TEXTILES FOR LIVING IN SPACE

International Space Station (ISS) and Beyond

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IFAI EXPO 2017, New Orleans, LA, USA
TEXTILES AND SPACE EXPLORATION

• **Why** use textiles for spaceflight?
• **What** type of spaceflight?
• **How** to select these textiles?
TEXTILES FOR SPACE EXPLORATION

• Human and textiles
  • Textiles are one of the oldest engineering material

• Unique engineering properties
  • Lightweight
  • Flexibility (minimize volume)
  • High strength to weight ratio
  • Composite structure
TEXTILES FOR SPACE EXPLORATION

Two Environmental Categories

Intravehicular Activity (IVA) – Inside spacecraft environment

Extravehicular Activity (EVA) – Outside spacecraft or planetary environment
TEXTILES APPLICATIONS

- Extravehicular Activity (EVA)
  - Thermal insulation blanket and cover
  - EVA tools – tether, restraint, etc
  - Spacesuit fabric layup
  - Inflatable structure
  - Composite material structure

- Intravehicular Activity (IVA)
  - Crew clothing
  - Acoustic insulation
  - Bag and storage containers
  - Sleep station cover, cushion
  - Exercise aids
SPACE / SPACECRAFT ENVIRONMENTS

• Atomic Oxygen (AO) - LEO
• Micro Meteor Orbital Debris (MMOD) - LEO
• Thermal Extreme – LEO (± 250 F)
• Space Vacuum – LEO, Moon, Mars
• Radiation (UV, Ionizing Protons & Electrons, Galactic Cosmic Rays) – LEO, Moon, Mars
• Solar Energetic Particles – LEO, Moon, Mars
• Closed System Environment – close loop life support system compatibility - Spacecraft
• Unique planetary conditions – Moon, Mars
UNIQUE CHALLENGES

- Desirable properties for various spaceflight applications
  - Nonflammable - IVA
  - Low toxicity - IVA
  - Thermal vacuum stable - EVA
  - Dust Resistance - EVA (planetary)
IVA CHALLENGES - FLAMMABILITY

- Flammable material creates fire and safety hazard
- Nonflammable in enrich oxygen spacecraft environment required
- Pass NASA flammability test (NASA-STD- 6001, Test 1) required
  - Bottom ignition upward flame propagation test
  - Burn length < 6”
  - No transfer of burning debris (melt and drip)
- Limit fabric choice for clothing and IVA applications

Flammability of common textile fibers in various oxygen environments

<table>
<thead>
<tr>
<th>Textile Fibers</th>
<th>Earth 21% O₂</th>
<th>ISS Airlock / Cabin 30% O₂</th>
<th>Future Spacecraft &gt; 34% O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton (LOI ~19%)</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Polyester (LOI ~ 22%)</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Wool (LOI ~ 22%)</td>
<td>✗</td>
<td>✗</td>
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</tr>
<tr>
<td>Modacrylic (LOI ~ 26%)</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Nomex (LOI ~ 31%)</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>P84 (LOI ~ 33%)</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>FR Cotton (LOI ~ 34%)</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Durette (LOI ~ 38%)</td>
<td>✔</td>
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<tr>
<td>PBI (LOI ~ 38%)</td>
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<tr>
<td>Carbon (LOI &gt; 55%)</td>
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<tr>
<td>Teflon (LOI &gt; 95%)</td>
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<td>✔</td>
<td>✔</td>
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<tr>
<td>Fiberglass (LOI ~ 100%)</td>
<td>✔</td>
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</tbody>
</table>
IVA CHALLENGES - TOXICITY

- Close loop system promotes accumulation of offgassed products that could create safety hazard
- Low toxicity outgassing required
- Pass NASA toxicity test (NASA-STD-6001, Test 7 or ISO-14624-3)
  - Tested for 72 hours at 122 F
  - Established spacecraft maximum allowable concentrations (SMACs) for contaminants per JSC 20584
  - Toxicity hazard index < 0.5
- May limit the use of coating or textile surface treatment (e.g. FR treatment)
EVA CHALLENGES – THERMAL VACUUM STABILITY

• Textile material outgassing in thermal vacuum environment

• Outgas product such as volatile condense materials (VCM) can contaminates critical space hardware
  • Thermal radiation surfaces
  • Solar panel surfaces

• Pass NASA TVS test (JSC SP-R-0022A and/or ASTM E595)
  • Total mass loss ≤ 1.0 %
  • Total VCM ≤ 0.1 %
EVA CHALLENGES – ATOMIC OXYGEN

- Atomic Oxygen (AO) is an element in the low earth orbit (LEO) environment that degrades certain structural materials
- LEO comprised of 96% AO
- Degradation of materials by oxidation and erosion
- Alter texture, hydrophilicity of material surface properties

Sources of Oxygen + UV $\rightarrow$ O
(Atomic Oxygen)
EVA CHALLENGES - DUST

- Lunar / Mars dust issues
  - Contamination and abrasion of spacesuit materials
  - Contamination of critical EVA hardware surface
  - Contamination of IVA crew cabin and equipment
IVA CASE STUDY – CREW QUARTER

- Crew Quarter / Sleep Station
  - Custom sleeping bag
  - Teflon fabric lined interior for ease of cleaning and maintenance
IVA CASE STUDY - AMCTB

- Acoustic Multipurpose Cargo Transfer Bag (AMCTB)
  - Multi-use concept technology demonstration
  - Convertible cargo bag
  - Acoustic blanket
IVA CASE STUDY – TVIS HARDNESS

- Treadmill with Vibration Isolation and Stabilization (TVIS) Harness
  - Nomex webbing
  - Cotton comfort liner
  - Nomex fabric outer layer
  - Teflon fabric cover
CASE STUDY – SPACESUIT

• Extravehicular Mobility Unit (EMU)
  • Thermal Micrometeor Garmet (TMG)
    • Outer layer – Ortho, Teflon / Nomex / Kevlar ripstop fabric
    • Multi Layer Insulation – aluminum Mylar with polyester scrim
    • Restraint layer – Dacon fabric
    • Micrometeror layer – Neoprene coated nylon
• Bladder layer – polyurethane coated nylon
• Liquid cooling garment (LCG) – polyester fabric with EVA tubing
CASE STUDY – EVA TETHER

- EVA Tether Functions
  - Safety tether
  - Translation anchoring
  - Secure tools and requirement

- Common cord/webbing materials
  - Nomex
  - Fiberglass
  - Vectran

- Unique glass webbing construction for AO resistance
CASE STUDY – BEAM

- Bigelow Expandable Activity Module (BEAM)
  - Inflatable habitat technology demonstration (2016)
  - 565 ft³ of habitable volume
  - Multi-layer fabric construction
    - Fabric & webbing restraint
    - Thermal and MMOD protection
    - Bladder system
BEYOND ISS– LONG DURATION MISSION

- Nonflammable textile fabric for enrich oxygen environment up to 35% O₂
- Lightweight quick drying fabric for exercise clothing
- Nonflammable acoustic insulation nonwoven materials
- Dust resistance spacesuit outer layer fabric for Mars exploration
QUESTIONS & COMMENTS
BACKUP
TEXTILES FOR LIVING IN SPACE

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VIDEO LINKS

BEAM Deportment

Running in Space

Living in Space