Session 4: Innovative Materials Applications

TransHab Materials Selection

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TransHab Materials Selection

crew habitation

crew support

environmental control

Micrometeroid/orbital debris protection

radiation protection

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Location of TransHab on the ISS

Node 1
Node 2
Node 3
U.S. LAB
ISS TransHab
Nadir
Multi-Layer Inflatable Shell

External Thermal Blanket

Meteoroid/debris Shielding

Bladder Restraint Layer

Redundant Bladders

Internal Scuff Barrier

Window

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Multi-Layer Inflatable Shell
TransHab Functions

• Crew Habitation Functions:
  – Private Sleeping Compartments
  – Food Preparation
  – Food Consumption
  – Food Stowage
  – Full Body Cleansing
  – Earth Viewing
  – Stowage (Personal, Food, Water)

• Crew Support Functions:
  – Social Gathering
  – Meeting Area
  – Private Gathering
  – Crew Health Care
  – Exercise
  – Housekeeping
  – Stowage
  – Radiation Protection
TransHab Materials Requirements

- Structural integrity
  - Hold 1 atm pressure differential
- Deployment in various thermal conditions
- LEO environment compatibility
  - Atomic oxygen
  - Ionizing Radiation
  - Plasma
  - meteoroids and debris
- Material properties/inflatable compartments
  - nonflammable
  - low offgassing
  - resistant to fungus and microbial growth
Expected Thermal Environment

- In Shuttle payload bay:
  - Approximately 20 °F average “bulk” temperature
    - Assuming no internal heat source
    - Based on engineering judgement, thermal analysis not yet performed

- At time of deployment:
  - Approximately 0 °F average “bulk” temperature
    - Assuming no internal heat source
    - Some local temperatures may be as low as -20 °F
    - Based on engineering judgement, thermal analysis not yet performed

- -20 °F expected material temperature spec. (-30 °F cold temperature limit for non-silicone mat’ls)
  - Heaters in seal region and core will be implemented if thermal analysis shows temperatures < -20 °F at deployment
**Materials Selection Challenges**

- Materials currently baselined or under consideration require further development, and their structural integrity must be sustained in a variety of environments.
- The finished shell, with multiple layered elements and a unique shape, requires the development of unique fabrication techniques for bladder seals and bonding.
- Progressive testing program will develop fabrication techniques and provide correction for currently unforeseen fabrication problems.
- An integral water tank is a new technology that requires further laboratory testing and engineering development.
Bladder Restraint Layer Materials

- Kevlar (Aramid) fibers
  - Bladder reinforcement
    - No degradation/embrittlement at cryogenic temps.
  - Meteoroid/Debris shielding
    - Bumper layer reinforcement
  - Scuff barrier
    - Kevlar felt cloth adds puncture resistance and protection from abrasion with other components
    - Applied early in manufacturing process to prevent handling damage
    - Assembled to bladder material using adhesive
**Bladder Assembly**

- Three bladders, separated by bleeder cloth and sealed to the interface at the bulkhead

- Each bladder gore cut out from (Polyurethane/Saran film) and heat sealed together

- Bladders indexed to each other; tabs provided for indexing to restraint and inner layers
**Bladder Materials Requirements**

- **Evaluation Criteria**
  - Must exhibit cold temperature ductility
    - % elongation @ -50 °F and -30 °F relative to Ambient Temperature.
    - No delamination between gas barrier and polyurethane
  - Must pass toxic offgassing
  - Must pass permeation
    - Leak rate not to exceed 2 cc/100 sq.in./24hr/atm
  - Must exhibit flex cracking resistance
    - Use Permeation testing to verify defect free samples
  - Must pass puncture test
Bladder Materials Testing

- Puncture resistance at -30 °F & 0 °F
- Triple point fold test at -30 °F & 0 °F
- Cut slit method tensile tests
- Permeability testing of 50% elongation at break samples
- Cold temperature bally flex testing
- SEM analysis of cold temperature tensile fracture surfaces and component layers
Bladder Materials Selection

• Polyethylene/ethyl vinyl alcohol/nylon laminate
  – light weight, low density
  – good offgassing/toxicity
  – low permeability (0.07 cc/100 in²·day·atm)*
  – very brittle at cold temperatures (flex cycling, puncture tests)

• Polyurethane/Saran laminate
  – higher permeability (0.32 cc/100 in²·day·atm)*
  – adequate mechanical integrity at cold temperatures (flex cycling, puncture tests)

• Tedlar-Mylar-Polyurethane-Polyester Scrim
  – higher permeability (barely meets requirement)*
  – poor mechanical integrity at ambient temperature (flex cycling, puncture tests)

* 2.0 cc/100 in²·day·atm requirement
**Bladder Materials Selection**

- -30 °F & -50 °F testing to characterize mechanical properties
  - Material Properties at Room Temperature after 100% Elongation of Peak Load
  - Material Properties at Room Temperature after 50% Elongation of Break

**-30 °F Typical Tensile Stress Curve**

**-50 °F Typical Tensile Stress Curve**

Stress(PSI) vs. Elongation(in)  
Stress(PSI) vs. Elongation(in)
50% Loading of Break Elongation at -50 °F

- Cracking in the polyurethane only
- Verified that these cracks are not thermally induced by examining unloaded samples
- Cracks in the polyurethane suppressed by thin saran layer
Bladder Materials – Future Testing

- Polyurethane/Saran
  - Thickness (4.75mil, 6.75mil, 12.75mil)
  - Seam Testing of Heat Seals
    - Tensile, Permeation and Bally Flex Testing
  - Adhesive Testing and Evaluation
  - S-Flex Testing of Bladder Layup
  - Testing to Determine Elongation Properties of Two Individual Components Saran and Polyurethane
  - Bally Flex Testing will continue past the 3000 cycles currently completed
  - Cold Temperature Laminate Failure Without Loading
Meteoroid/Debris (MMOD) Shielding

• Shield Requirements
  – meet or exceed ISS requirement for probability of no penetration

• Design
  – based on ISS multishock shield (Kevlar/Nextel)
  – shield layers separated by foam spacers
  – manufactured in gores similar to bladder
  – gaps in foam allow MMOD to fold
  – vacuum-packed to minimize folded volume, foam expands during deployment/inflation
  – all fabric system
  – state of the art in hypervelocity impact protection
**Meteroid/Debris Protection Materials**

- Test Matrix
  - Large historical data base on ceramic based bumper shields
  - Over 50 shots completed by TransHab Program at JSC/WSTF (6.5 km/sec.)
    - Sub Scale
    - Full Scale
    - Variety of Configurations
  - Current design viable solution to meet ISS requirements
  - 12 Full scale shots underway to determine ballistic limit curve
**Multilayer Insulation (MLI)**

- **Requirements**
  - Provide Thermal Insulation
  - Atomic oxygen protection
  - Electrically grounded
  - Foldable for launch packaging
  - Vented
  - Not load bearing

- **Design**
  - Based on ISS standard MLI design
  - Beta Cloth outer layer protects against atomic oxygen attack (aluminized on inside to block light transmission)
  - 20 layers of reinforced double aluminized Mylar with inner and outer cover of reinforced double aluminized Kapton
  - Atomic oxygen protection and MLI split into two separate layers
  - Deployment system on separate load bearing layer between MLI and Beta Cloth
Manufacturing Processes

• Key Special Processes
  – Adhesive bonding to bladder materials
  – Sewing, weaving
  – Folding, packing
  – Control of foreign materials in-and-around shell and bladder
    • bladder damage (sewing equipment, fasteners, sharp objects)
    • contamination control

• Key Controlled Materials
  – Bladder material
  – Adhesives
  – Kevlar restraint layer material
Project Status

• Remains candidate for ISS Habitation Module

• In competition with aluminum Habitation Module (shell fabricated at MSFC several years ago, not outfitted)
  – Transhab provides higher potential for long-term applications, higher volume
  – Aluminum Hab provides lower risk, lower cost