COMPOSITE TECHNOLOGY DEVELOPMENT, INC.

ENGINEERED MATERIAL SOLUTIONS

SOFI/Substrate Integrity Testing For Cryogenic Propellant Tanks

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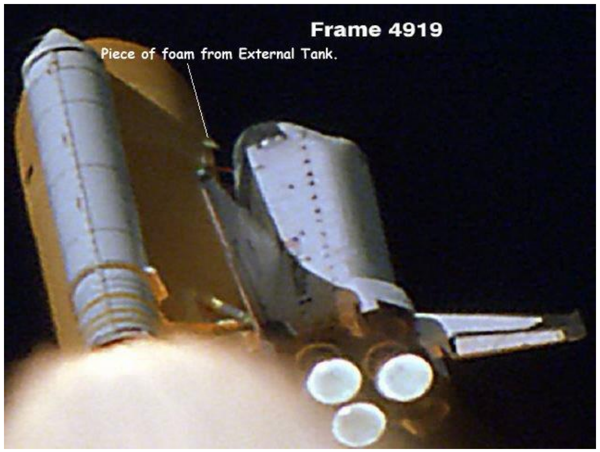
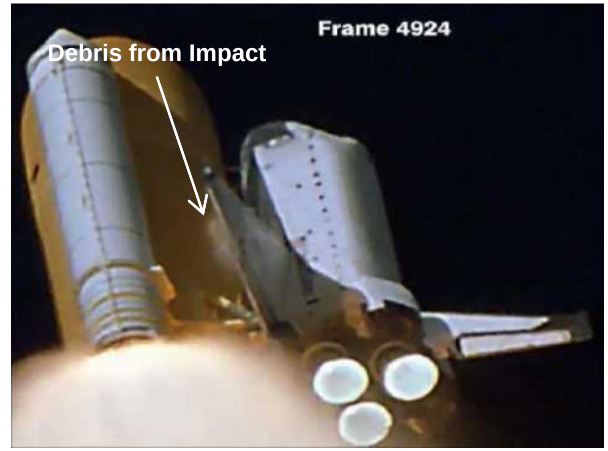
Introduction



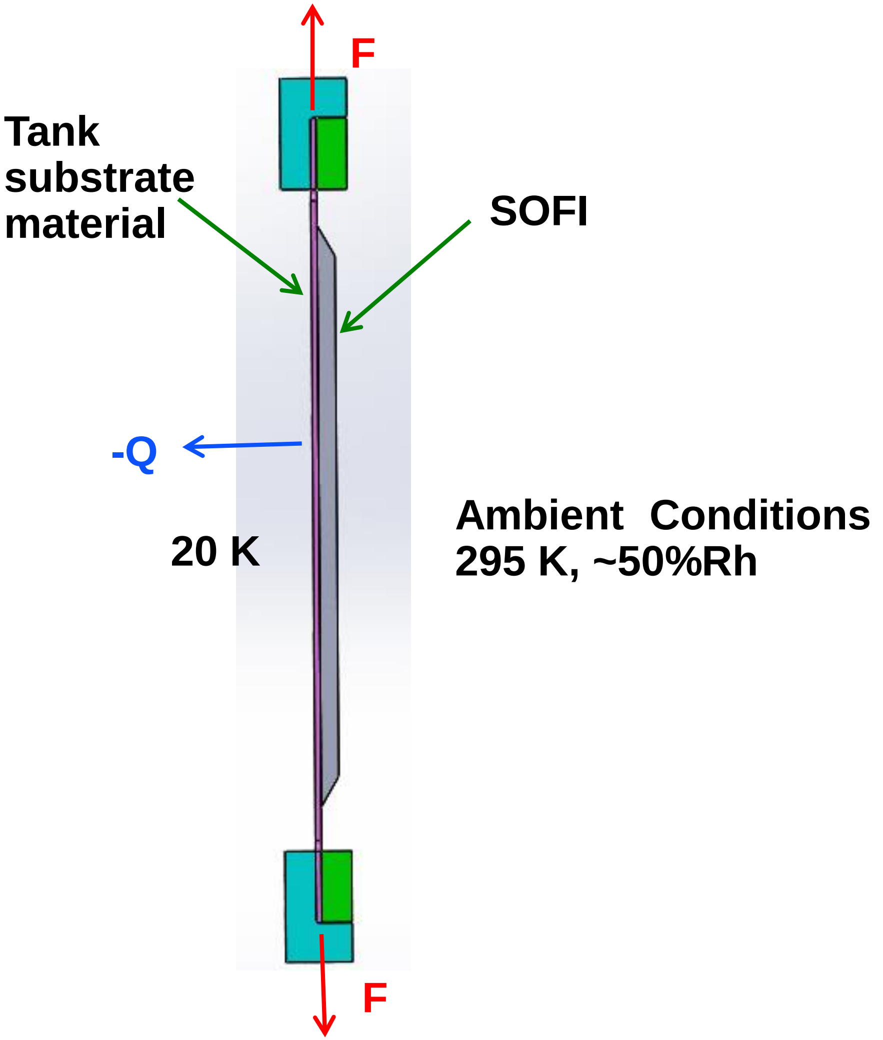


Source: NASA CAIB

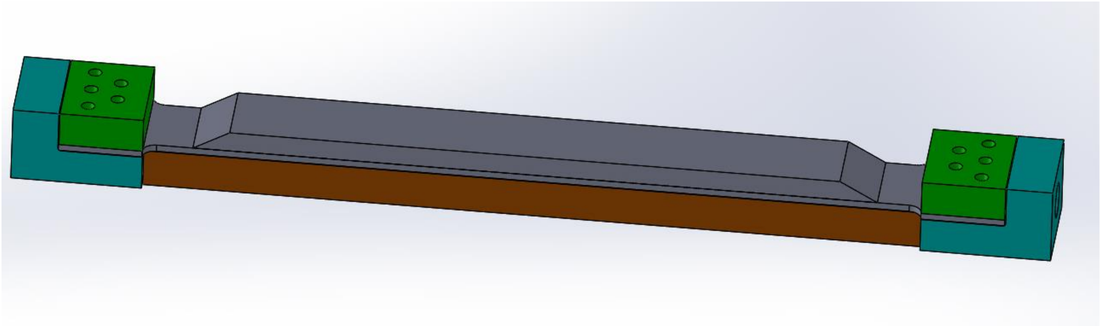
- **Thermal Protection System Integrity in launch systems is a critical factor in both manned and unmanned spaceflight**
- **Testing of bond integrity and TPS durability through multiple fill drain cycles is required to simulate possible lifecycle use.**
- **NASA Cryoflex tensile test has historically been done using Liquid Hydrogen (LH_2)**

The Cryoflex Test Concept

- **Apply both thermal and mechanical strains to a SOFI/Substrate specimen which reflects actual use conditions**
- **Rapid substrate cooling simulating sudden exposure to cryogen as tank fills**
- **Repeated fill/drain cycles- Mechanical strain**
- **Thermal gradient forms between low temperature substrate and ambient condition exposure to SOFI outer surface**



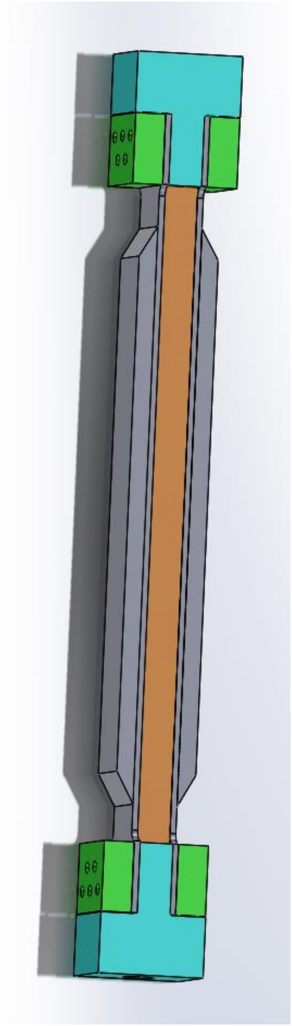
Design Parameters



- Grips to hold 6500+ lbs load, potentially at 20 K
- Needed to cool substrate to 20 K -5/+0 K, while keeping the TPS exposed to ambient conditions
- Use Liquid Helium (LHe) to cool rather than Liquid Hydrogen (LH_2)
- Measure temperature of substrate at 2 points minimum
- Measure average strain of substrate

Design Challenges

- Cooling of substrate to 20 K evenly
- Maintaining TPS exposure to ambient temperature
- Perform real time temperature measurements at substrate without interfering with cooling
- Perform real time strain measurements of substrate without interfering with cooling
- Two specimens to be tested at once
- Reduce parasitic losses



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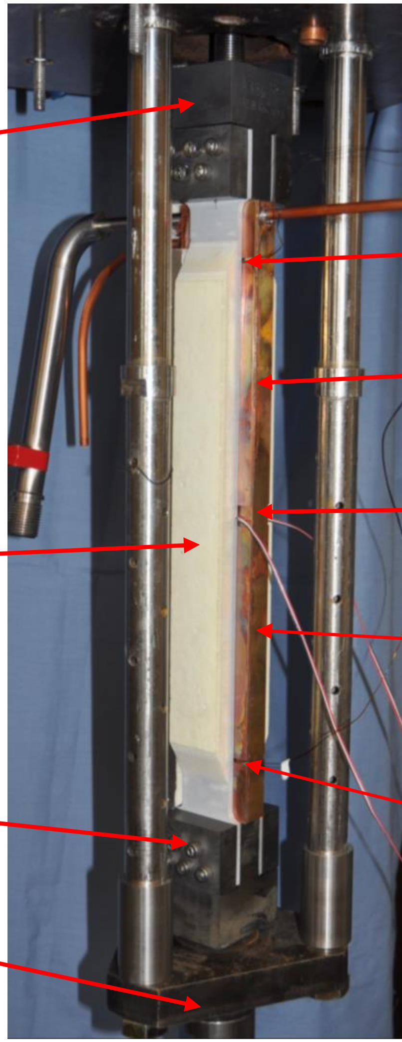
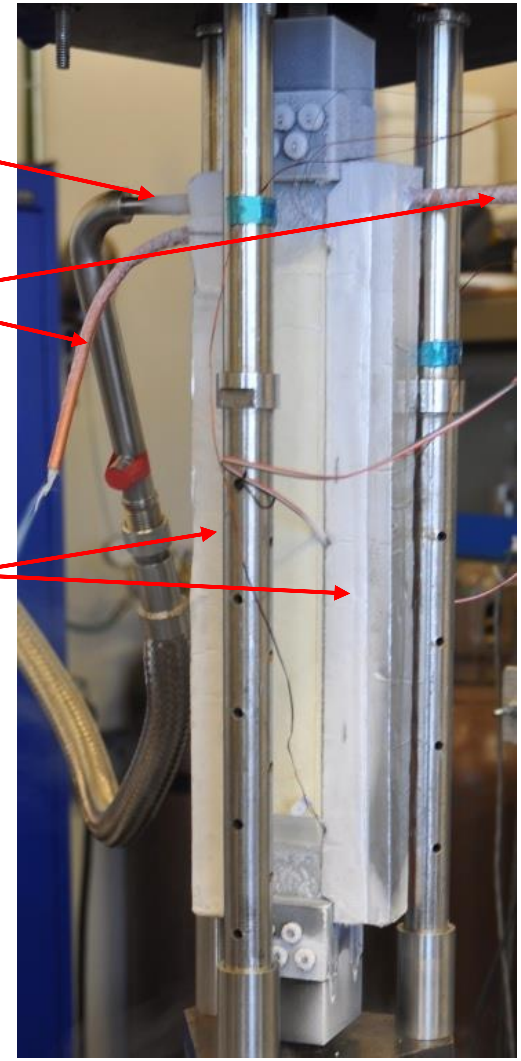
Test System Solutions

- Use the Endothermic property of expanding gases to augment the heat extraction from the substrate
- Create a cold shroud through intelligent gaseous Helium (GHe) exhaust routing
- Cool both sides of the block evenly by minimizing and equalizing the thicknesses that contact the substrates
- Constrain the cooling block using the substrates themselves with no parasitic attachments
- Slots in cooling block to clear strain gage wires and Silicon Diodes

Cryoflex Test System

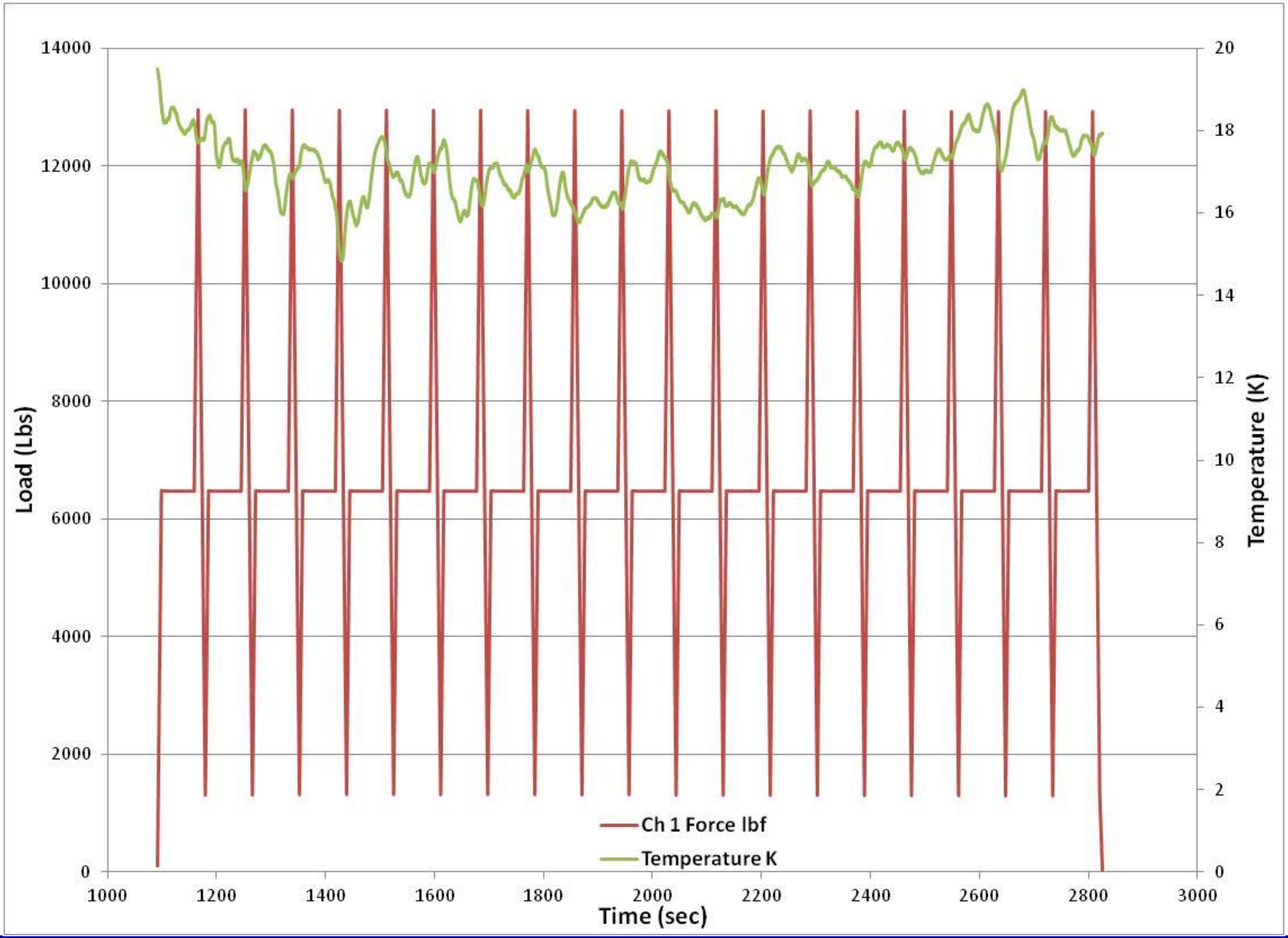




Test Procedure

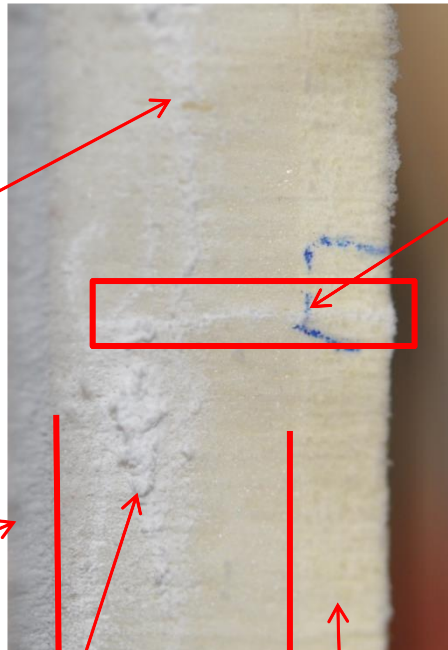
- **Initial cool-down from 295 K to 50 K**
  - **Ramp rate of 12-16 K/min**
- **Secondary cool-down from 50 K to below 20 K**
  - **Ramp rate of >18 K/min**
  - **Simulates rapid fill of tank**
- **Initiate mechanical loading**
  - **All loading performed at a rate of ~900 lbs/sec**
- **Maintain substrate temperature and perform load cycling**
  - **Maximum and minimum loads determined by substrate thickness and desired strain level**
  - **Holds at certain stress or strain levels can be used**
- **Repeat load cycling (mission cycles) while holding substrate at <20 K**
- **Monitor TPS foam integrity and surface temperature**

Load & Temperature Vs Time



TPS Cracking

Typical TPS Failures



Crack across outer surface layer

Crack Detection/Observation

Crack while actively cooling

Same Crack at room temperature; almost invisible

- **Ability to actively monitor specimen during the test is critical**
- **Acoustic emissions indicate crack formation and propagation and enhance data reliability.**

Conclusions

- **CTD's Cryoflex test system demonstrates the ability to use LHe to achieve an intermediate cryogenic temperature of a metallic substrate and ambient temperature exposure to SOFI foam, while allowing mechanical loads to be applied to the substrate**
- **The system accurately simulates actual conditions in the fill, pressurization, and draining of a cryogenic fuel tank used in aerospace applications**
- **Allows direct monitoring of the condition of the foam and the foam/substrate interface to immediately locate and identify a disjuncture within the foam or the foam to substrate bond**
- **Reducing the safety precautions by using LHe (as opposed to the use of more volatile cryogens) results in additional cost savings**