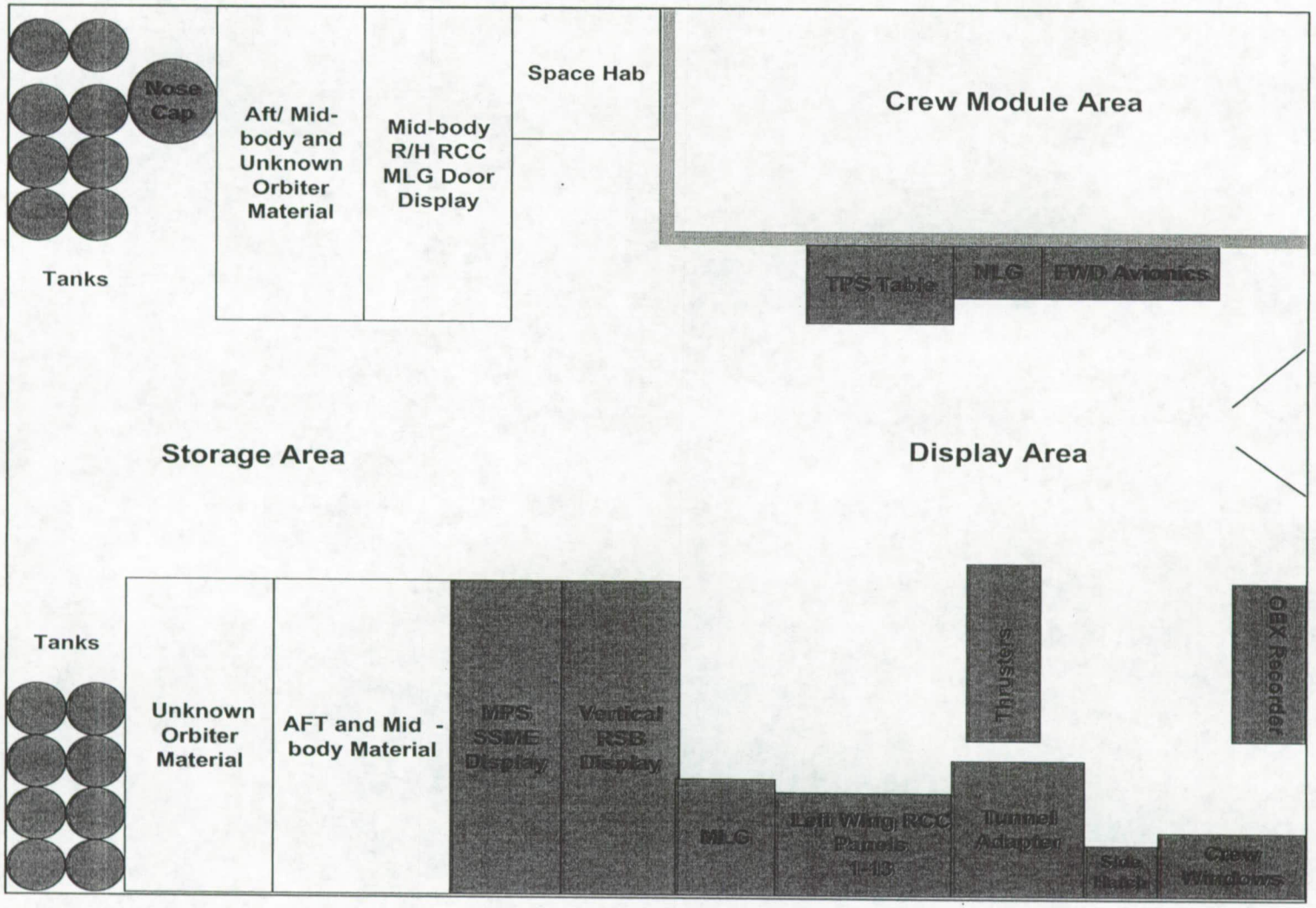
External to Space Shuttle Program

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

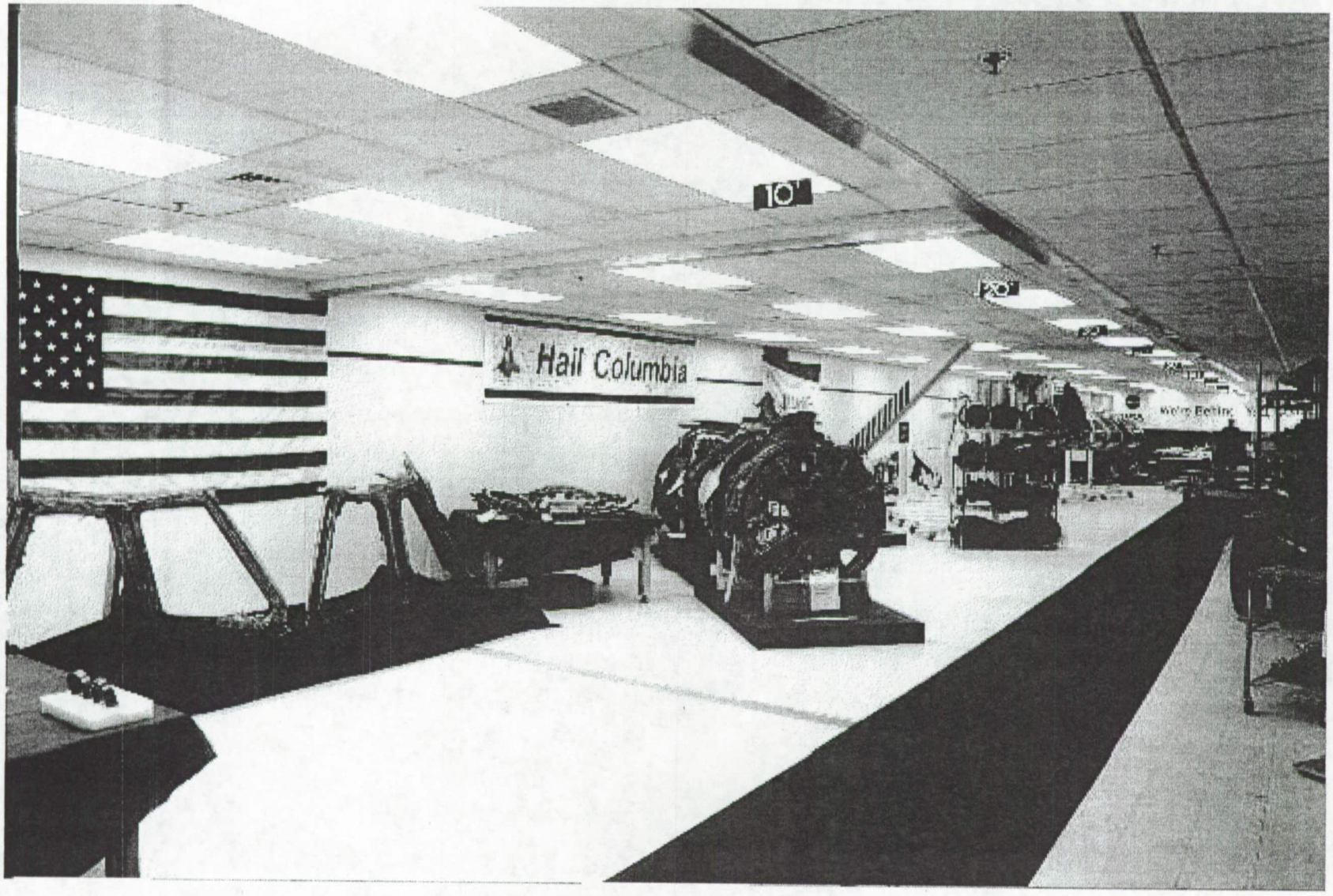
- Designated NASA Approval Authority (Space Shuttle Program Manager)
- Technical Expert (Subsystem Manager)
- NASA expert in research process.
- NASA Legal
- NASA Education (education-related request)
- FCOD/Astronaut Office



Columbia Preservation Project

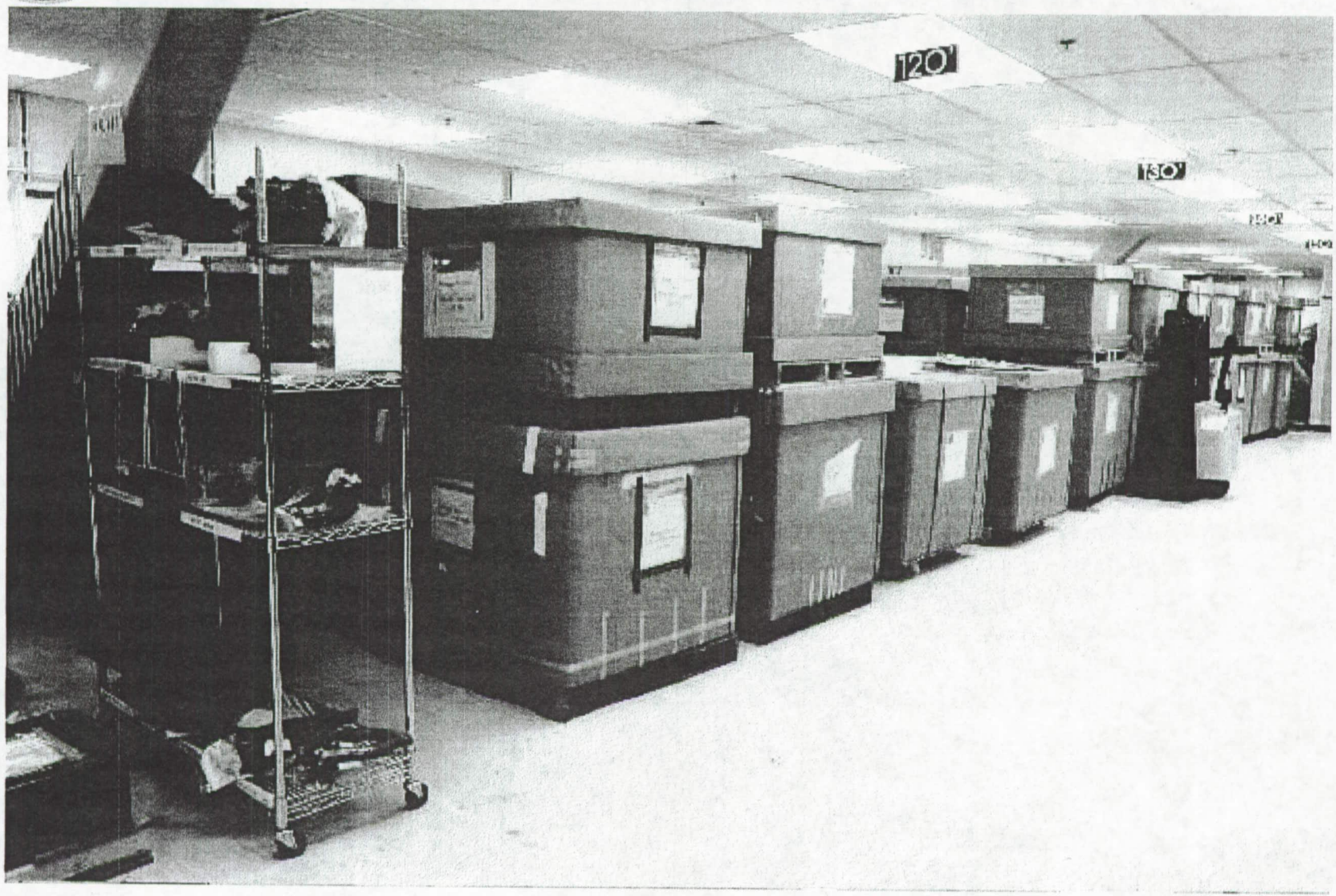


Columbia Preservation Project



Columbia Preservation Project

Columbia Preservation Project



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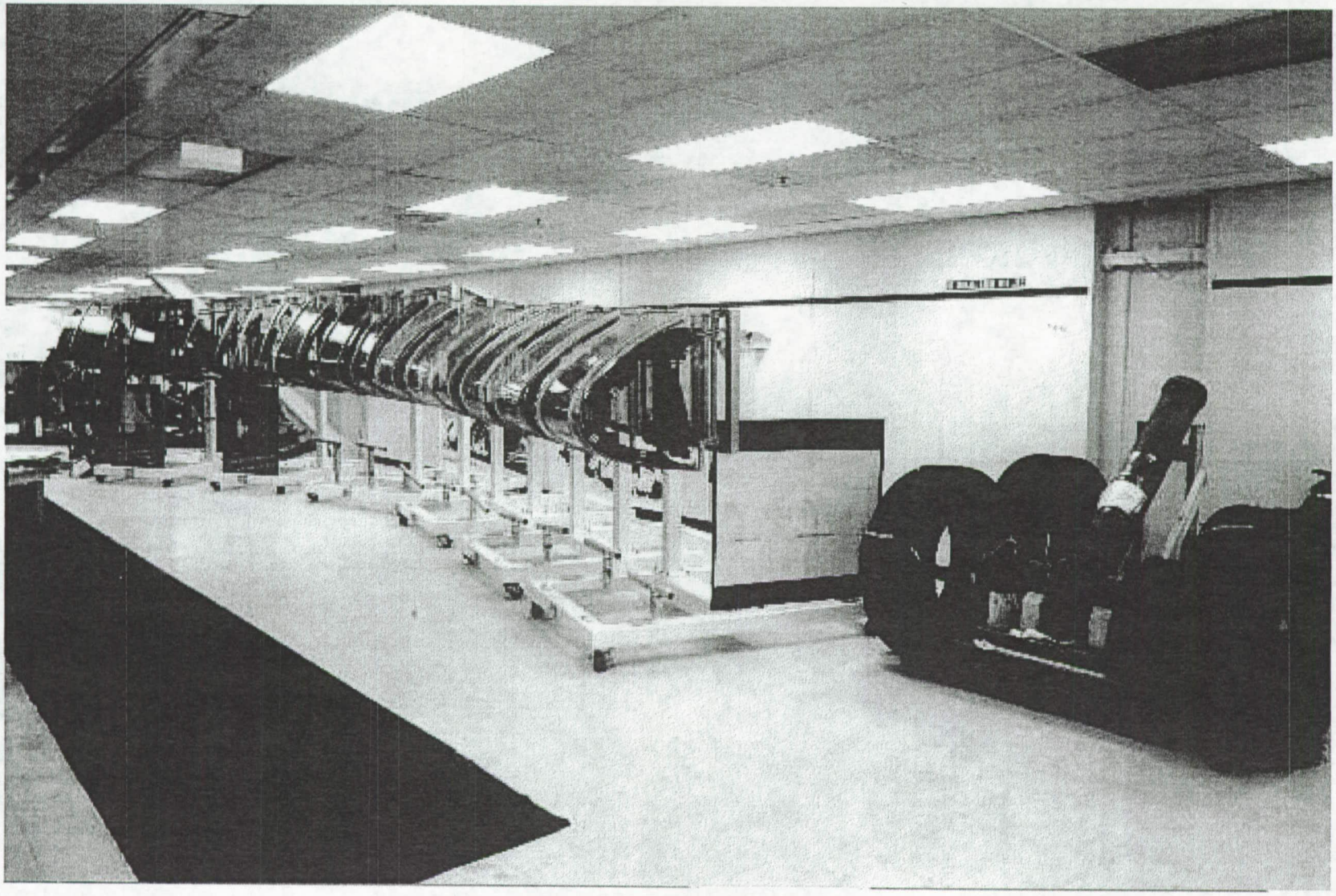

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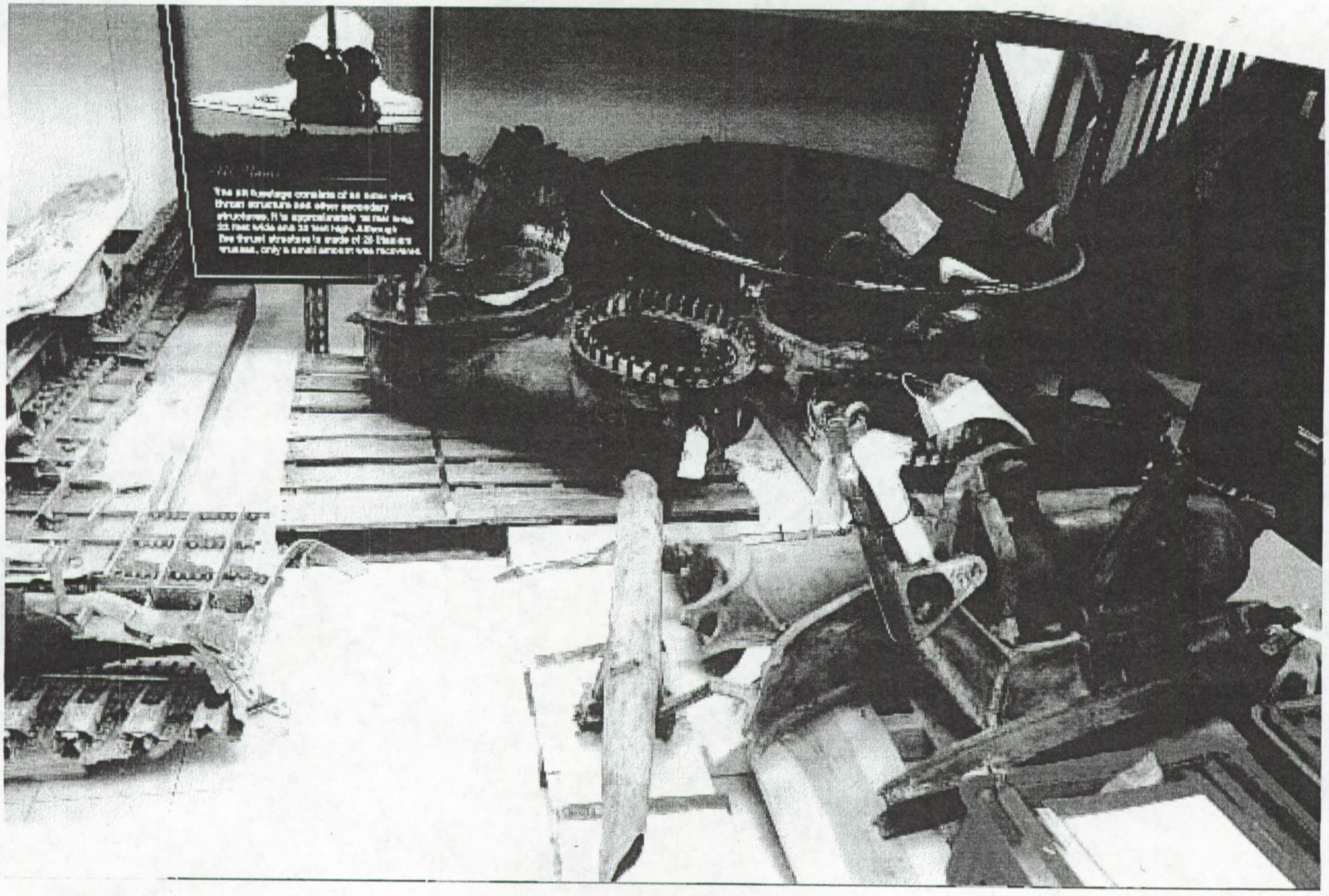
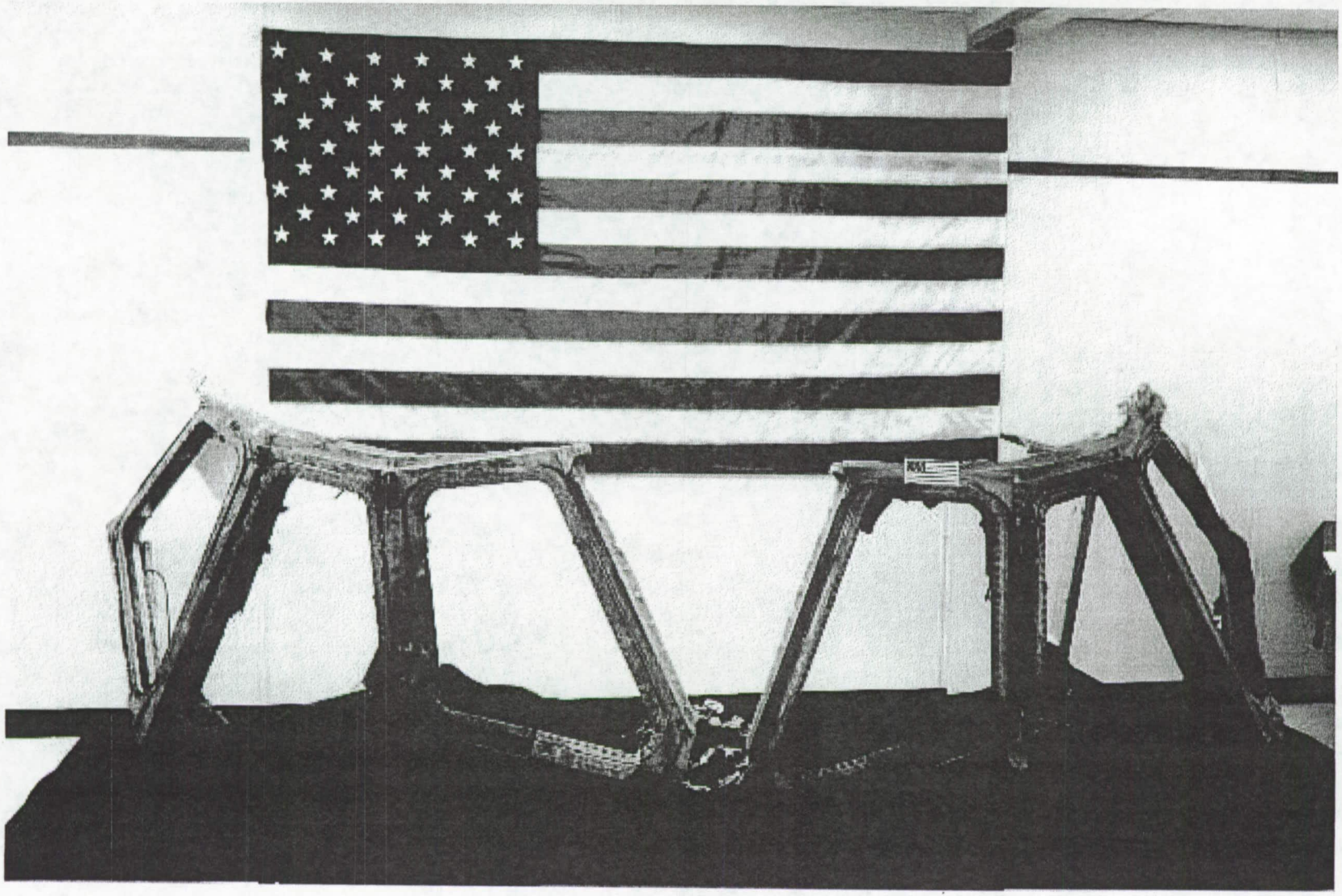
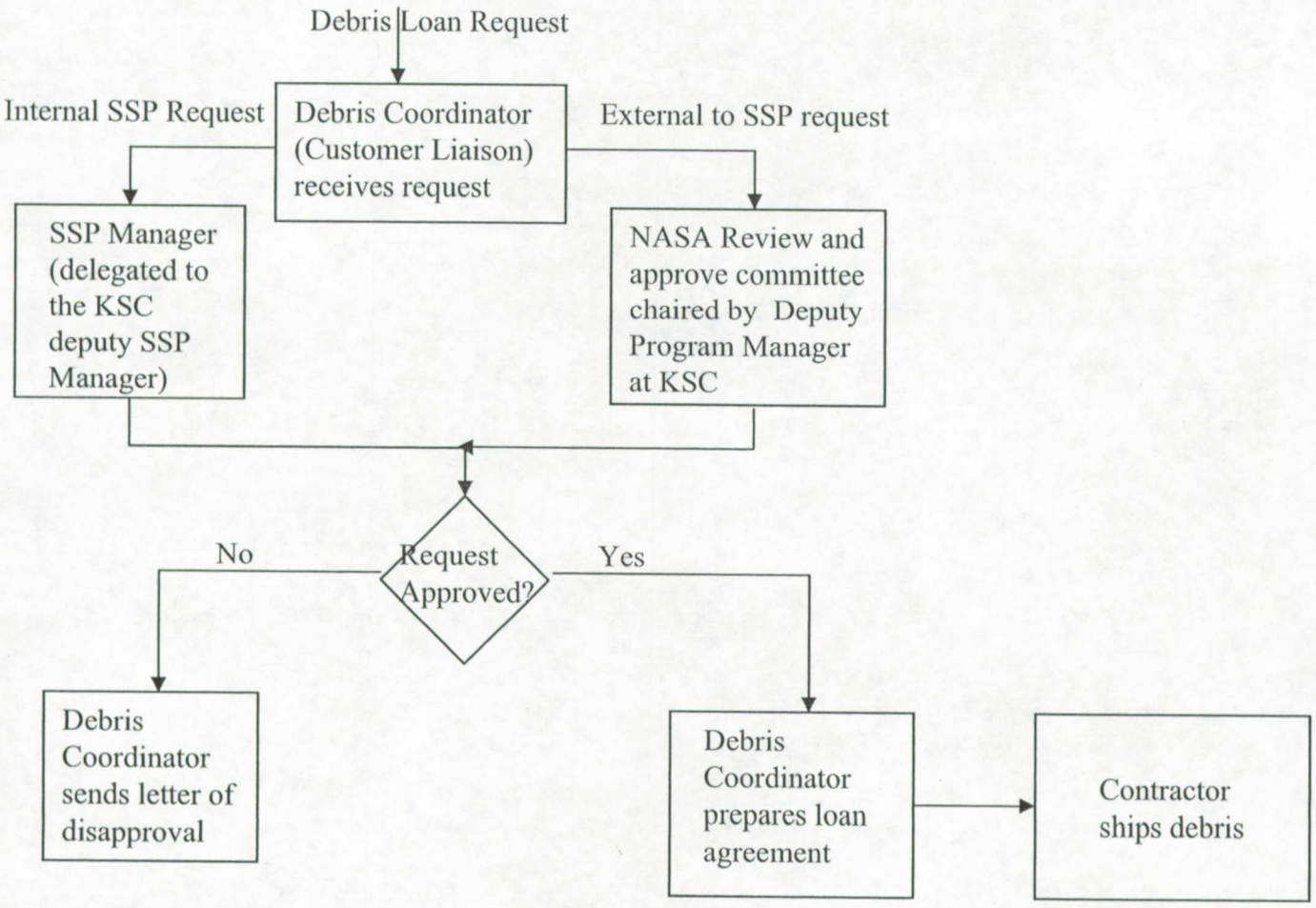


Columbia Preservation Project



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*

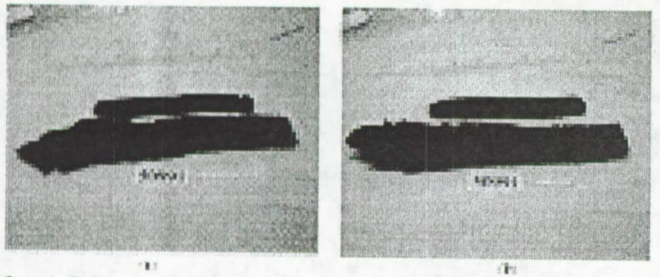
The Process

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

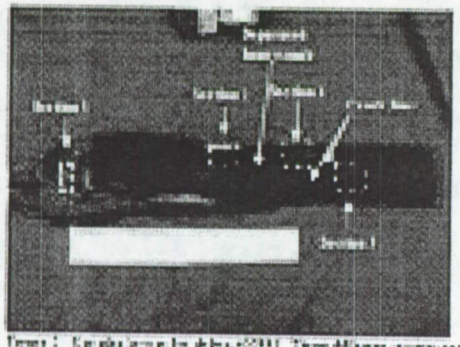
Emphasized throughout –

DOCUMENTATION* and *SECURITY

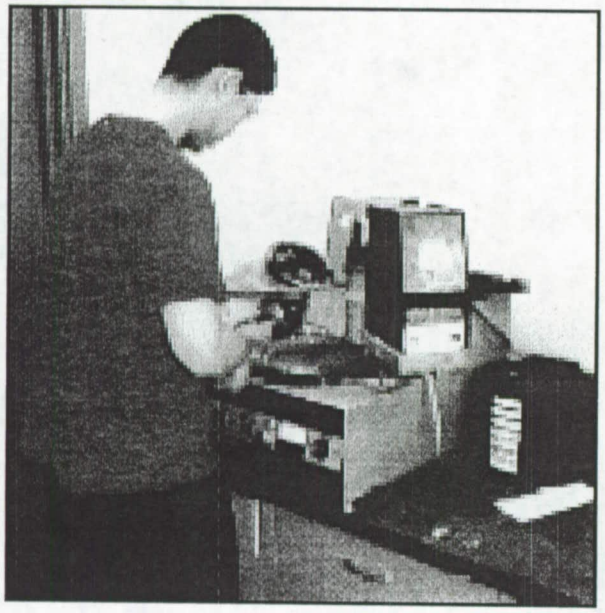
Sample Cut Plan



(a) (b)



Sample Preparation

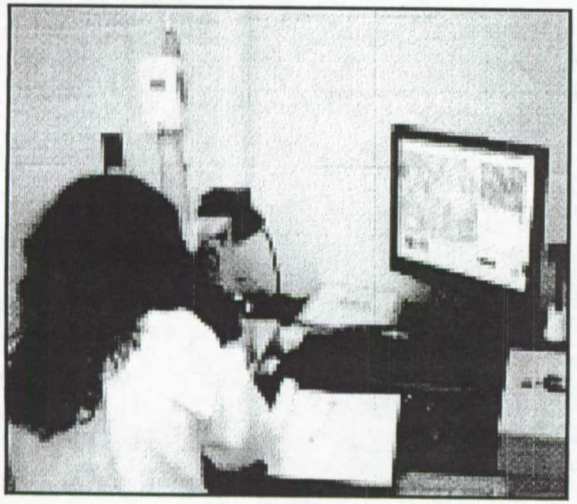


Polishing Aluminum Samples

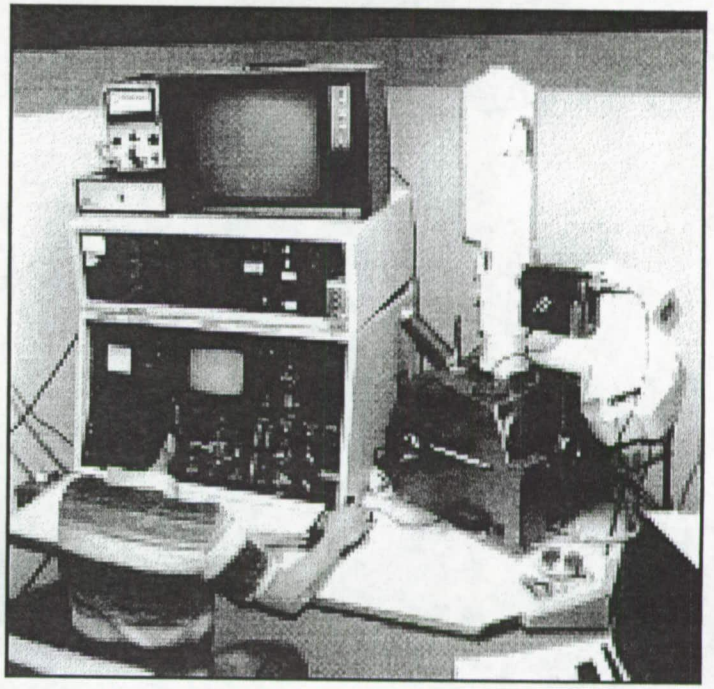
Epoxy Impregnation

Mounting Tile Sections

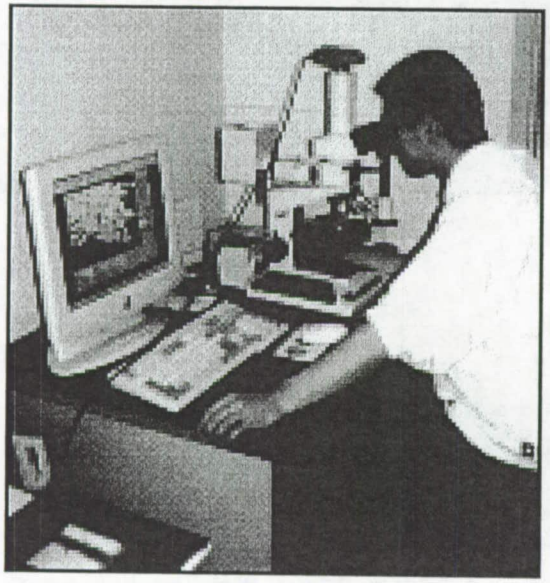
Image Analysis, LOM, SEM



Digital Image Analysis



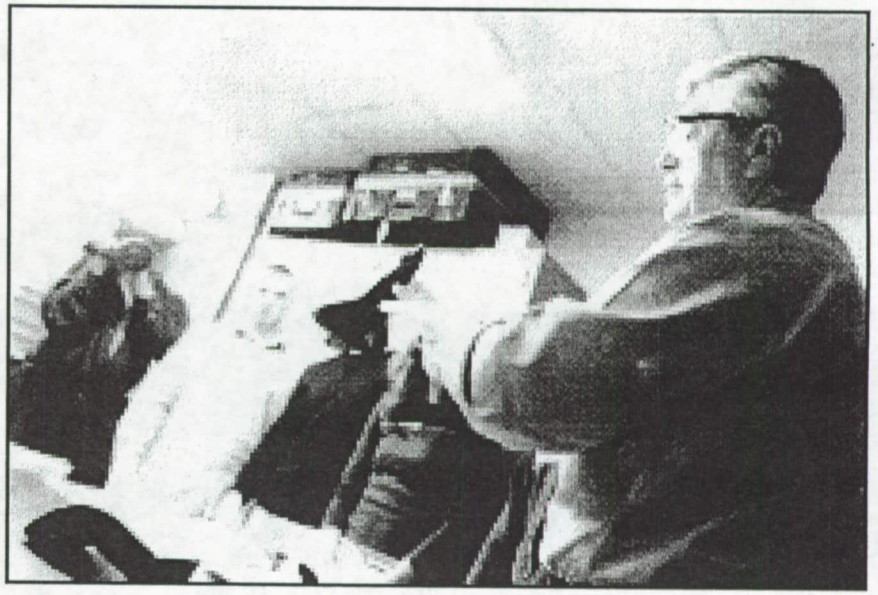
Dedicated Undergraduate Scanning Electron Microscope



Digital Image Archiving System

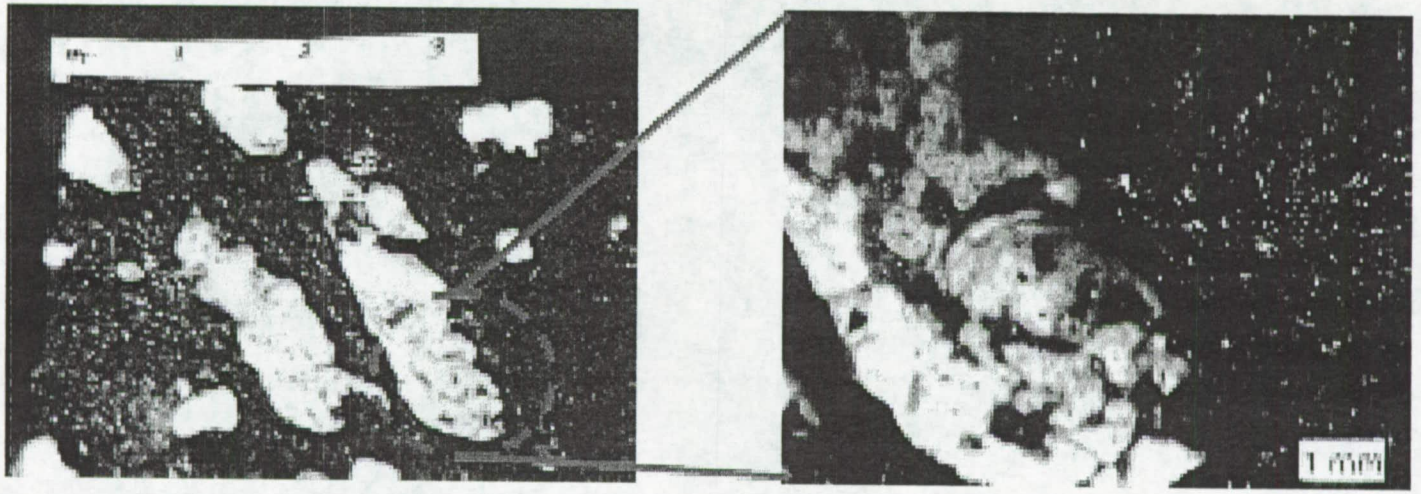
Media Coverage

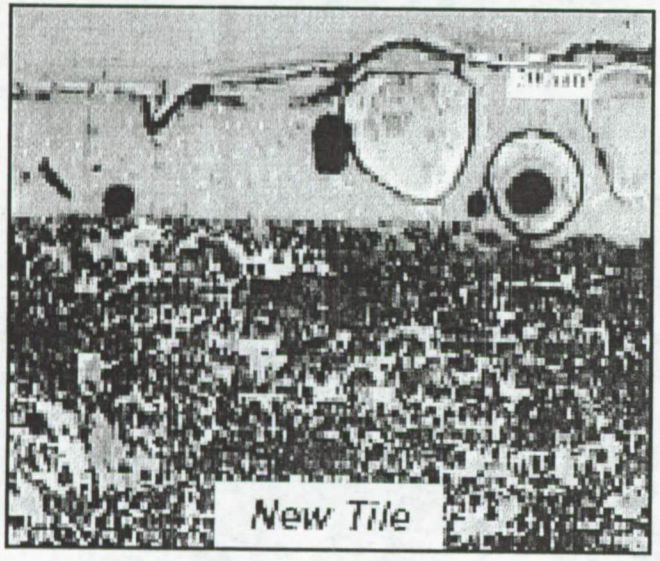
- *Associated Press*
- *Fox Philadelphia*
- *CBS Harrisburg*
- *Lehigh Valley Tempo*
- *The Morning Call*



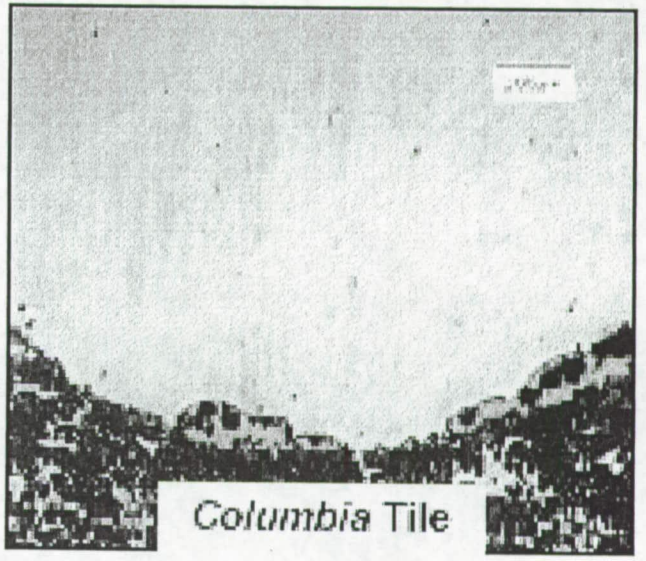
Professional development experience

Analysis of Columbia Tile:
Slumping of RCG Layer

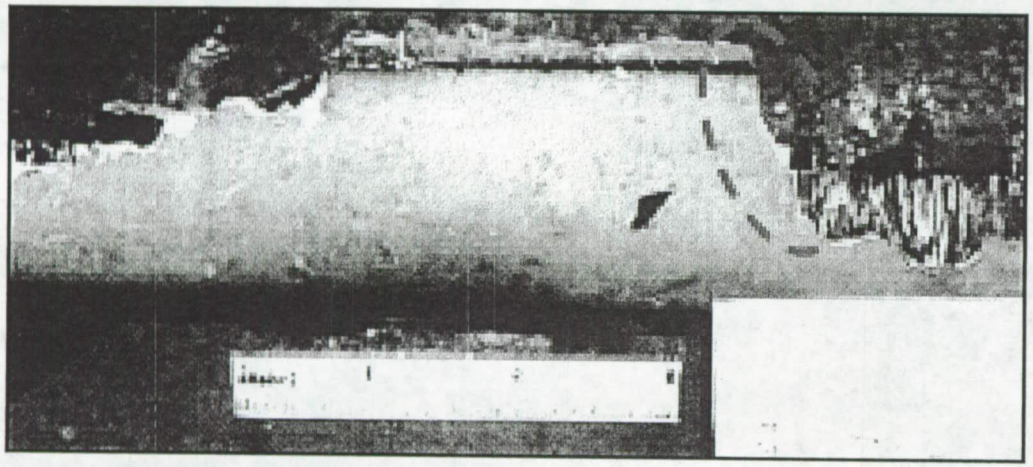


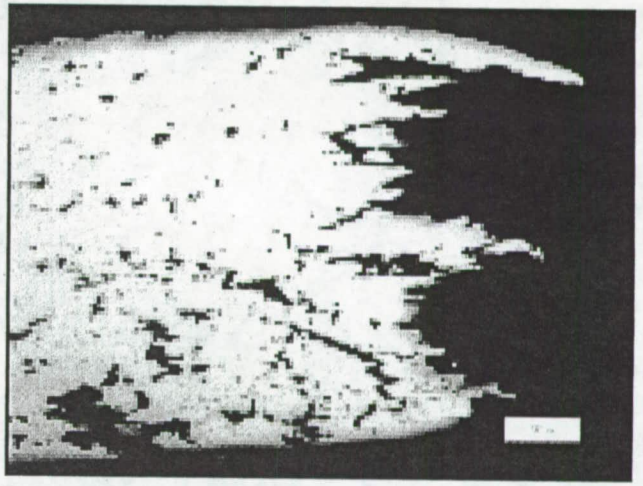


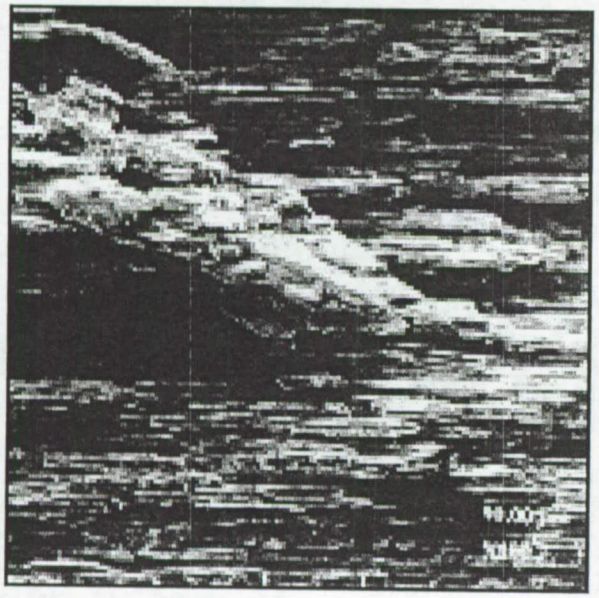
Comparison of RCG Layer on New and Recovered Columbia Tiles



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

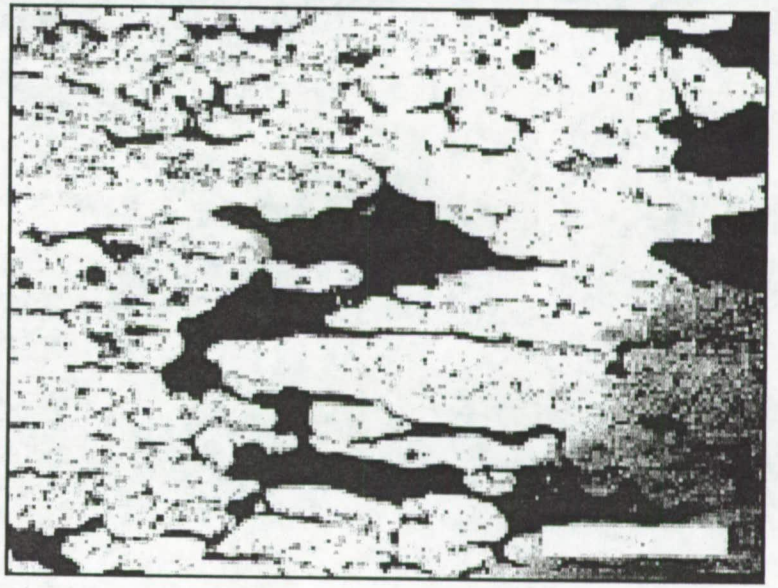






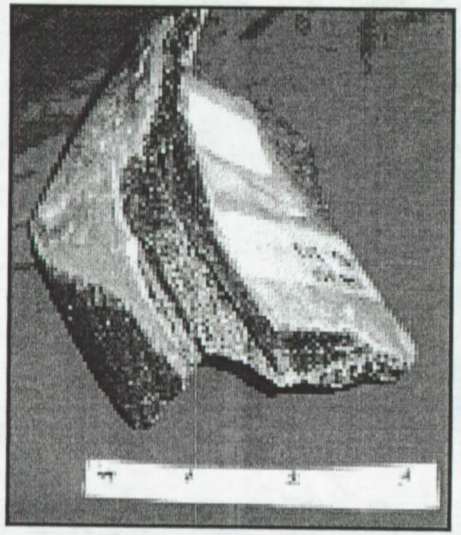
Intergranular Fracture

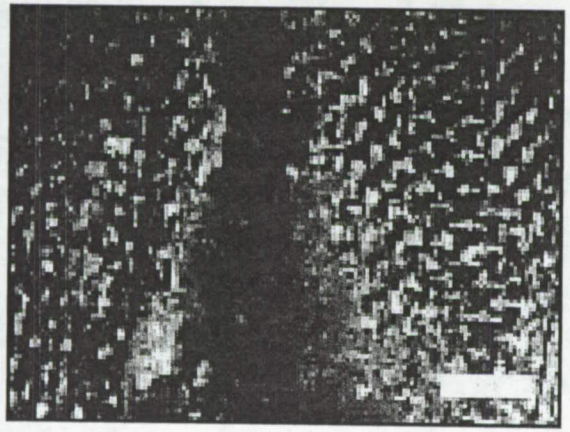
Void Formation



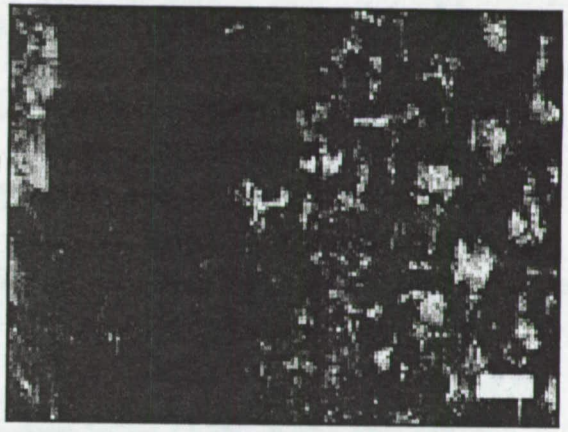
Analysis of RCC T-Seal:

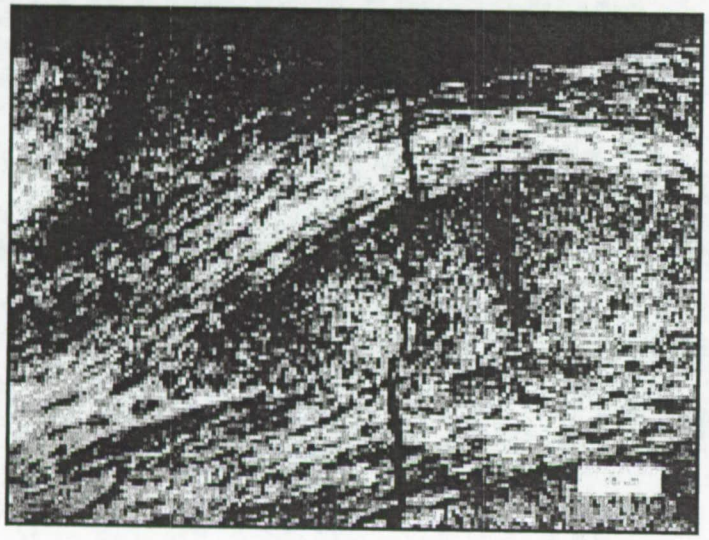
SiC Erosion and Cracking





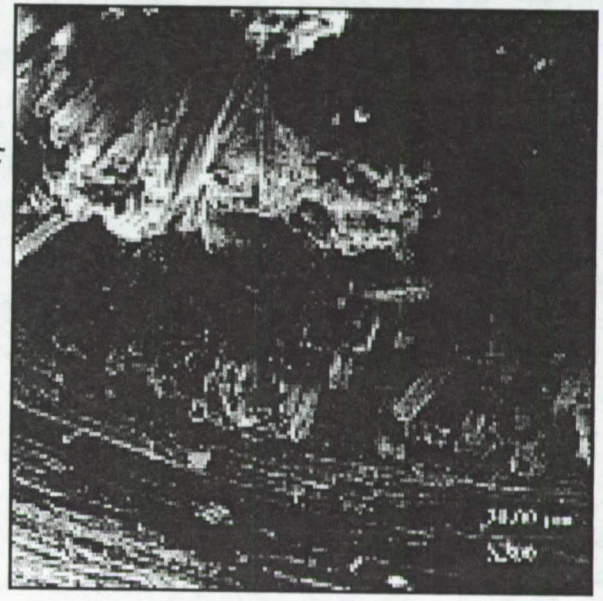
Erosion of SiC Layer





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