X-33 LH$_2$ Tank Failure Investigation Findings

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Aerospace Materials, Processes, and Environmental Technology Conference

September 18 - 20, 2000
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Introduction

- Tank History and Test Objectives
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Tank Description

- Structural component of the aft body
- Quad-lobe design
- Sandwich - honeycomb graphite epoxy construction
Outer Face Sheet - 0.034 in. thick (7 plies)  
$[65/0/-65/90/-65/0/65]_T$

Inner Face Sheet - 0.066 in. thick (13 plies)  
$[45/90_3/-45/0_3/-45/90_3/45]_T$

Geometry of sandwich structure
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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
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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
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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
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X-33 LH2 Proto-Flight Tank Test

Camera 14: Lobe 1 and Lobe 4 Longeron
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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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Subsequent Findings

- Core pressures behaved unexpectedly
- Microcracking
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