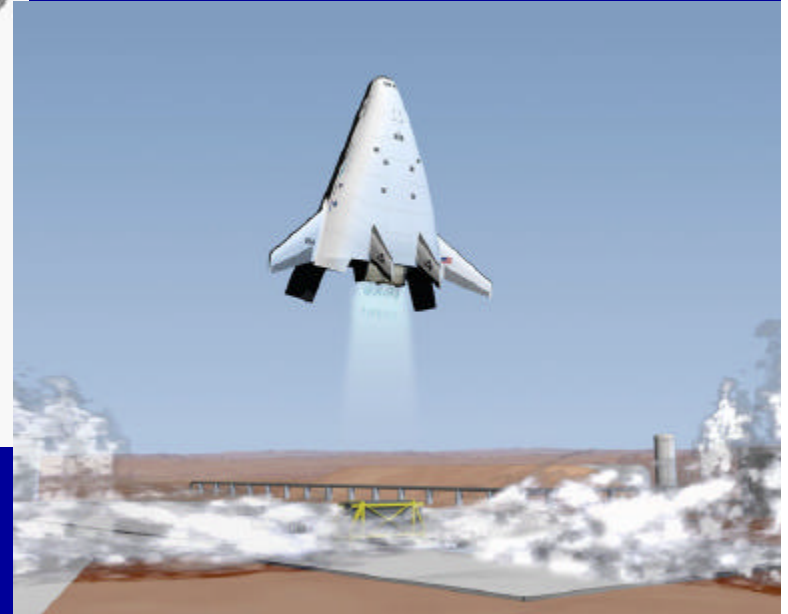
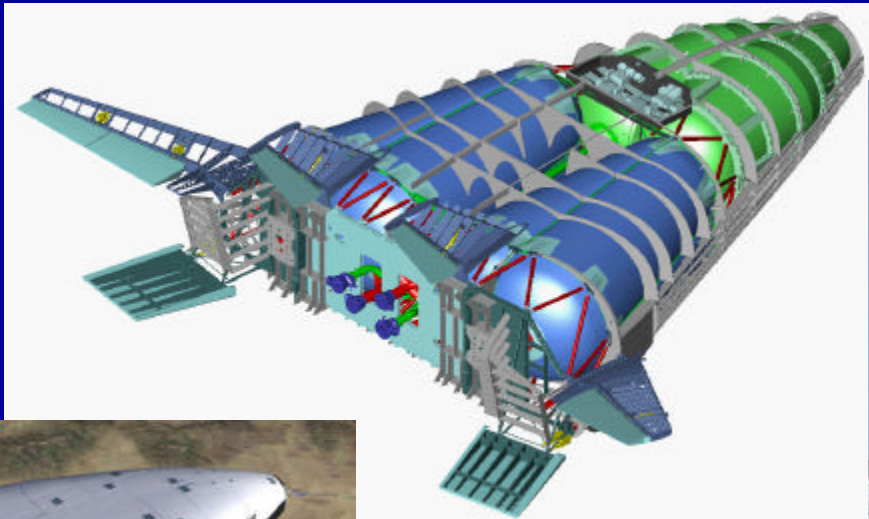


# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*



*Presented by*  
Mindy Niedermeyer  
MSFC

*Aerospace Materials, Processes, and Environmental  
Technology Conference*

9/22/00

September 18 - 20, 2000

# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

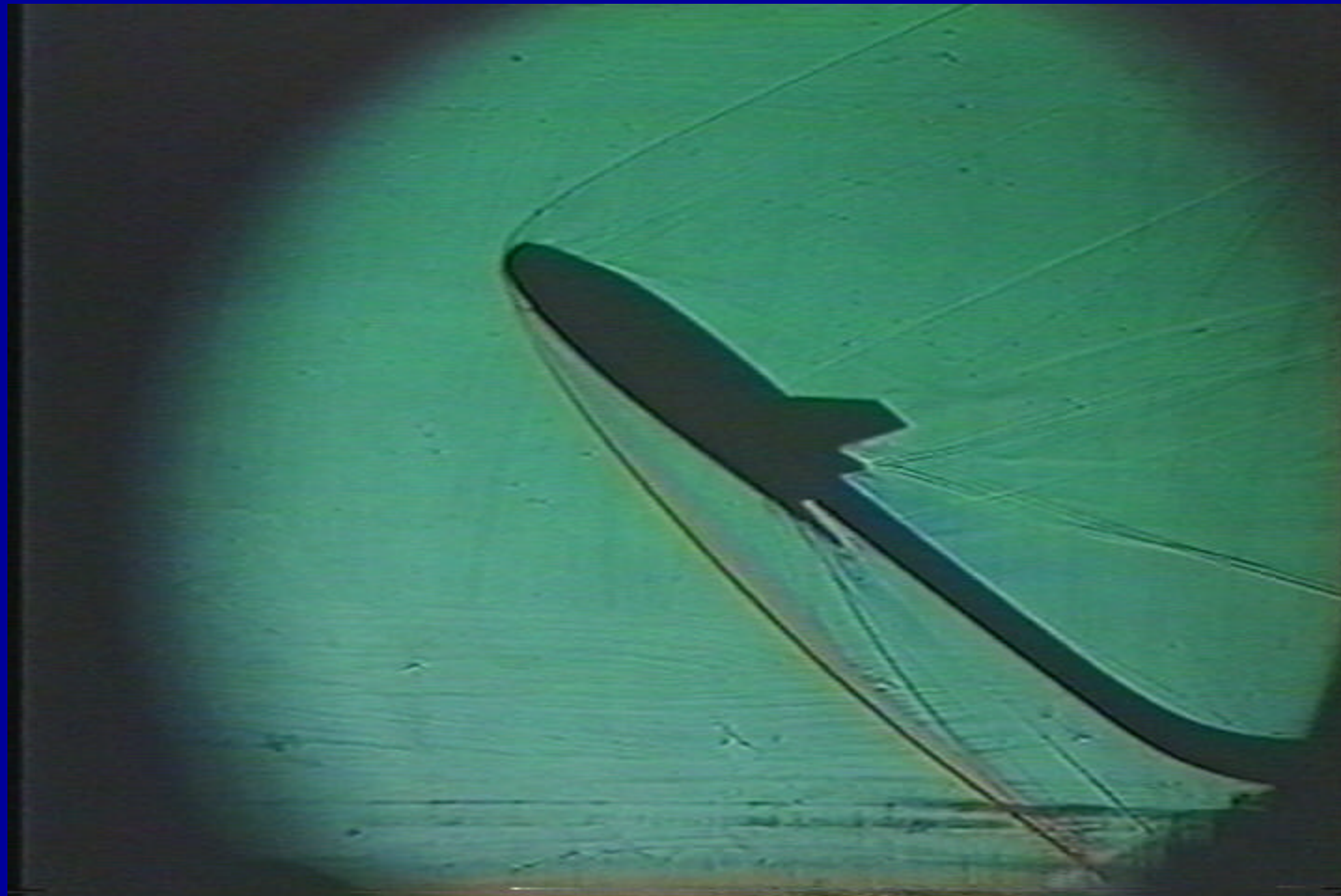


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# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

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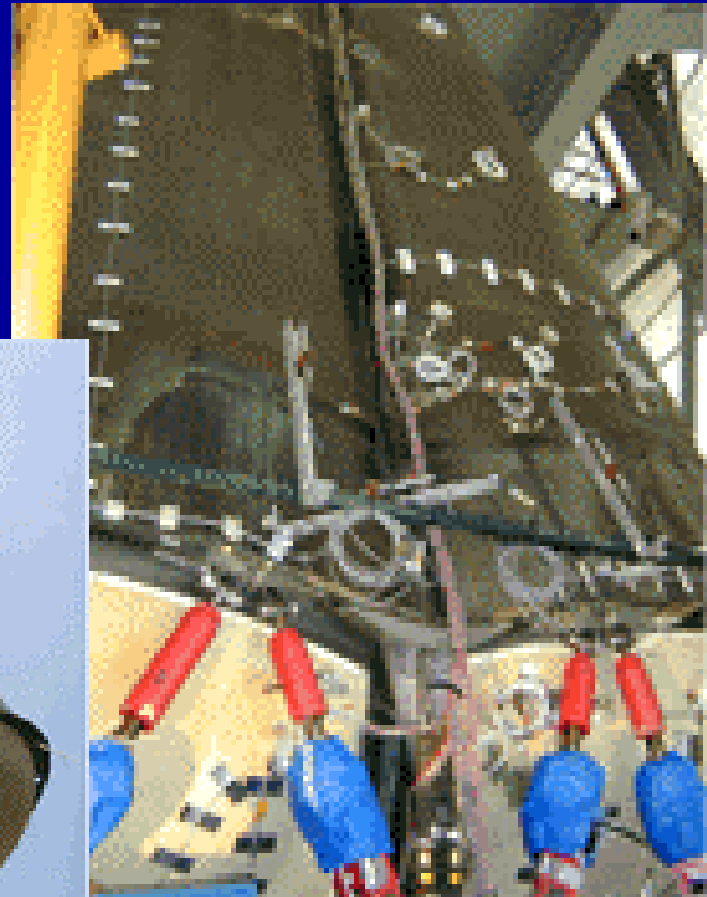
# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

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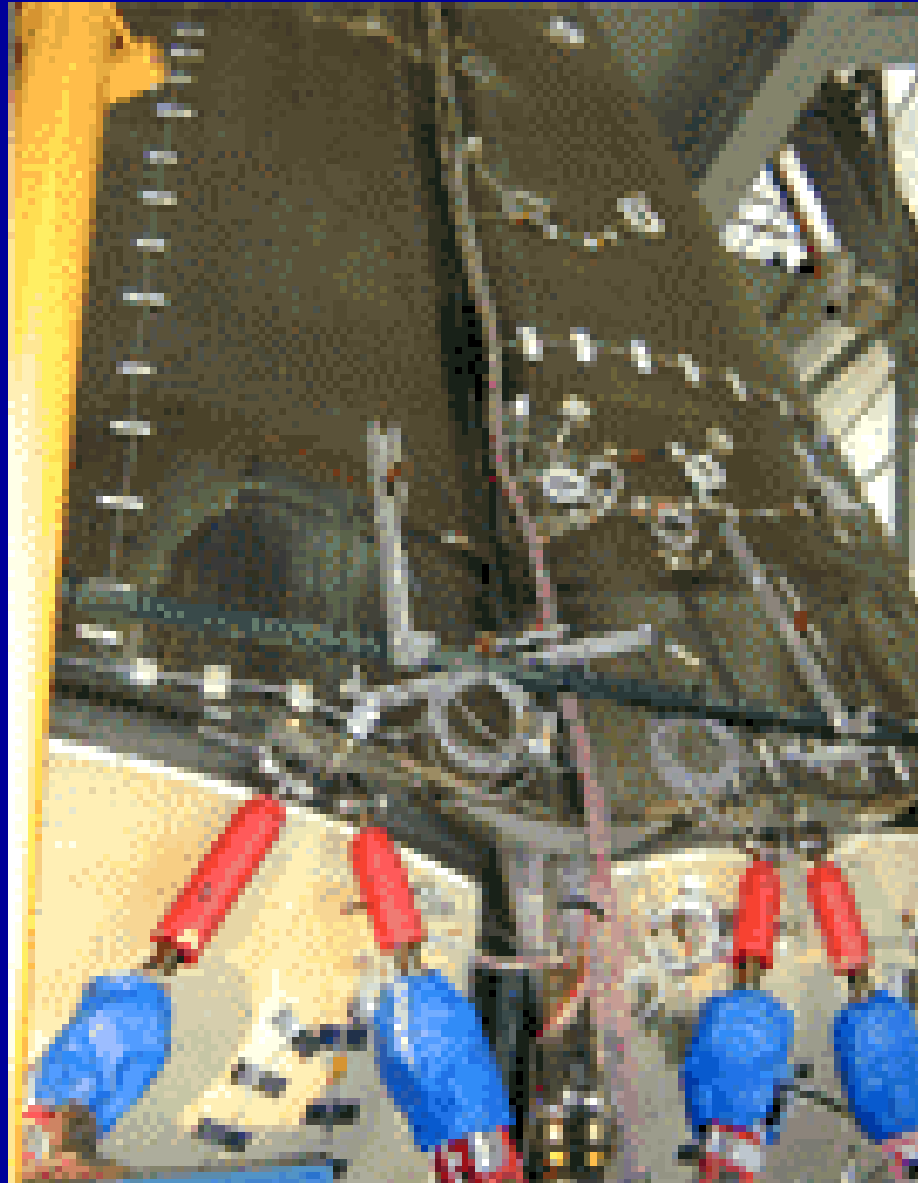
## **Introduction**

- Tank History and Test Objectives
- Failure Description
- Investigation
- Conclusions

# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*



# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*



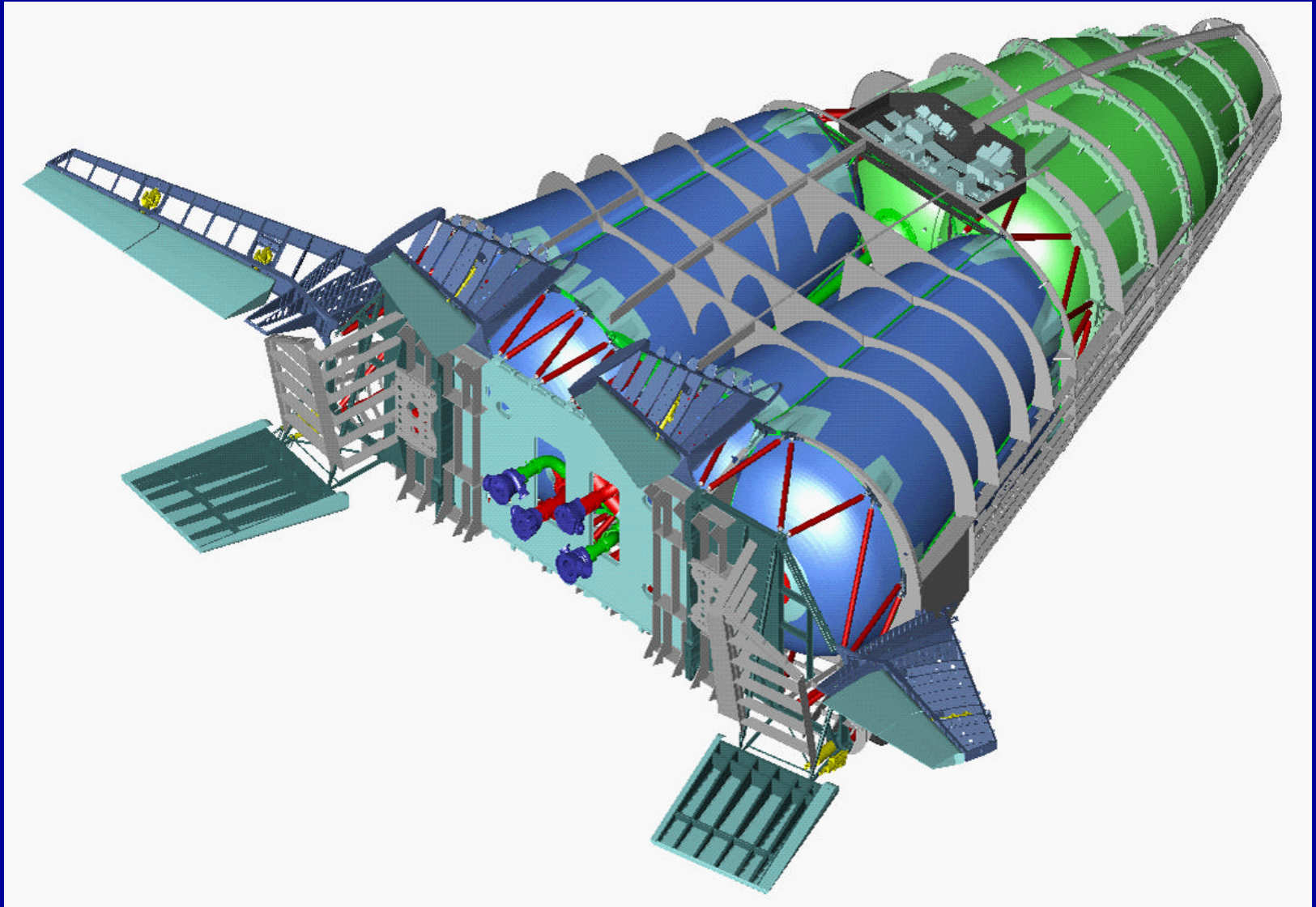
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# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

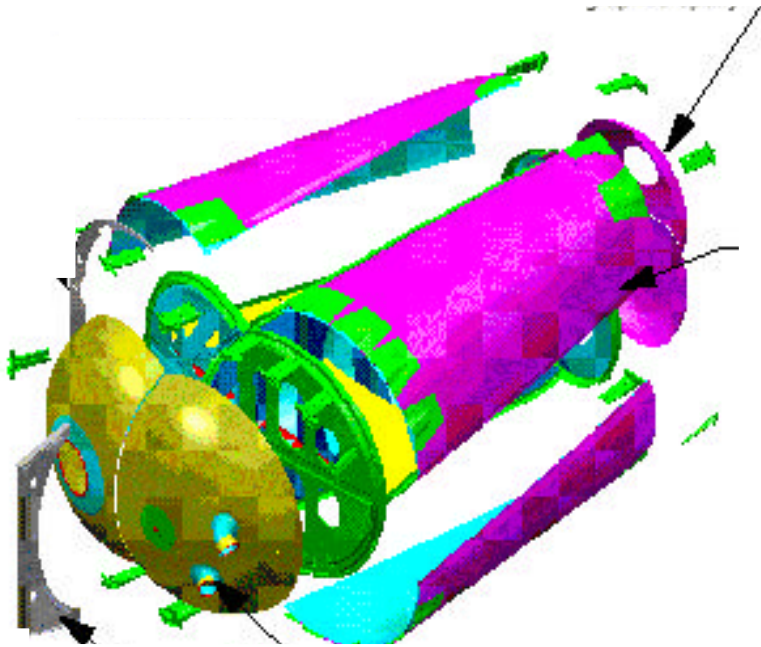
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## **Tank Description**

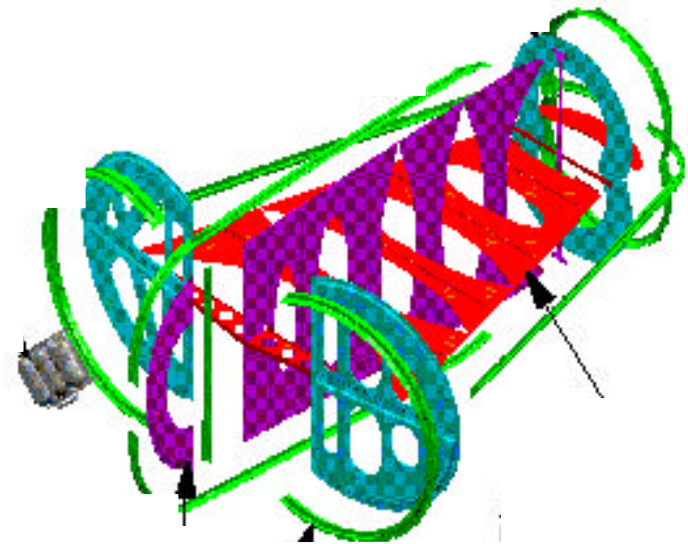
- **Structural component of the aft body**
- **Quad-lobe design**
- **Sandwich - honeycomb graphite epoxy construction**





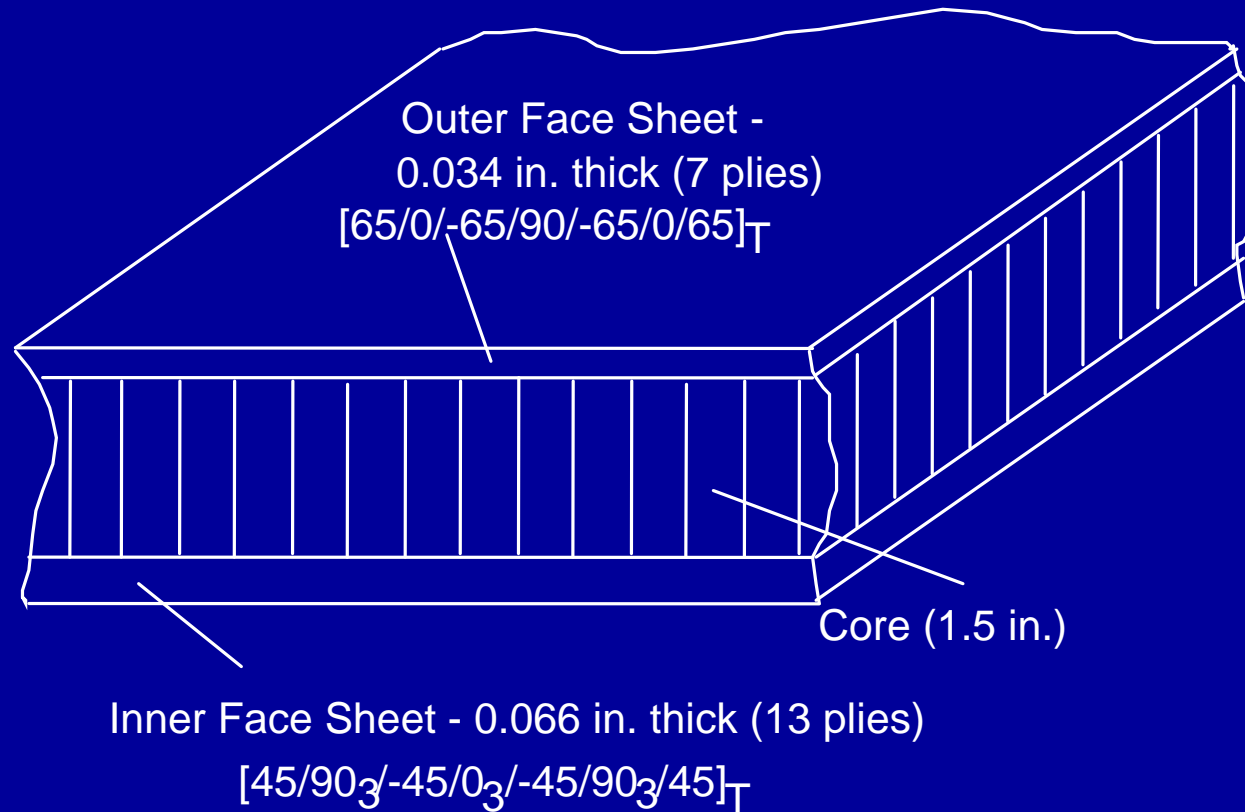


External View



Internal View

# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*



## **Geometry of sandwich structure**

# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

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## **Test Objectives**

- **Verify structural integrity at 105% expected flight load limit varying the following parameters**
  - **Cryogenic temperature**
  - **Internal pressure**
  - **Mechanical loading**

## *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

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- September 21, 1999 test aborted due to hydrogen leaks
  - 100% cryogen fill (LH2)
  - 20 psig internal pressure
- November 3, 1999 test completed
  - 100% cryogen fill (LH2) at 42 psig internal pressure
  - Load case 5 applied at 5 psig internal pressure
  - Tank drained of cryogen

# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

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## **Timeline**

- Tank filled, 12:30 PM
- Tank pressurized to 42 psig, 2:00 PM
- Tank vented to 2 psig, 3:00 PM
- Loads applied, pressure increased to 5 psig, 4:40 PM
- Tank drained, 6:00 PM
- Lobe 1 failure, 6:24 PM

# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

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**X-33 LH2 Proto-Flight Tank Test**

**Camera 14 : Lobe 1 and Lobe 4  
Longeron**

# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

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## **Initial Findings**

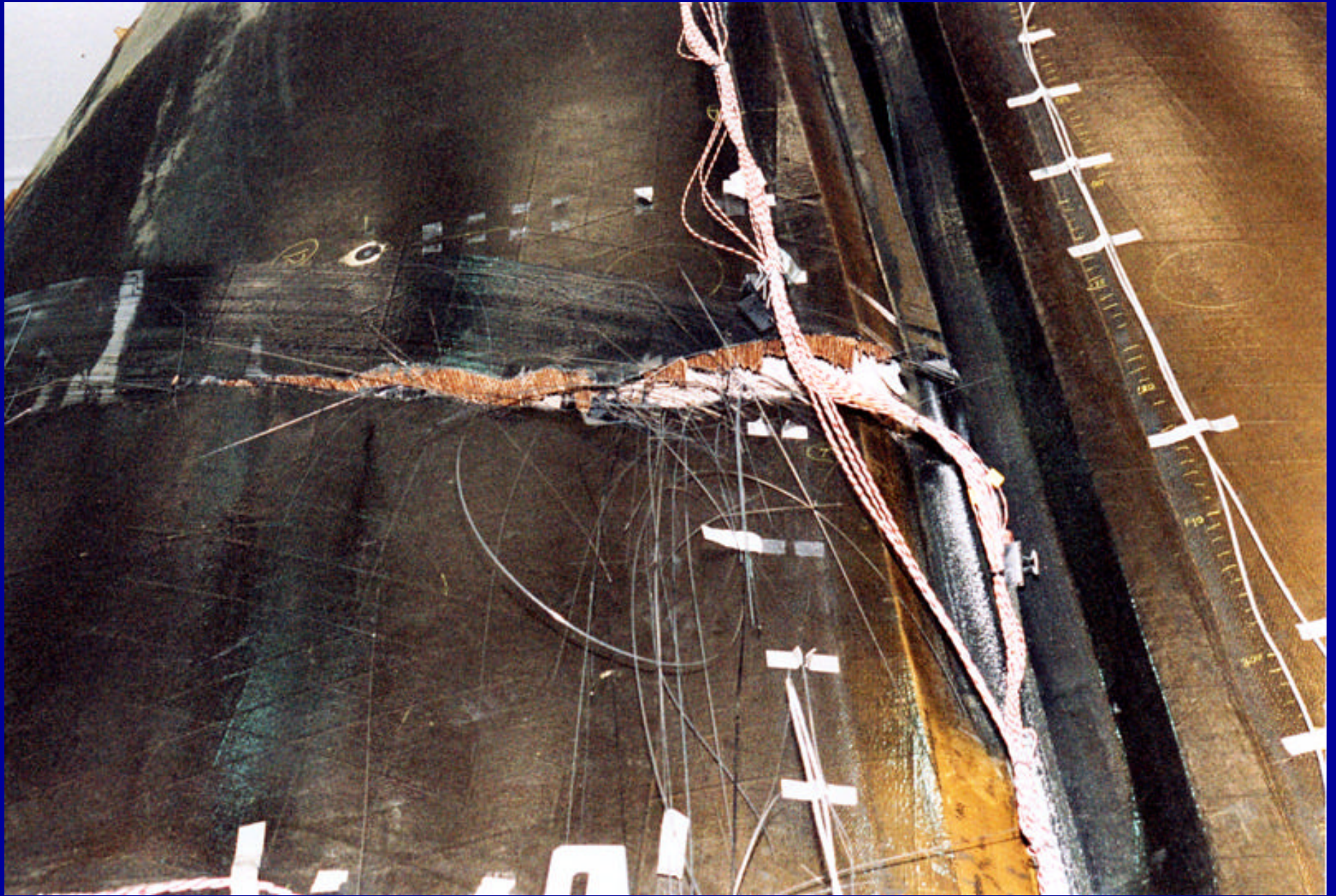
- **Peel Failure**
  - Outer skin and core peeled away from inner skin
- **Core Failure**
  - Core is 'mangled'
- **Hydraulic fluid on test article**
- **Foreign Object Debris (FOD)**
- **Poor bondlines**
- **Pressure in core above ambient 13 hours after failure**



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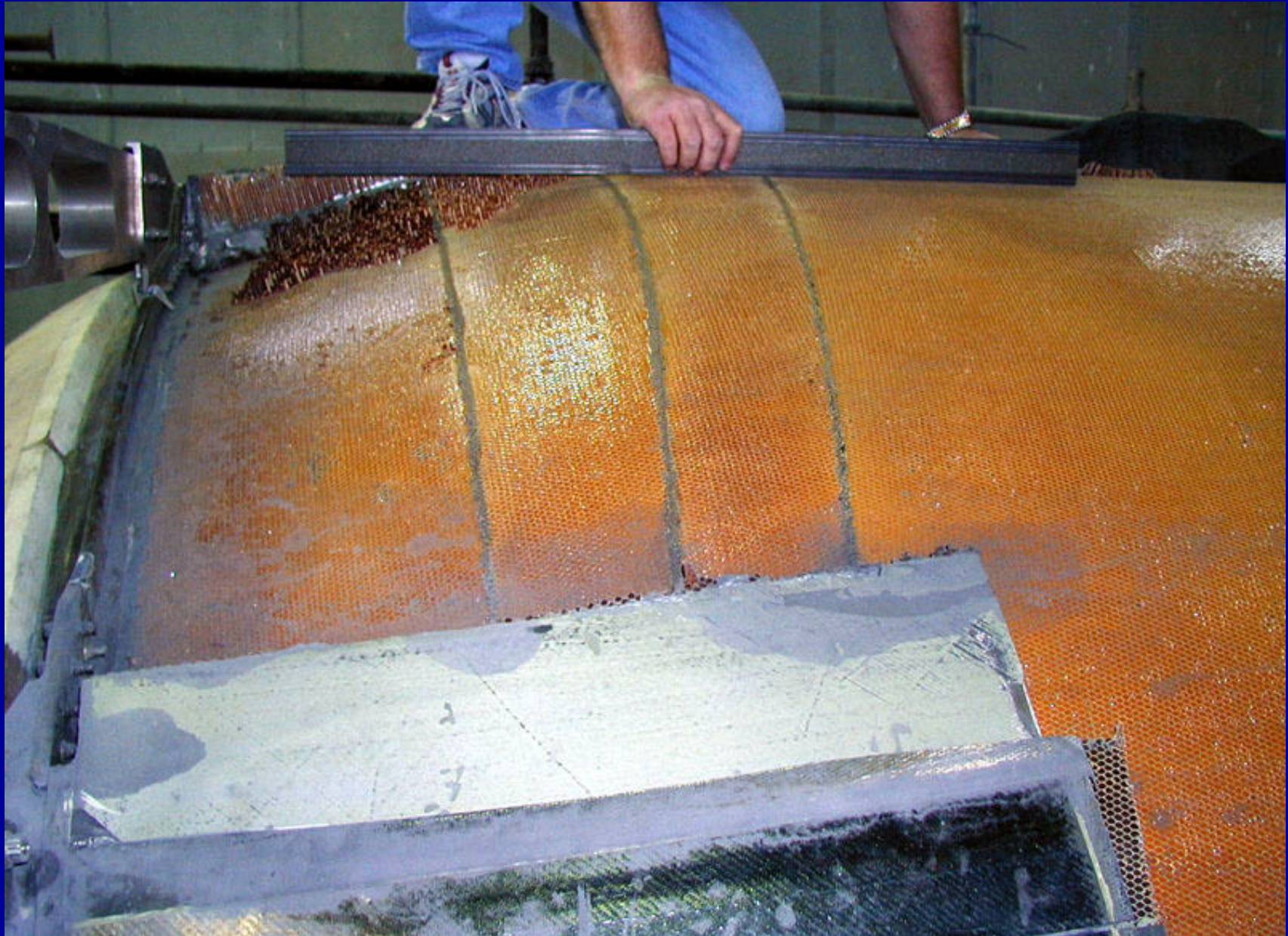
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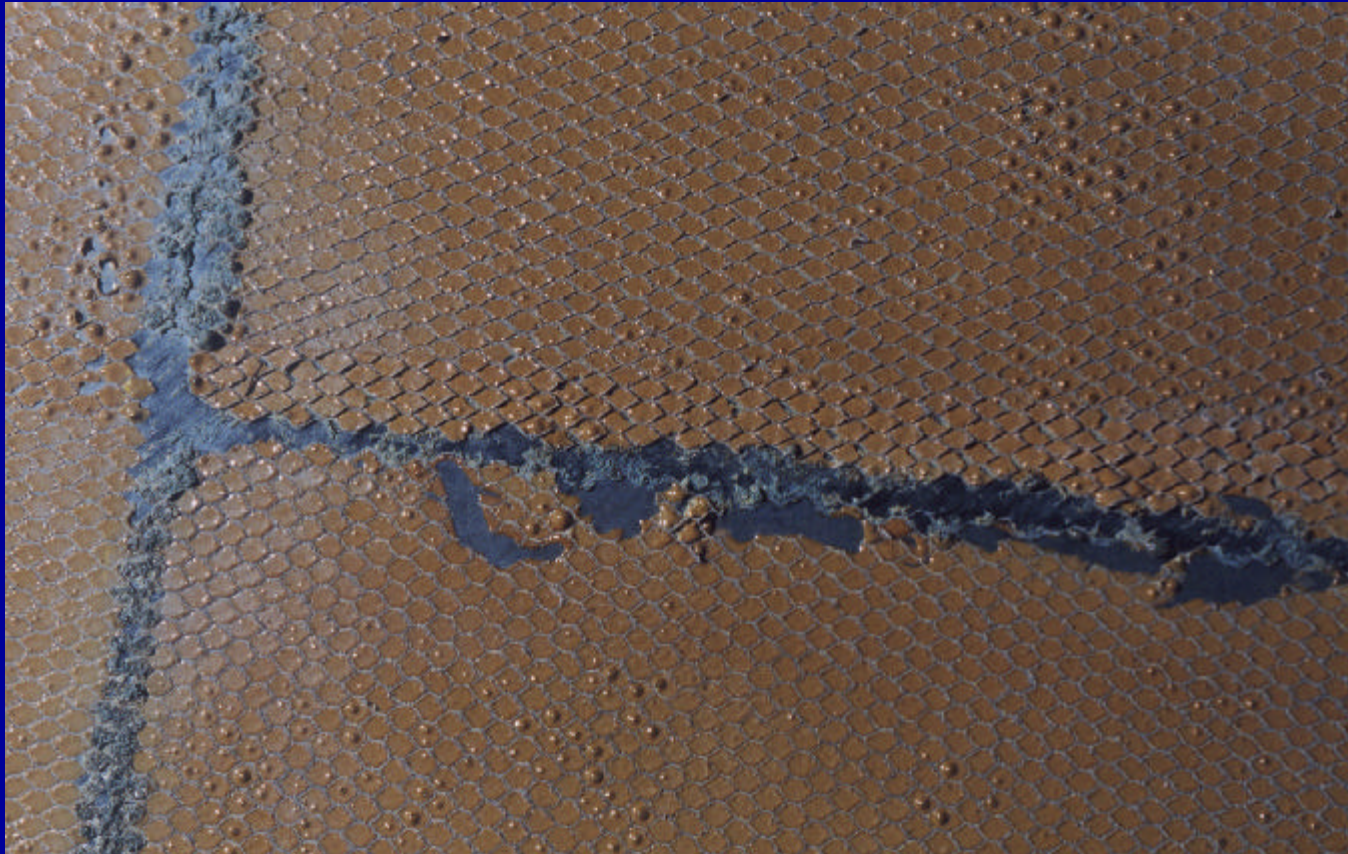
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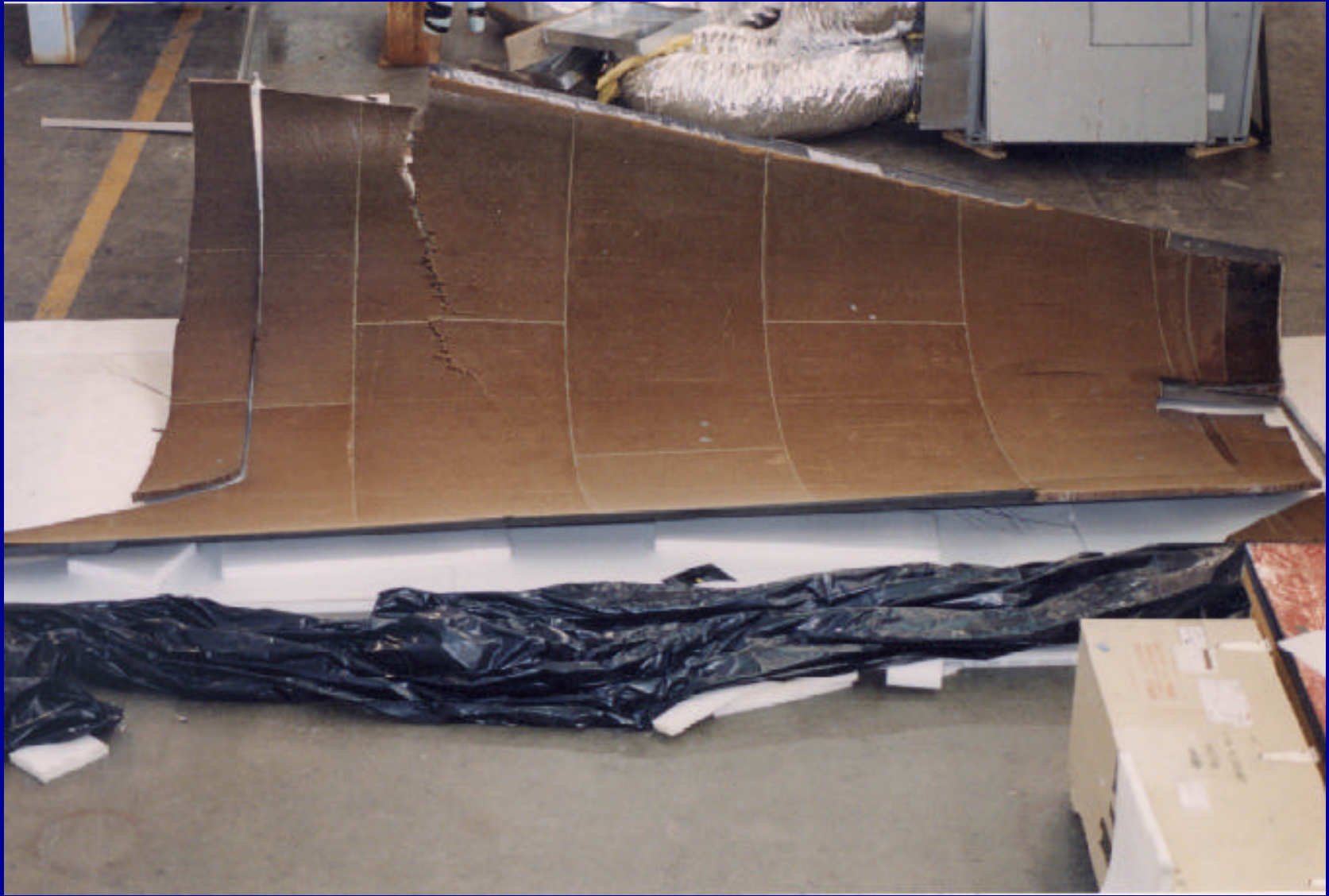
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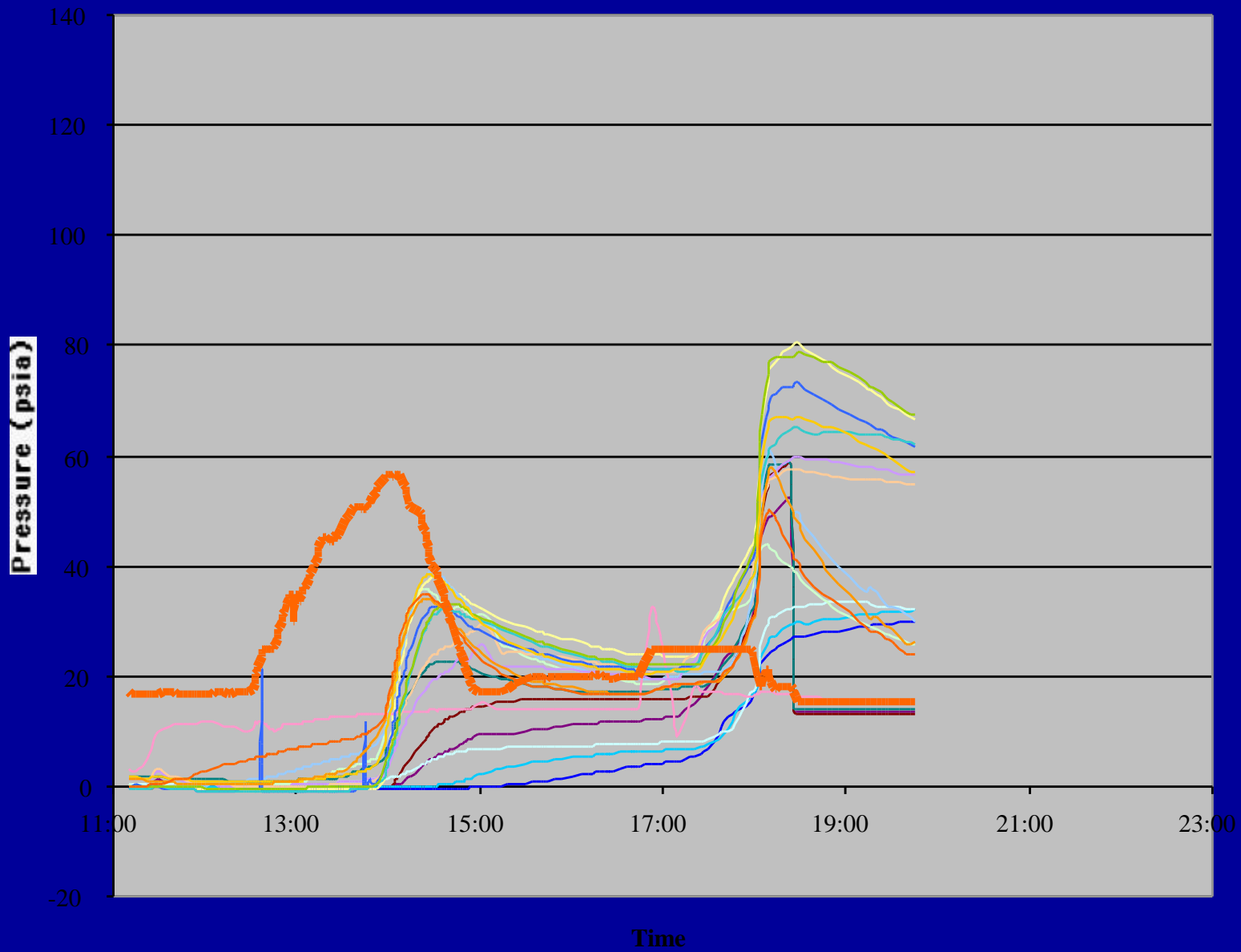
# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

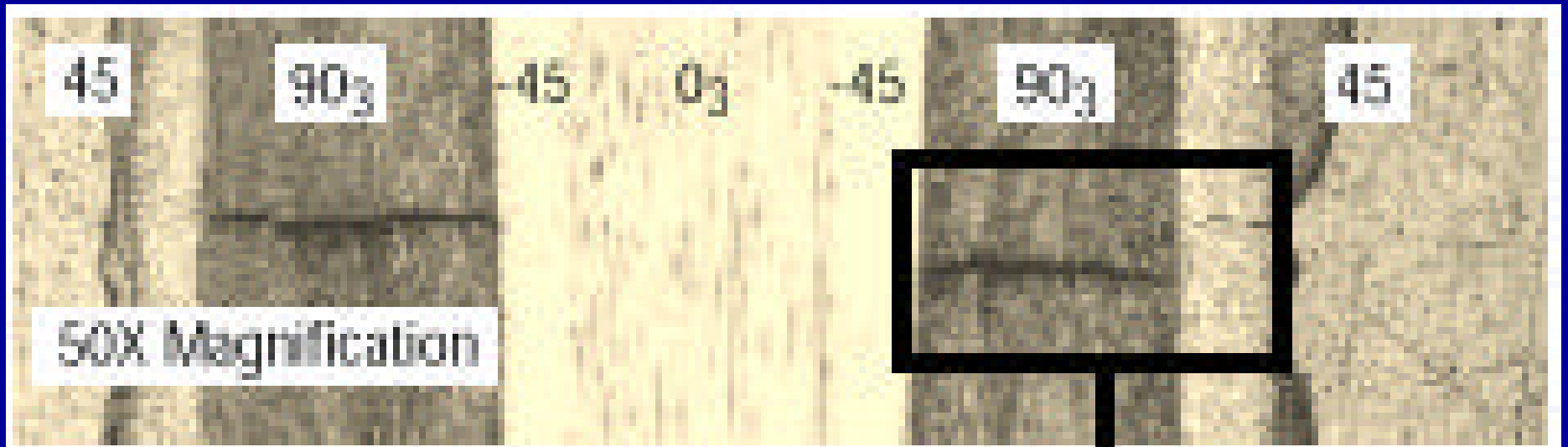
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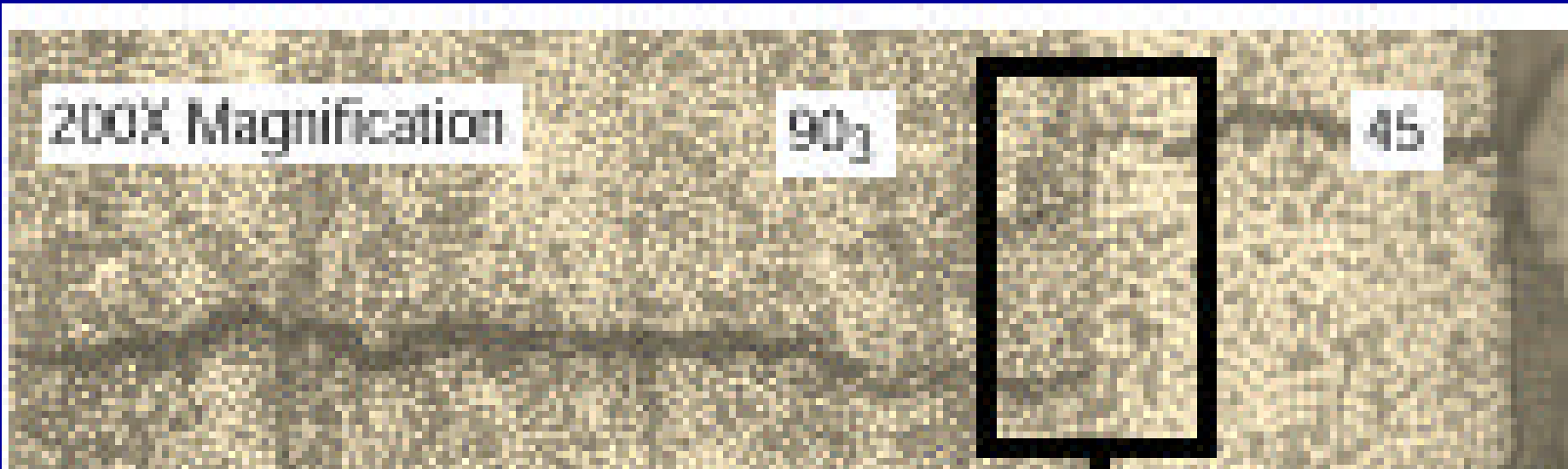
## Subsequent Findings

- Core pressures behaved unexpectedly
- Microcracking

# Core Pressure vs Time







500X Magnification

90<sub>3</sub>

45

# *X-33 LH<sub>2</sub> Tank Failure Investigation Findings*

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## **Conclusions**

- The inner skin microcracked and hydrogen infiltrated
- The cracks grew larger under pressure
- When pressure was removed cracks closed slightly
- When tank was drained and warmed, cracks closed and blocked leak path
- FOD and debond areas provided an opportunity for a leak path
- There is still hydrogen in the other 3 lobes today