AMPET Aerospace Materials, Processes, & Environmental Technology

Session 4: Innovative Materials Applications

TransHab Materials Selection

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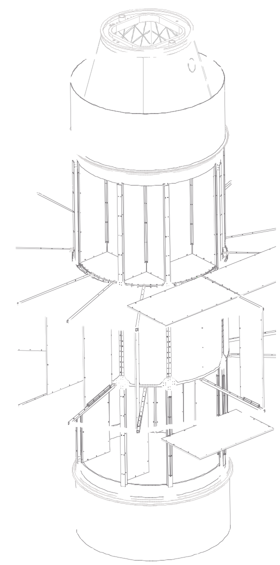

NASA-Johnson Space Center
Manufacturing, Materials, and Process Technology Division

TransHab Materials Selection

crew habitation

crew support

environmental control

Micrometeroid/orbital debris protection

radiation protection

Acknowledgments: Tim Burns, Joe Lovoula, Benny Ewing, Jeremy Jacobs, Rajib Dasgupta

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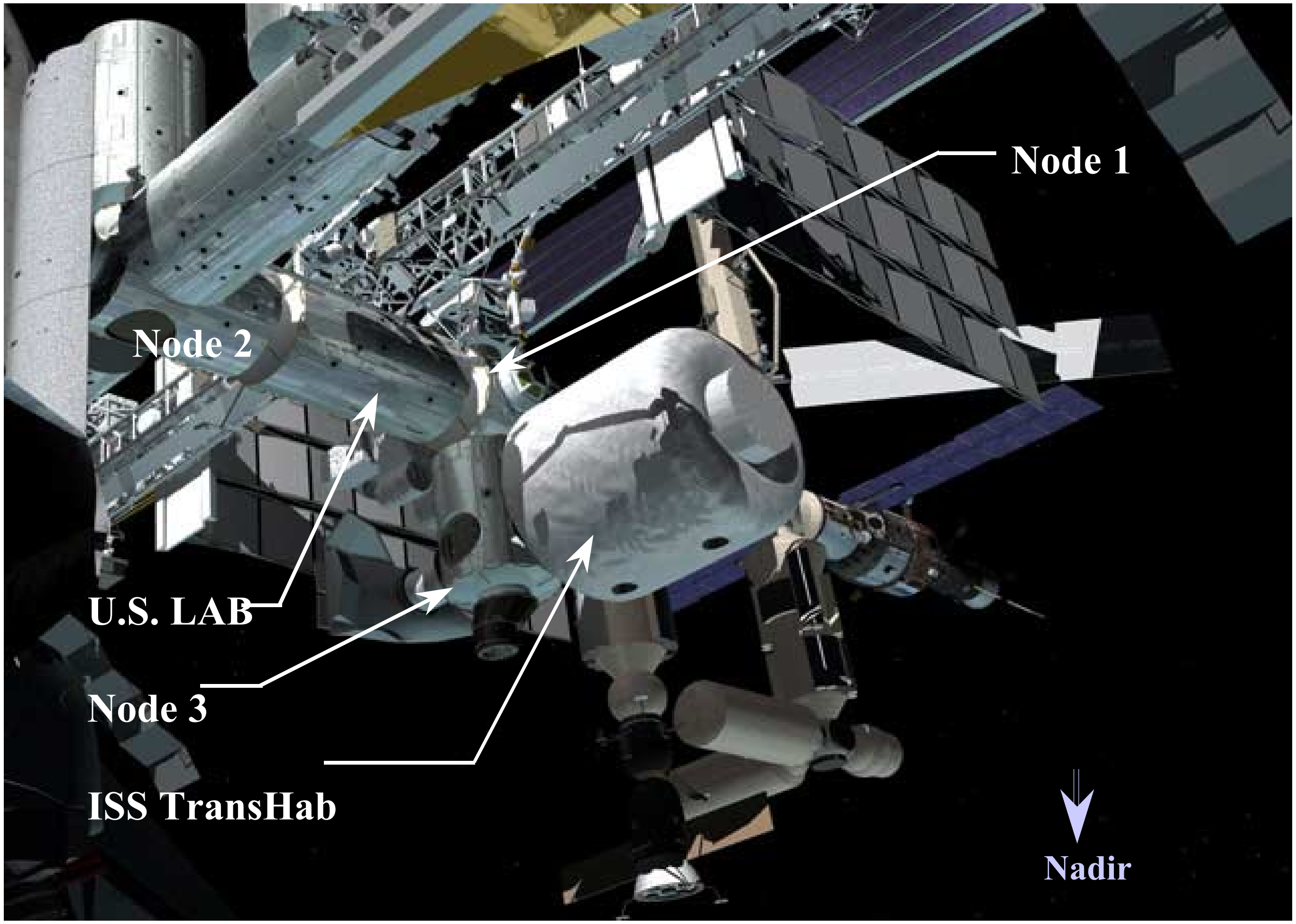
Location of TransHab on the ISS



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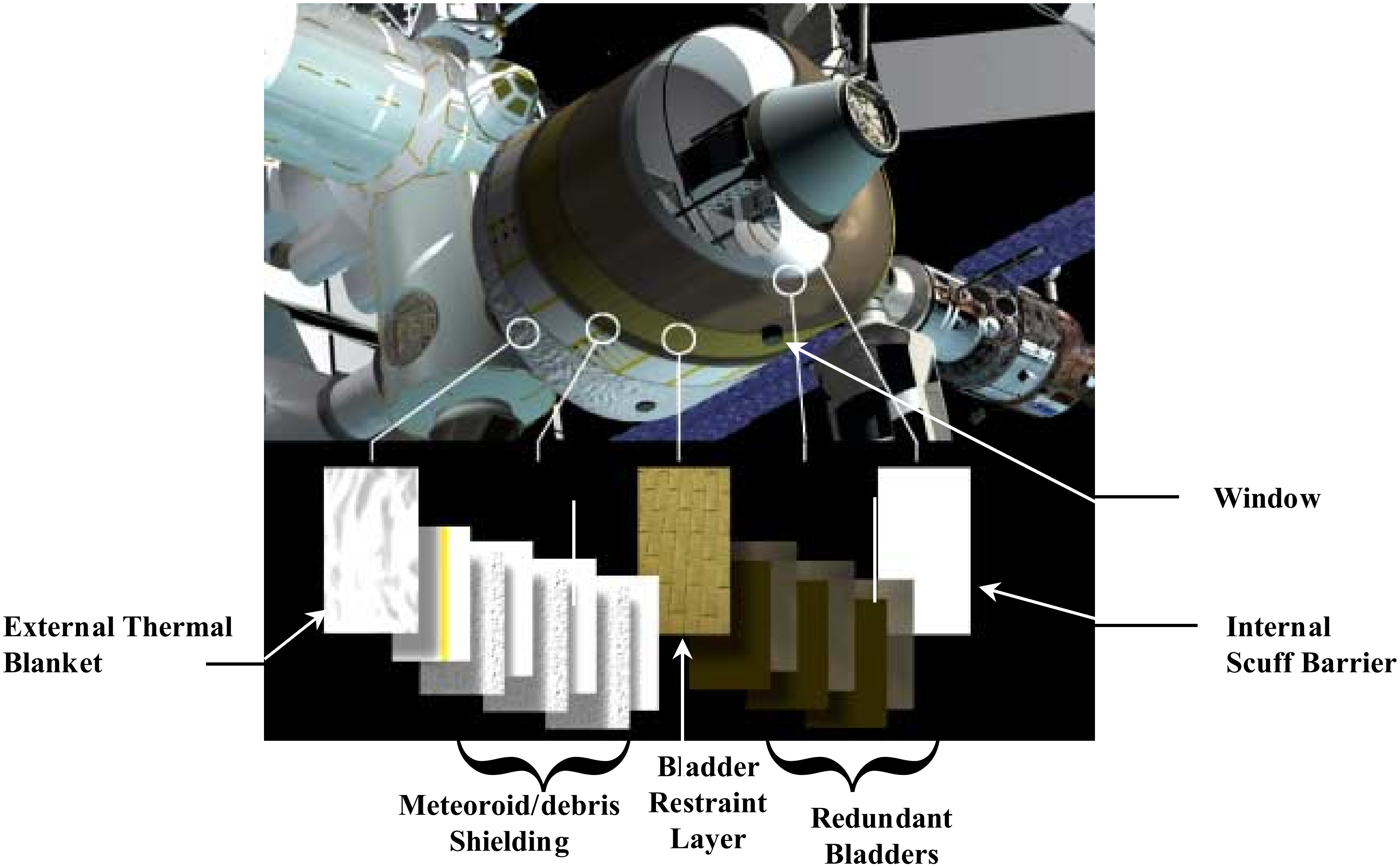
Multi-Layer Inflatable Shell



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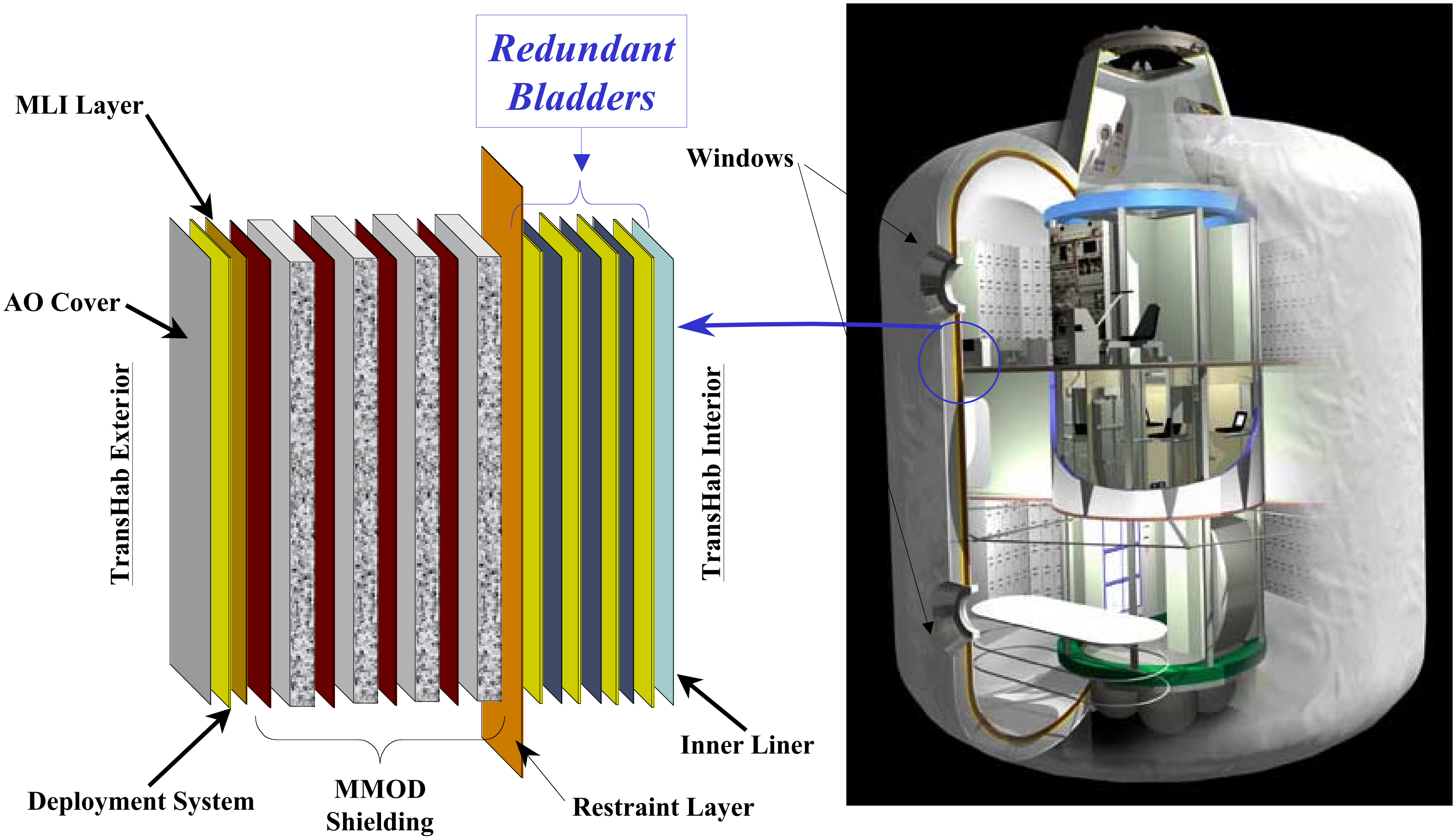
Multi-Layer Inflatable Shell



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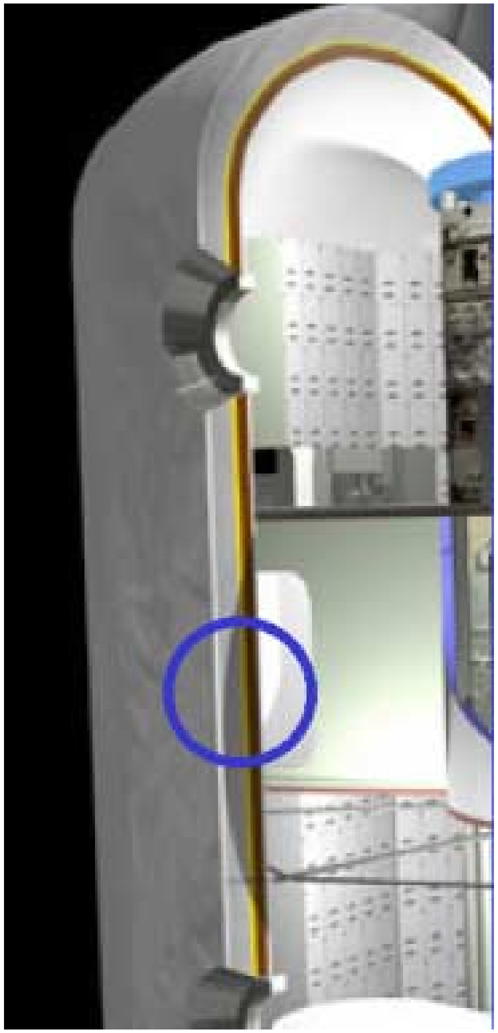
TransHab Functions

- **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

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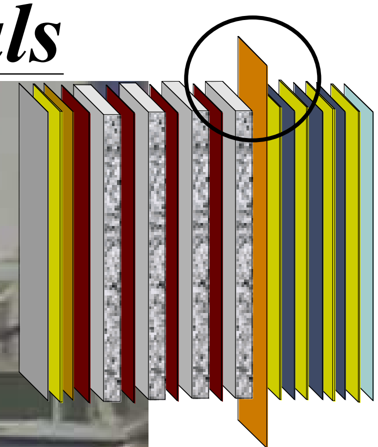
Expected Thermal Environment

- In Shuttle payload bay:
  - Approximately 20 ^oF average "bulk" temperature
    - Assuming no internal heat source
    - Based on engineering judgement, thermal analysis not yet performed
- At time of deployment:
  - Approximately 0 ^oF average "bulk" temperature
    - Assuming no internal heat source
    - Some local temperatures may be as low as -20 ^oF
    - Based on engineering judgement, thermal analysis not yet performed
- -20 ^oF expected material temperature spec. (-30 ^oF cold temperature limit for non-silicone mat'ls)
  - Heaters in seal region and core will be implemented if thermal analysis shows temperatures < -20 ^oF 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

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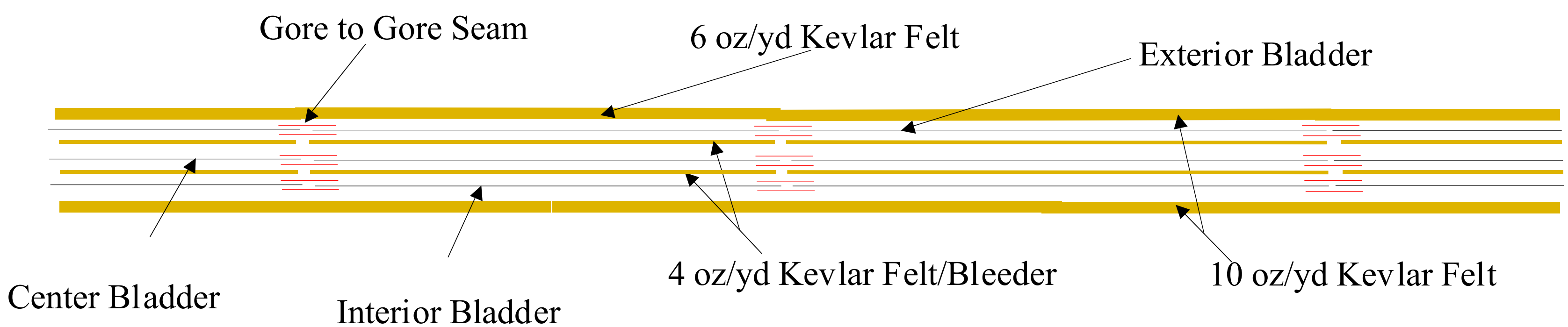
Bladder Assembly

- 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



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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

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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

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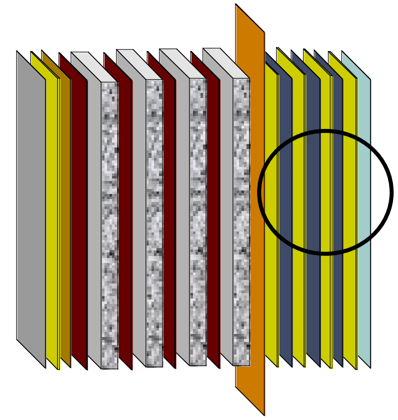
Bladder Materials Selection



- **Polyethylene/ethyl vinyl alcohol/nylon laminate**
  - light weight, low density
  - good offgassing/toxicity
  - low permeability (0.07cc/100in^2*day*atm)*
  - very brittle at cold temperatures (flex cycling, puncture tests)

- **Polyurethane/Saran laminate**
  - higher permeability (0.32cc/100in^2*day*atm)*
  - adequate mechanical integrity at cold temperatures (flex cycling, puncture tests)

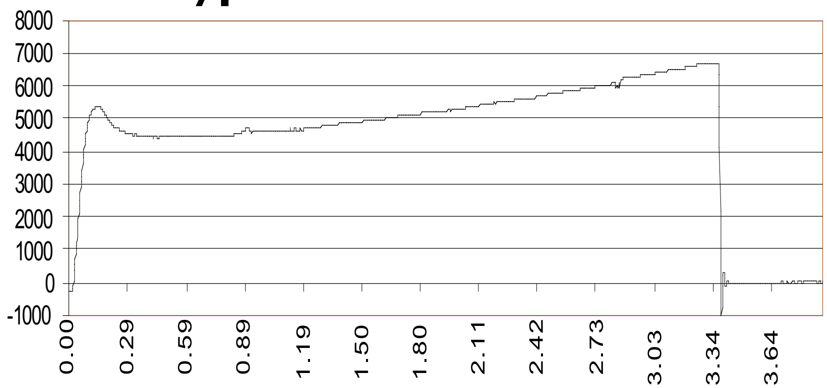
- **Tedlar-Mylar-Polyurethane-Polyester Scrim**
  - higher permeability (barely meets requirement)*
  - poor mechanical integrity at ambient temperature(flex cycling, puncture tests)

* 2.0cc/100in^2*day*atm requirement

Bladder Materials Selection

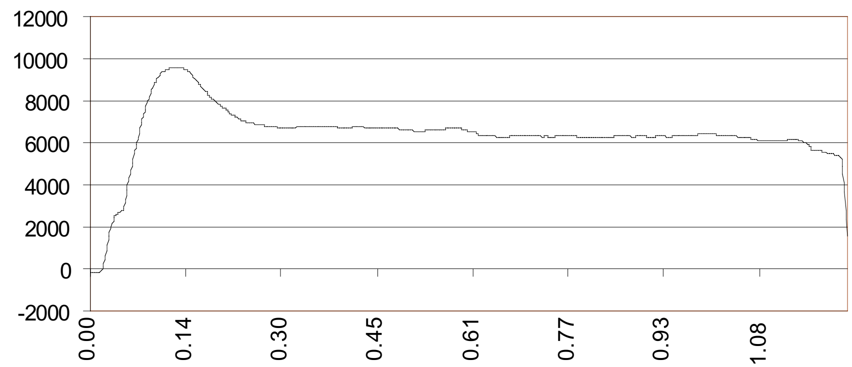
- -30 °F & -50 °F testing to characterize mechanical properties
  - Material Properties at Room Temperature after 100% Elongation of Peak Load
  - Material Properties at Room Temperature after 50% Elongation of Break

-30 °F Typical Tensile Stress Curve



Stress(PSI) vs. Elongation(in)

-50 °F Typical Tensile Stress Curve



Stress(PSI) vs. Elongation(in)

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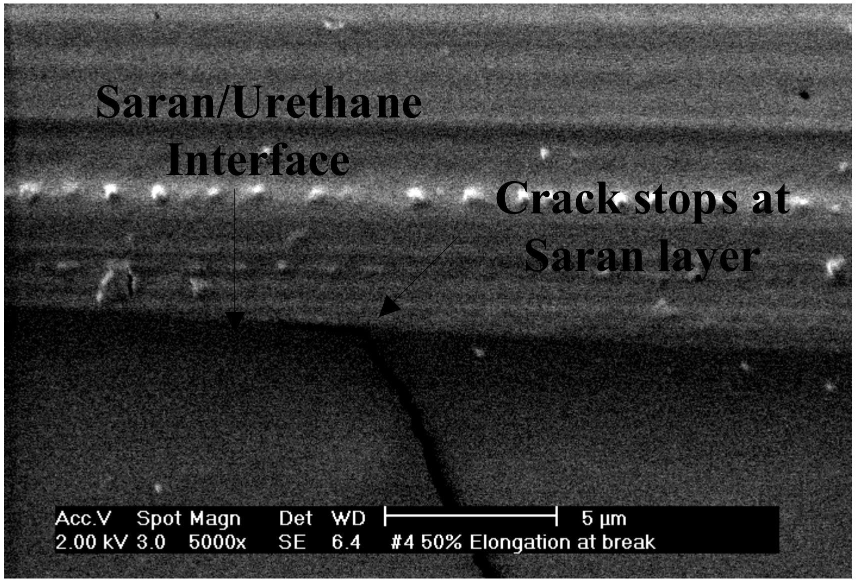
Bladder Materials Selection (Polyurethane/Saran)

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



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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

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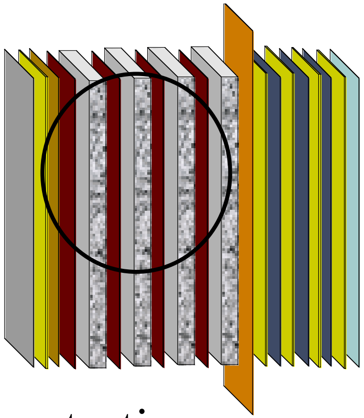
Meteoroid/Debris (MMOD) Shielding



- 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

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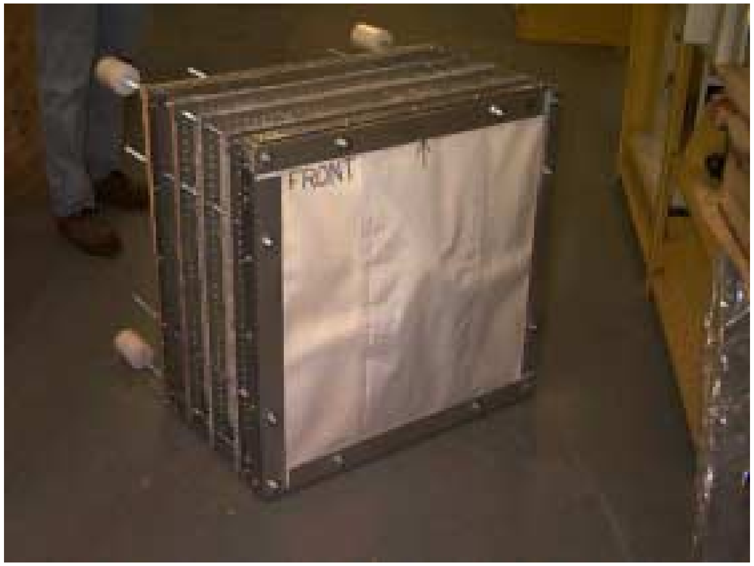
Meteroid/Debris Protection Materials

- 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



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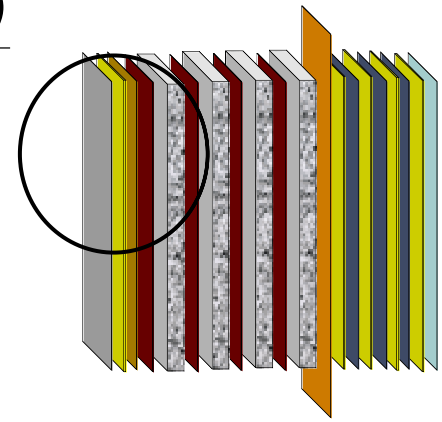
Multilayer Insulation (MLI)



- **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

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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

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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