# *Space Shuttle Stiffener Ring Foam Failure Analysis, a Non-conventional Approach.*

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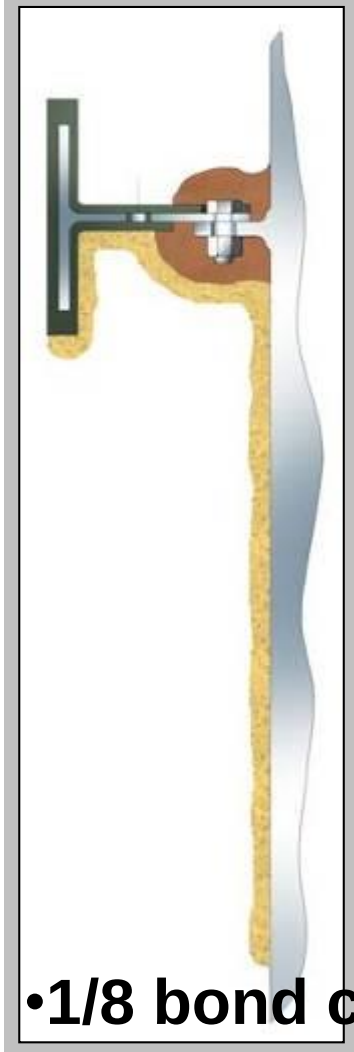
## *Shuttle Legacy Flight Hardware will Fly on the Space Launch System*

# *Space Shuttle on Ascent*

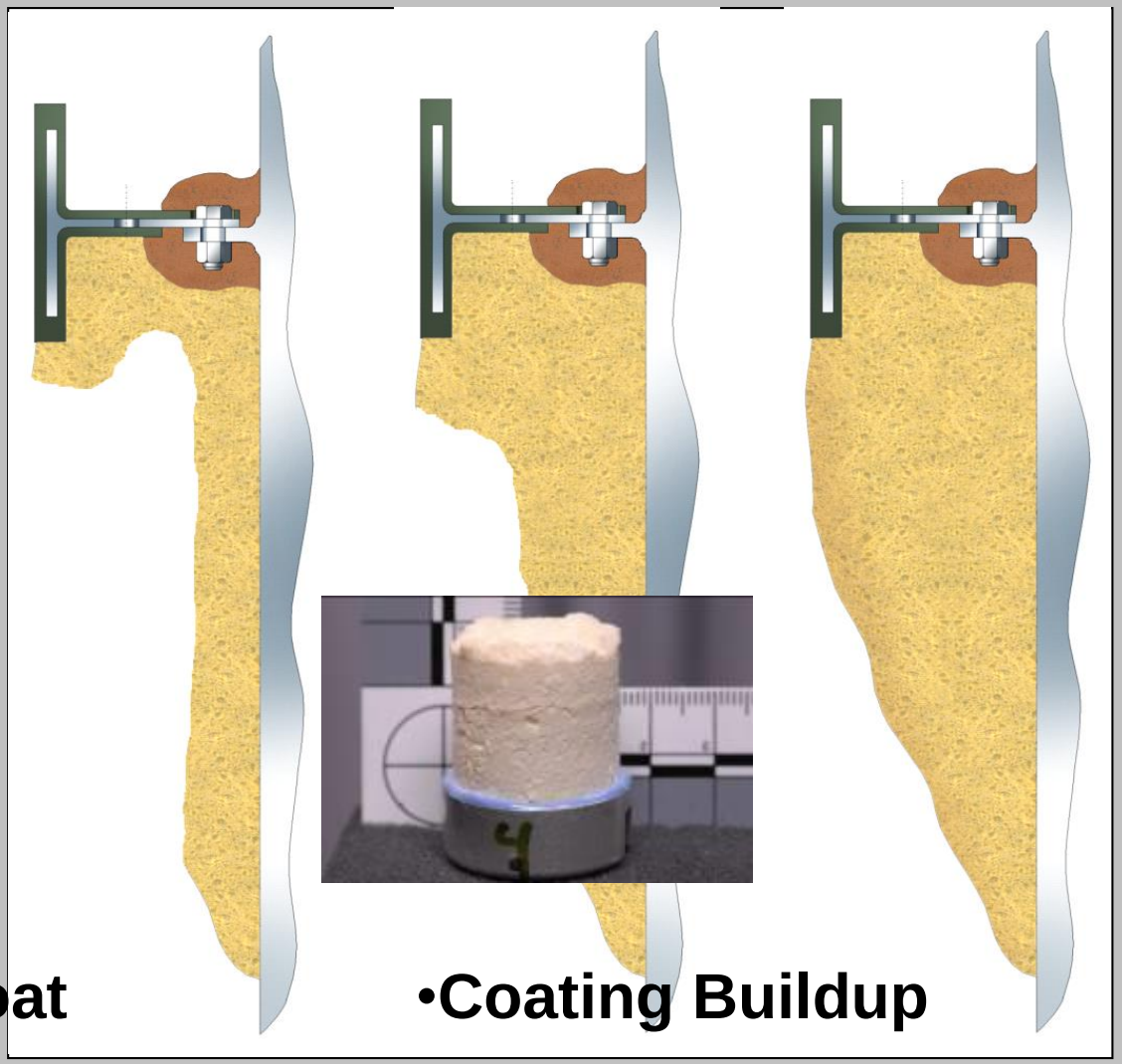
# *SRB Recovery*

# *Stiffener Ring*

# *SRB Foam Buildup*

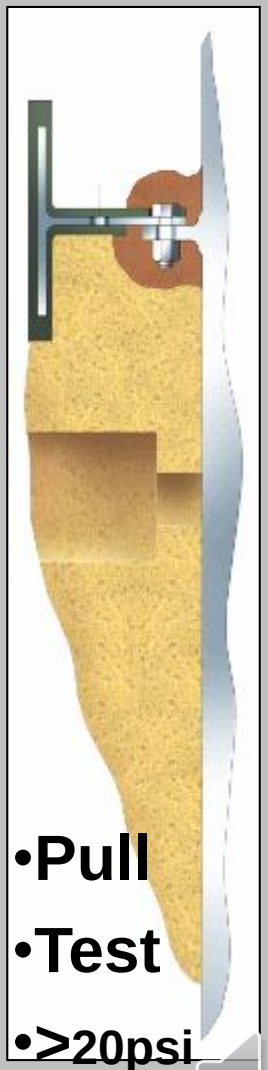


•1/8 bond coat





•Coating Buildup



•Pull

•Test

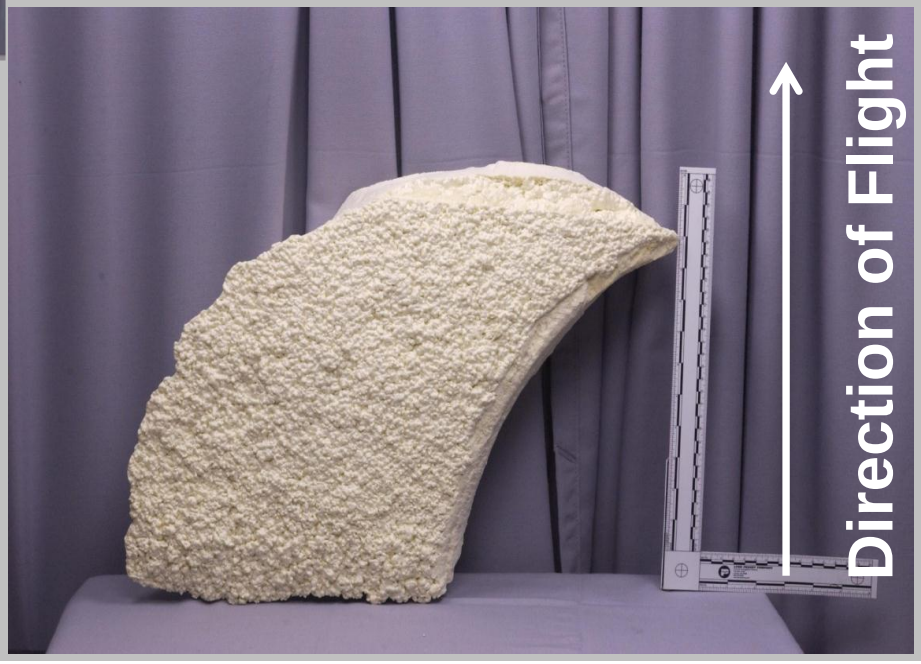
•>20psi

## *Qualitative Inspection*

- ATK define the foam failures qualitatively by visual inspection of the presence or absence of foam residue on the de-bonded surface.

- Foam Failures fall into two categories
  - Adhesive
  - Cohesive
  - Mixture of both

# *Solid Rocket Booster Stiffener Ring Foam Failure*



# *Solid Rocket Booster Stiffener Ring Foam Failure*

The classical methods of analysis failed to provide a root cause into this foam failures for the last 25 years.

- Chemistry-extraction of residues
- Bulk property test
- Fracture analysis
- No known nondestructive analysis
- 10,000's of hours testing "process" variables

## A new approach was needed

### How would a microscopist look at this?

Cell morphology determines the mechanical strength of the foam.

Foam is the ideal media to preserve its own failure.

Cross sectioning to observe the cell morphology.

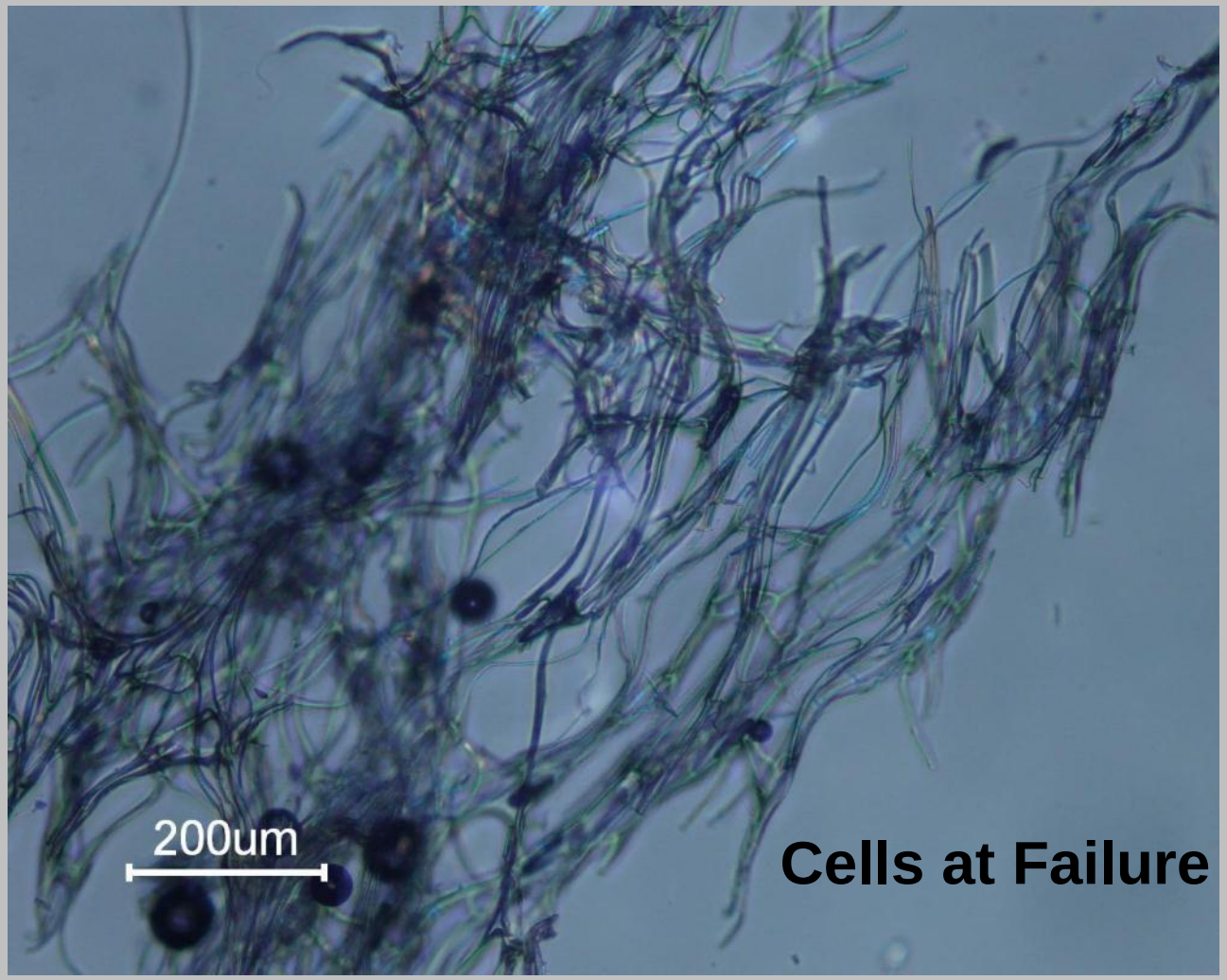
# *Foam Chemistry*

- A/B Ratio- mechanical strength and flexibility
- Blowing agent function of vapor pressure and temperature
- Exothermic reaction –driving the reaction rate
- Moisture

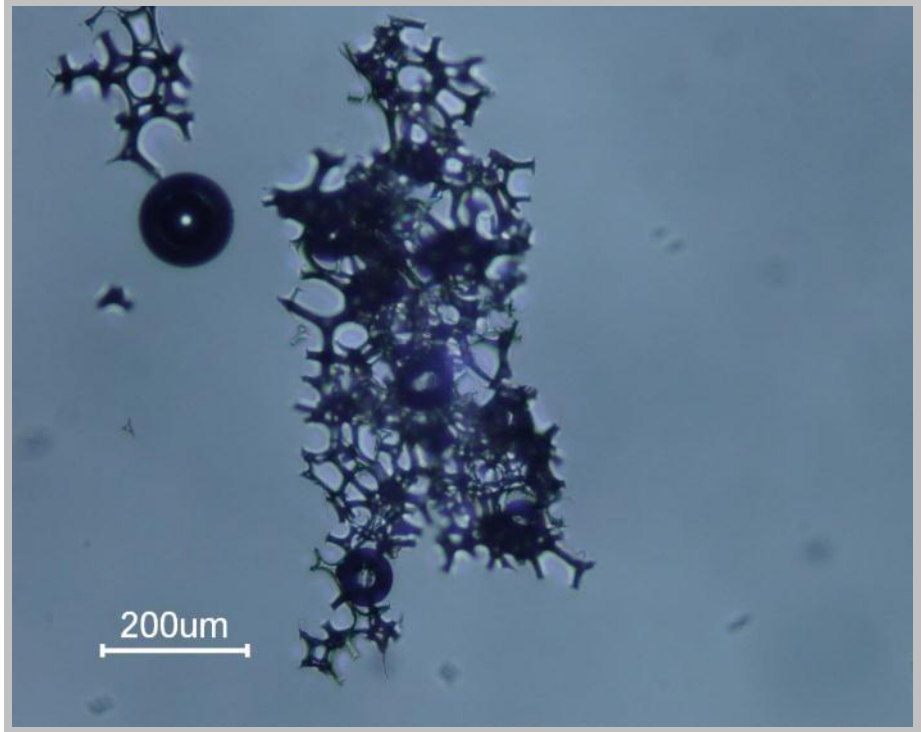
# *Application parameters*

- Optimum two part ratio
  - Viscosities
  - Delivery Pressures
- Temperature
  - **Substraight temperature – infinite heat sink**
  - Exothermic reaction ~140 F
  - Ambient - outdoor conditions
- Operator application technique
  - Spray pattern
- Formulation changes
  - Blowing agent
  - Catalyst
- Humidity-dew point
  - Cure rate
  - Substraight

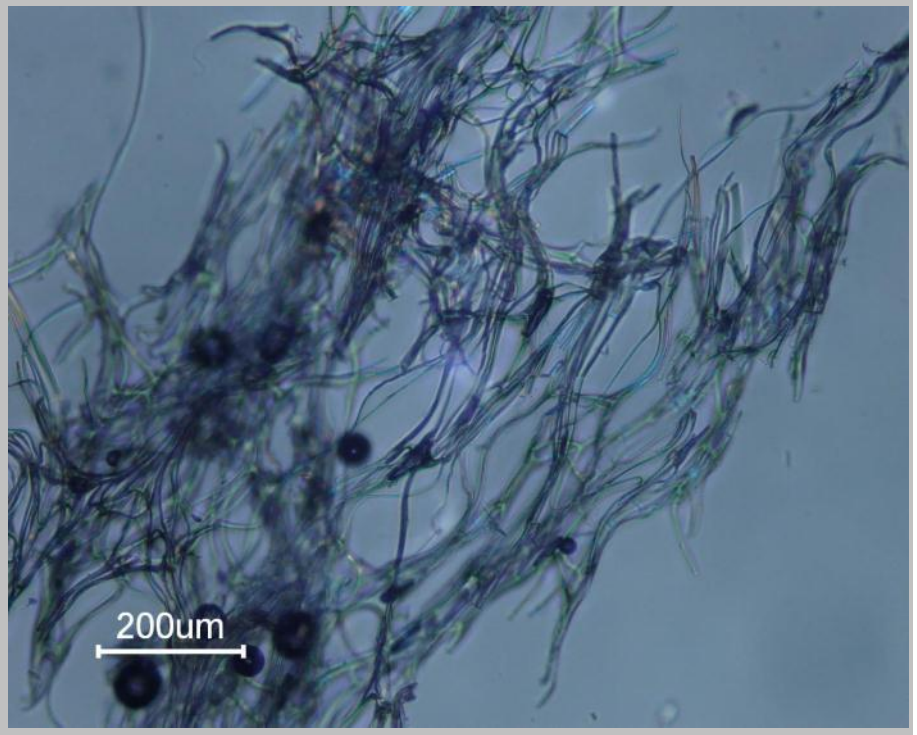
# *Polarized Light Microscopy*



# *Polarized Light Microscopy of Foam*

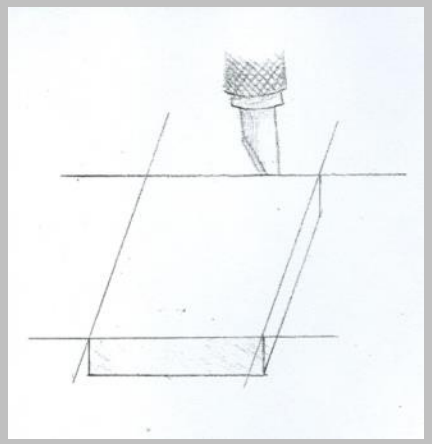


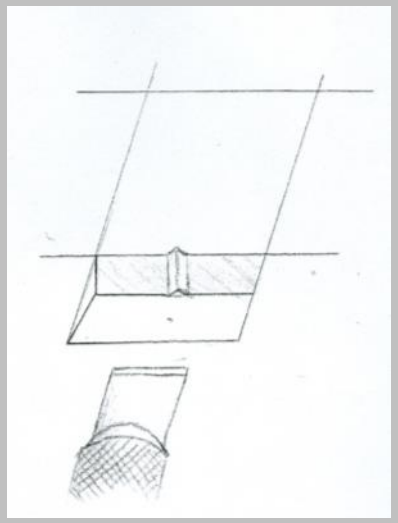

**Exemplar**

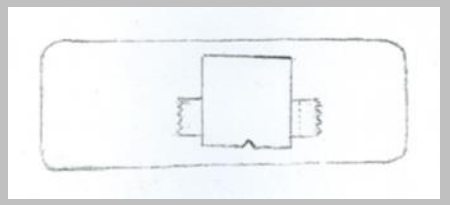



**Failed Surface**

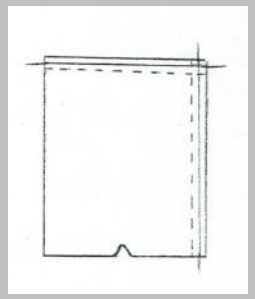
# *Cross Sectioning of Foam*



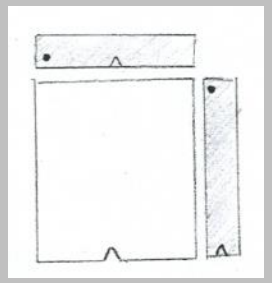




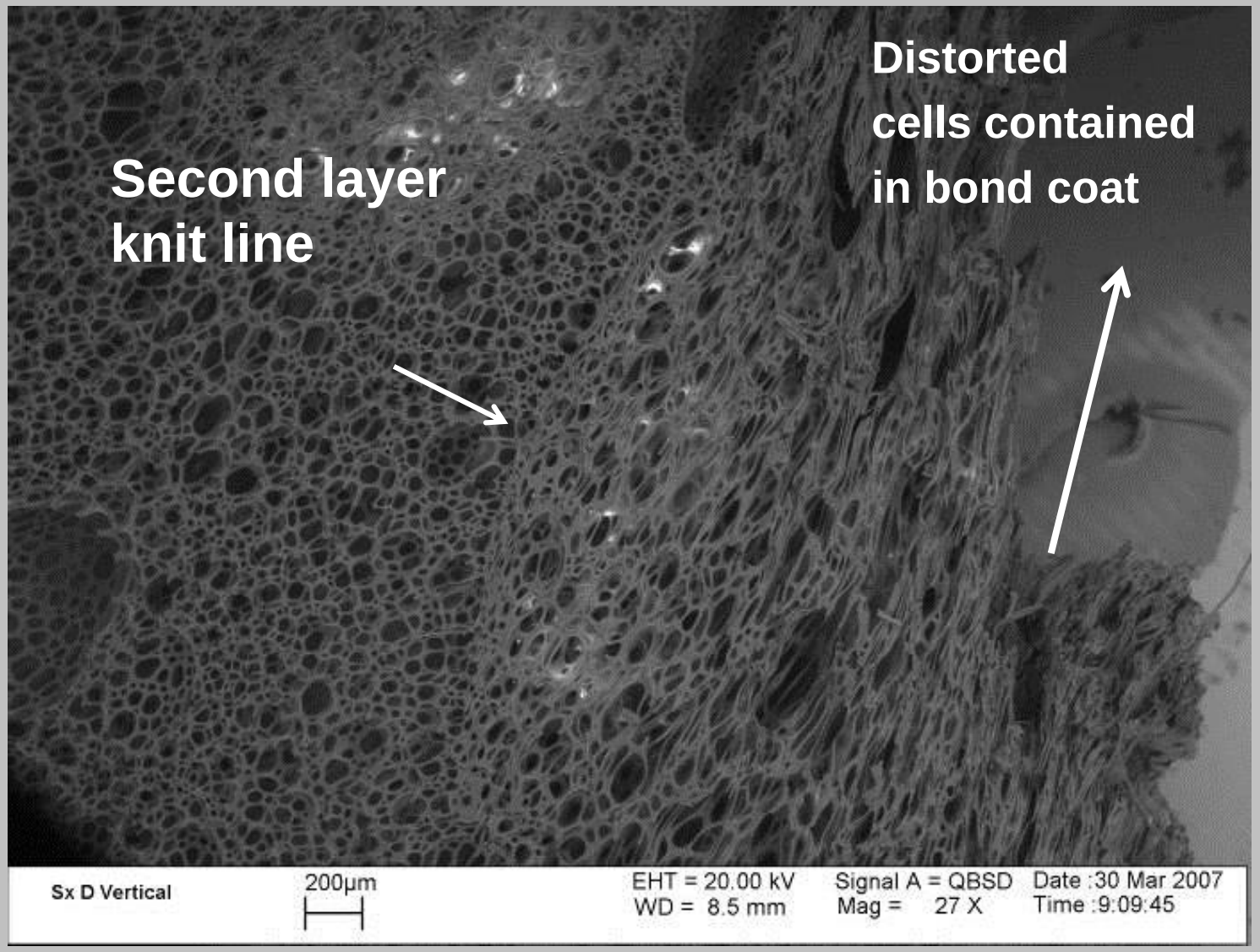
- **Plastic slide with double**
- **sided tape**



- **1st cut 1 mm section single edge razor**
- **2nd cut 0.5-1mm section double edge razor**

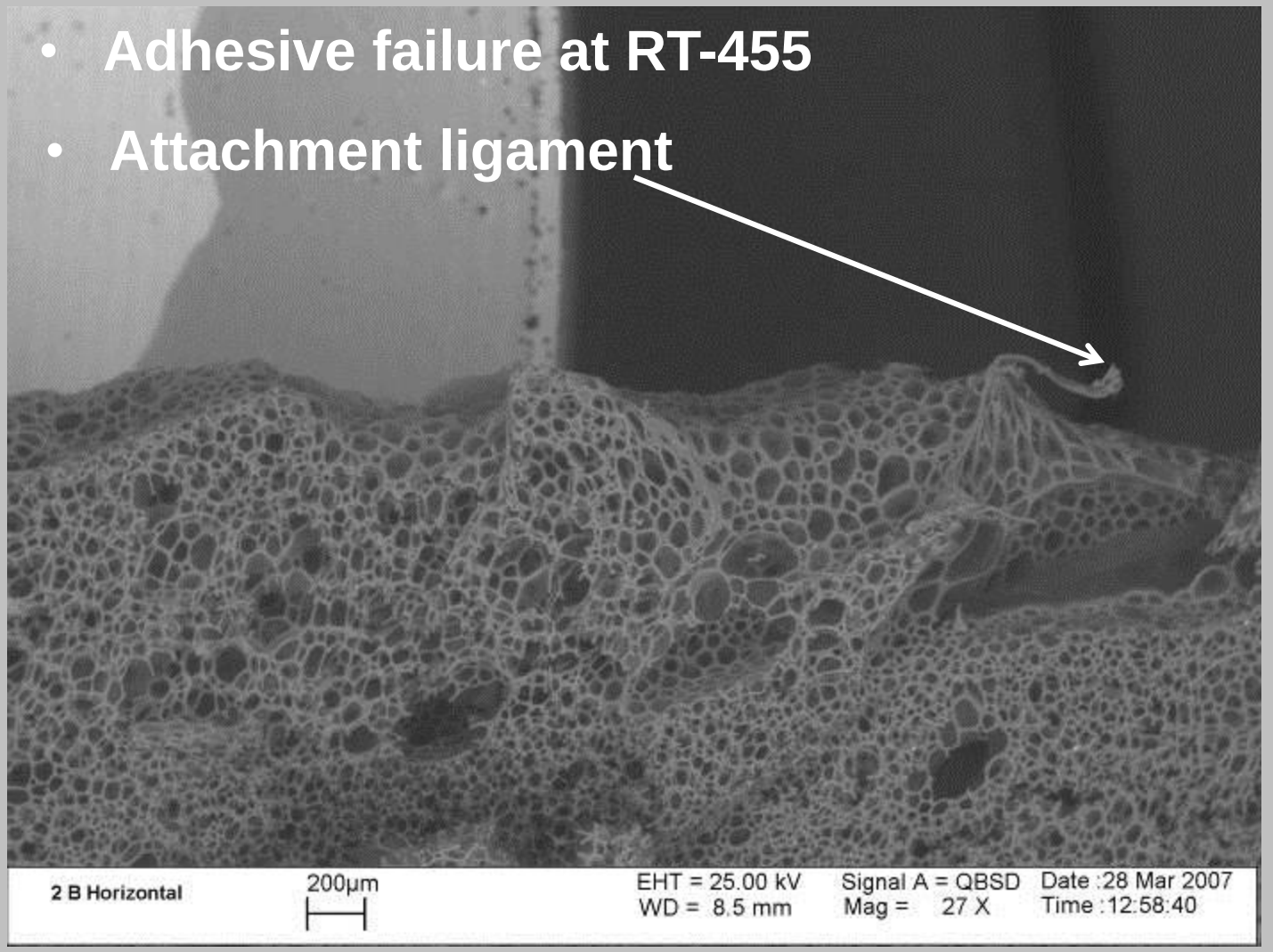


# *Cross Section of SRB Foam Failure*

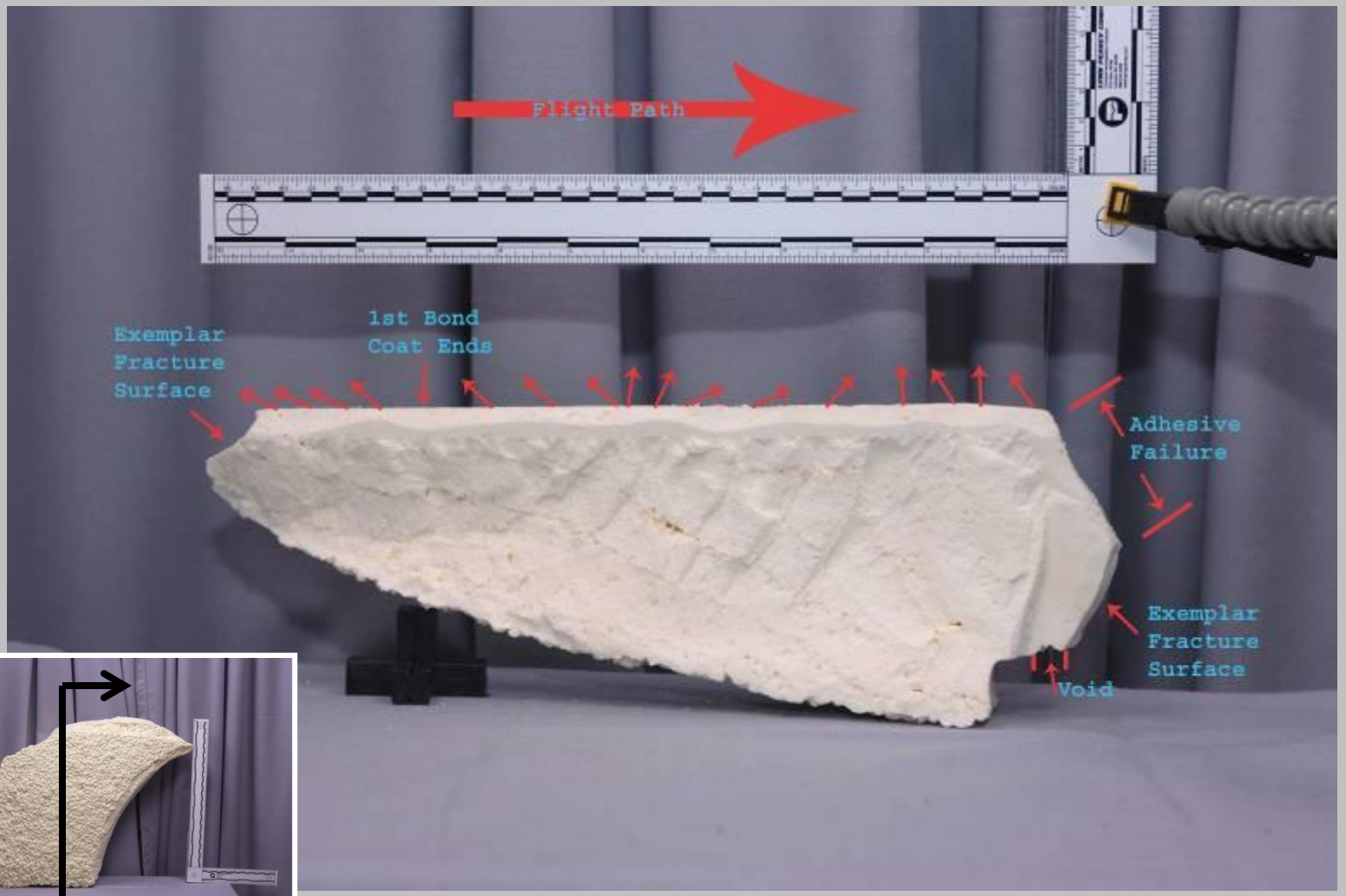



**Chief SRB Engineer –we have never looked at foam like this**

# *SRB Foam Failure*



# *SRB Foam Failure*



# *SRB Foam Failure*

The foam bond coat displayed two modes of failure:

- >80 percent application failed
- Cohesive failure was observed due to severely deformed foam cells in the bond coat
- Adhesive failure was observed at the RT-455 Epoxy interface.

The observed morphology indicates that the bond coat was not fully cured before other forces were applied, e.g. the expansion forces of the second coat distorted the bonding cells.

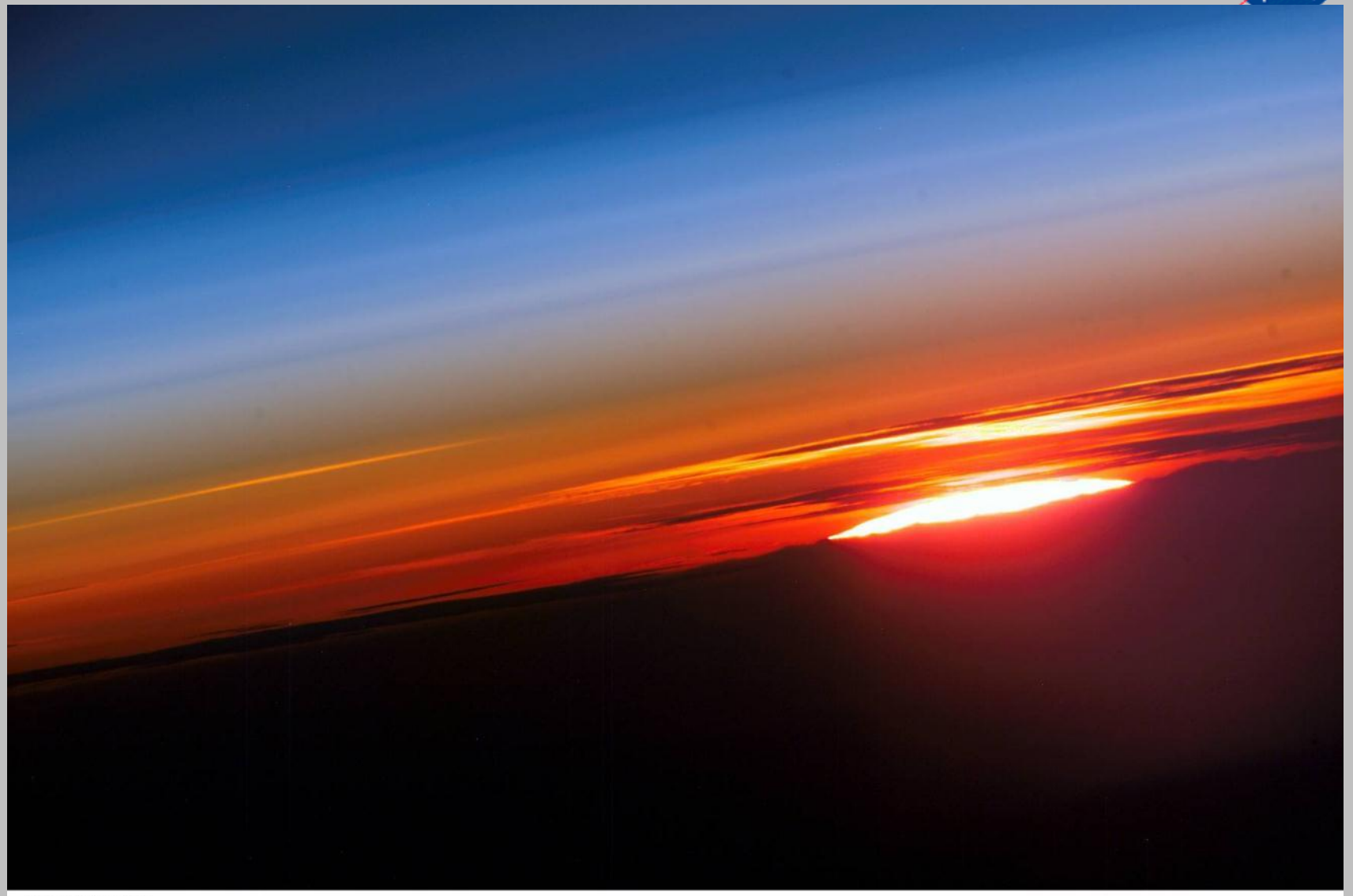
# *Process Changes*

- Develop spray hardware to apply micro bond layers (< 1/8” layers)

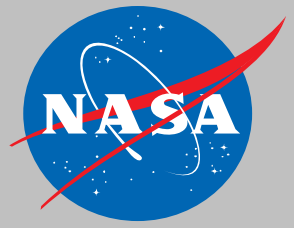
- The bond coat should be allowed to completely dry/cure
  Never apply over wet uncured layers

- Smaller Soup can (1/2 inch) inspection plugs for SEM analysis should be developed

# *Sunset on International Space Station Expedition 15*



ISS015E10469

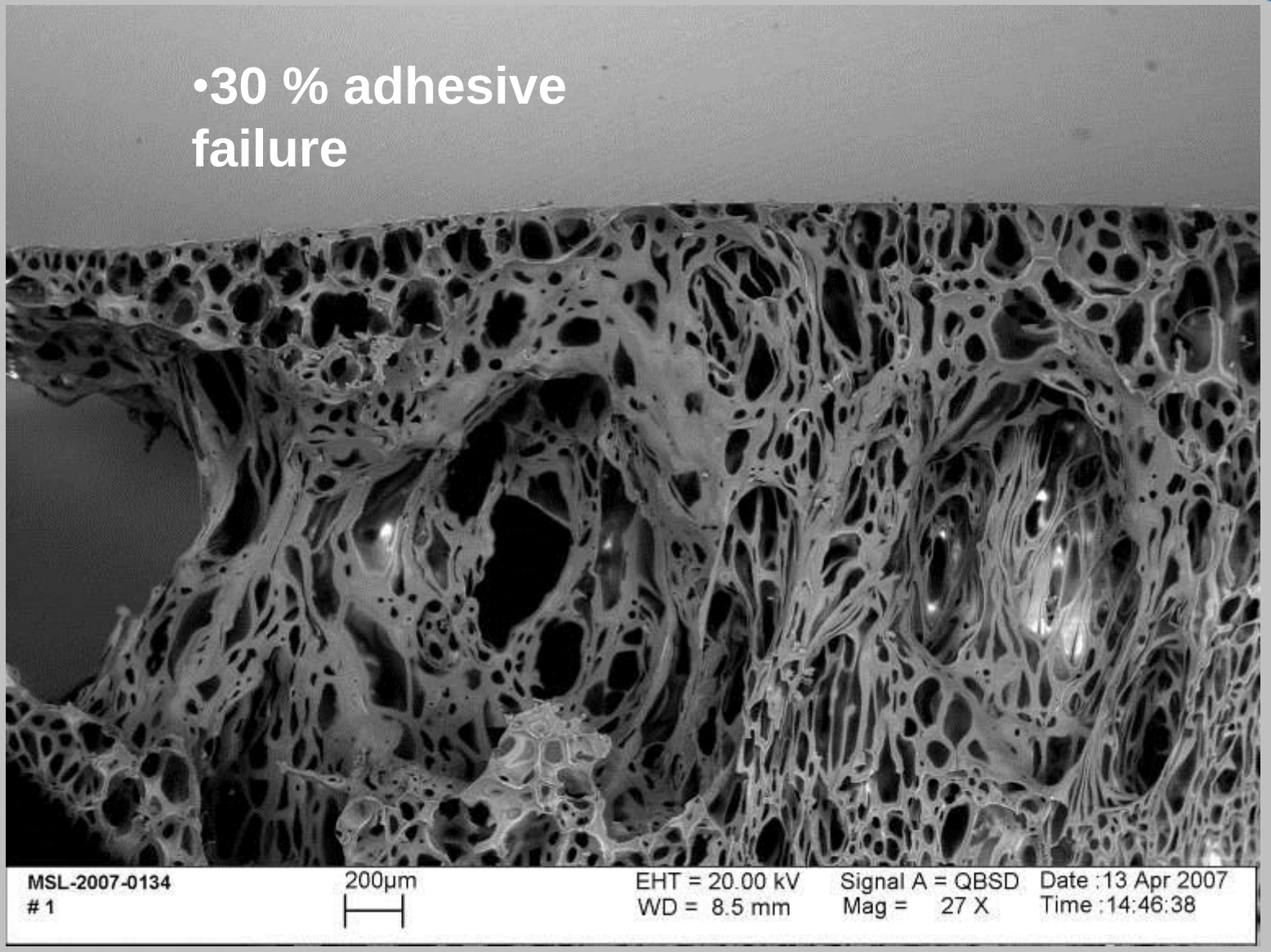

NASA

# *A View from Above!*

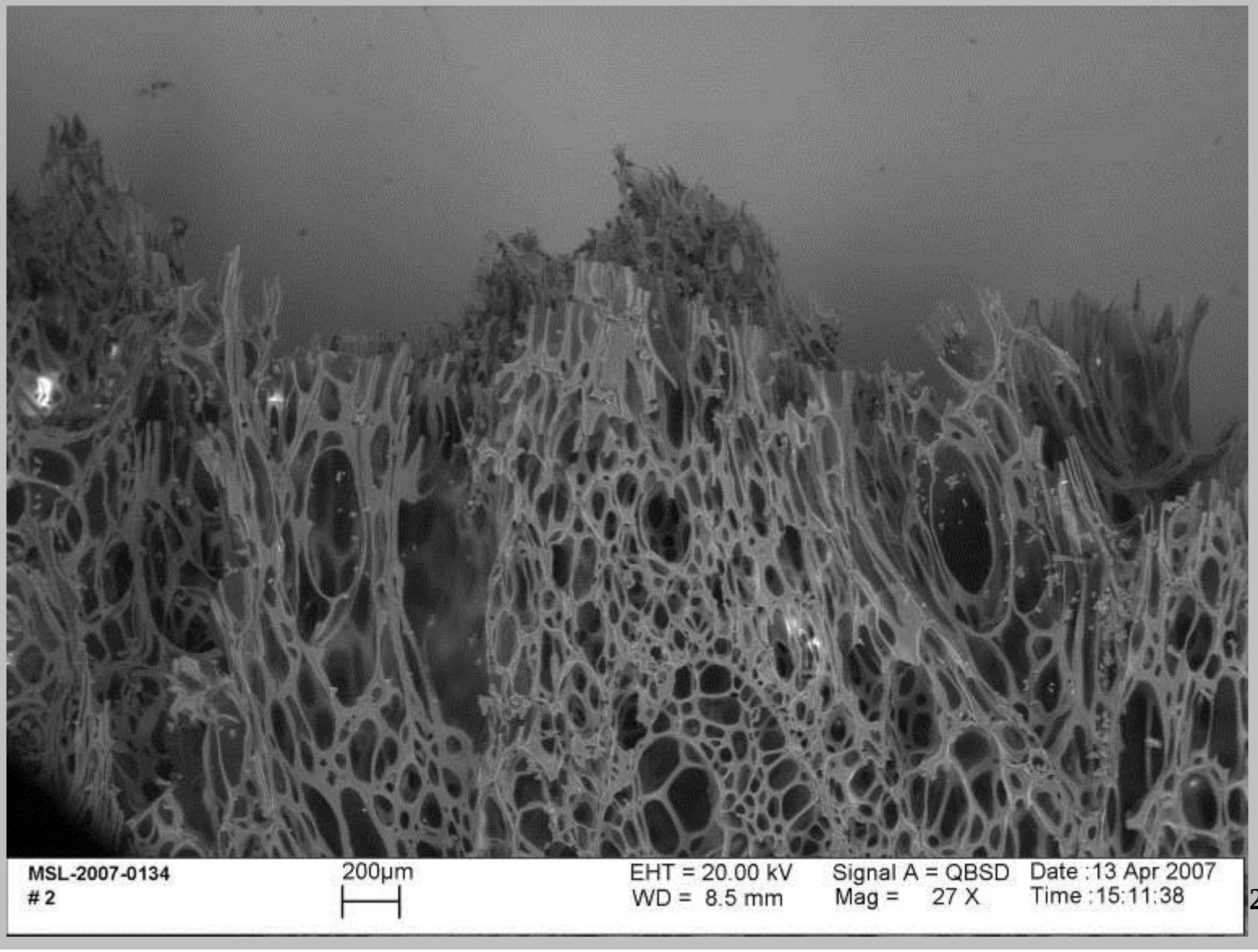
ISS007E07306

# Supplemental Data

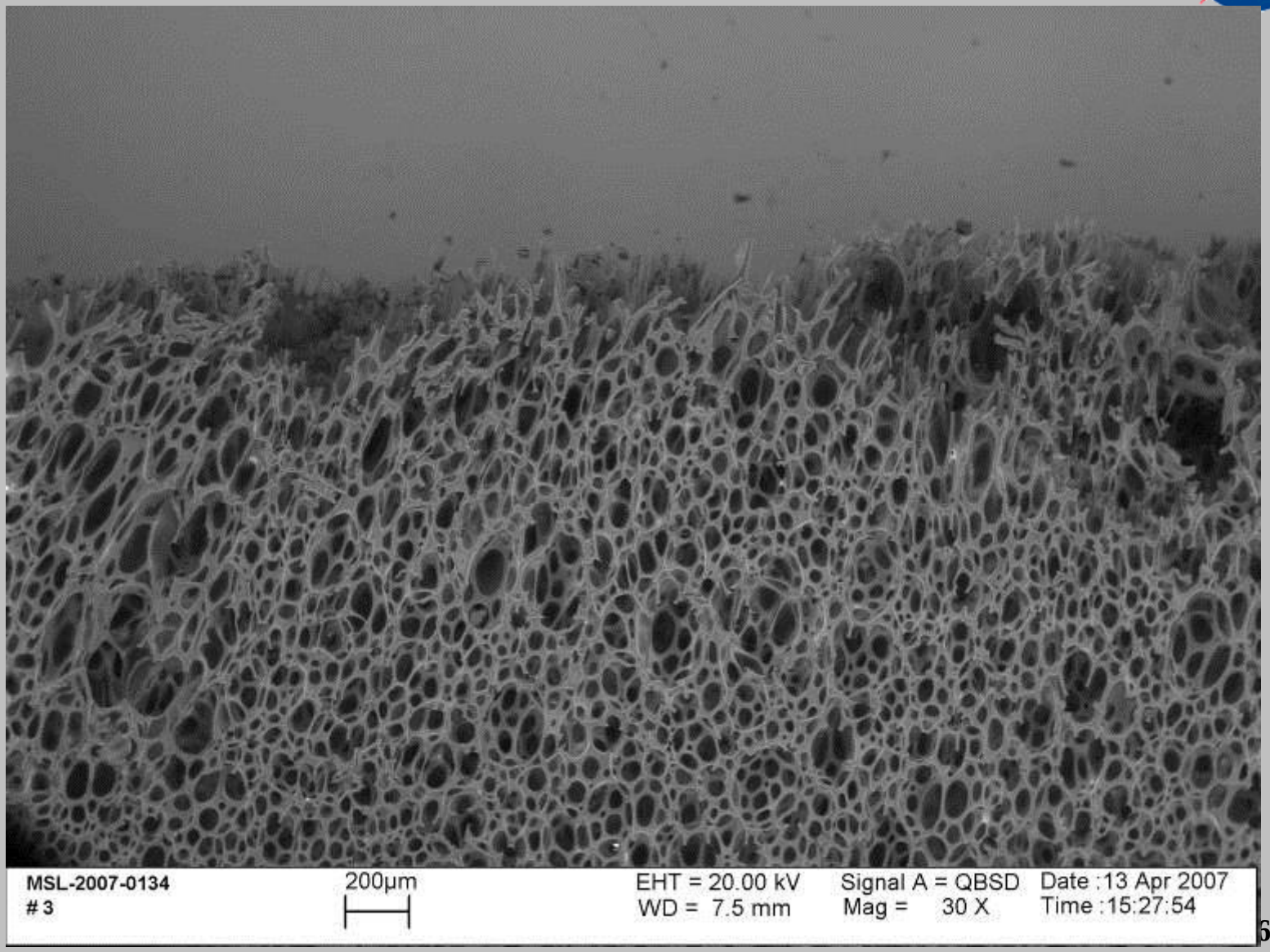
*25 PSI*


•30 % adhesive failure
MSL-2007-0134
# 1
200µm
EHT = 20.00 kV
WD = 8.5 mm
Signal A = QBSD
Mag = 27 X
Date :13 Apr 2007
Time :14:46:38

***50 PSI***


MSL-2007-0134
# 2
200µm
EHT = 20.00 kV
WD = 8.5 mm
Signal A = QBSD
Mag = 27 X
Date :13 Apr 2007
Time :15:11:38

## *78 PSI*


MSL-2007-0134
# 3
200µm
EHT = 20.00 kV
WD = 7.5 mm
Signal A = QBSD
Mag = 30 X
Date :13 Apr 2007
Time :15:27:54