Inflatable Habitat Inspection Needs

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Overview

• Inflatable Structure Brief History
• Inflatable Module Shell Layers
  – Shell Layer Inspection Needs
• Flight Testing Inspection Needs
• Ground Testing Inspection Needs
• Inspection Hardware Needs
Inflatable Structures Brief History

• Inflatable habitats are fabric based pressure vessels, composed of multiple layers of materials

• Fabric layers can be packed tightly for launch and expanded in orbit, providing significant volume savings

• TransHab (1990’s)
  – Originally designed for Mars transit
  – 25-ft diameter x 3 stories high
  – Morphed into ISS Design

• Bigelow Aerospace (1999+)
  – Launched two sub-scale modules (Genesis I, 2006) and (Genesis II, 2007)
  – BEAM launched on SpaceX-8 berthed to ISS in April and inflated in May 2016, currently planned for 2-year mission
  – 10.5-ft diameter x 13-ft long
  – Technology demonstrator on ISS that potential for equipment testing in space

• NextSTEP (2014+)
  – Commercial habitat concepts for cis-lunar and Mars architectures
  – Multiple companies looking at utilizing inflatables as habitats and airlocks
Inflatable Module Shell Layers

- Habitat is composed of high strength materials, stacked in a layered configuration for structure, pressure, micro-meteoroid and thermal considerations.
## Inner Liner

**Material Needs**
Flame Resistant, puncture resistant. Typical Nomex, Kevlar felt.

**Inspection Needs**
Detect, identify and locate damage.

**Consideration**
May have to be removed to perform a through inspection of the bladder.

## Bladder

**Material Needs**
Flexible at low temps, low permeability, single or multi-layered, oversized, able to be manufactured (seam). Typical polymer film.

**Inspection Needs**
Detect, identify and locate damage.

**Consideration**
Some low permeable layers may have a metalized layer which may cause inspection challenges. Seeing through metalized layers is beneficial.
### Shell Layers Inspection Needs

#### Restraint Layer

**Material Needs**

High strength fabrics that carry the structural pressure load. Typical Vectran or Kevlar.

**Inspection Needs**

Detect, identify and locate damage in real-time and post-damage. Measure strap load/strain in real-time.

#### MMOD Layers

**Material Needs**


**Inspection Needs**

Detect, identify and locate damage size and depth of damage in real-time and post-impact.

**Consideration**

May be separated by cored out open cell foam possibly in vacuum packed bags. Orbital debris protection required for LEO drives shield size and mass.

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TransHAB Layer Configuration
Shell Layers Inspection Needs

### Thermal Layer

**Material Needs**

Helps minimize large thermal gradients. Typical multiple layers of aluminized Kapton, aluminized Beta Cloth.

**Inspection Needs**

Detect, identify and locate damage, monitor thermal performance.

**Consideration**

Seeing through metalized layers is desirable.

### Deployment Layer

**Material Needs**

Wraps folded layers in stowed configuration, supports launch ascent loads. Typical Kevlar or Nylon webbing or cords.

**Inspection Needs**

Monitor real-time deployment process. Detect, identify and locate damage.

### Atomic Oxygen Layer

**Material Needs**

Required for low earth orbit (LEO). Typical Beta Cloth.

**Inspection Needs**

Detect, identify and locate damage.
Flight Testing Inspection Needs

- Prelaunch packaged state
  - 3D metrology scan
- Launch/Ascent
  - External video (Optional: Measure billowing)
- Vehicle extraction
  - External video
- On-orbit before deployment
  - Thermal imaging
- Deployment
  - Measure deployment dynamics
  - Video imaging (internal/external)
  - Position and shape of layers during deployment
- Post-deployment (Validation of initial deployment)
  - Leak detection/location
  - Damage detection/location
  - Thermal imaging
Flight Testing Inspection Needs

- On-orbit operations
  - Monitor on-orbit environments
    - Temperature
    - Pressure
    - Radiation
  - Leak detection
    - Acoustic emissions
    - External gas emitting sensors
    - Video
  - Measure strain/load of structural restraint layer
  - Detect impact damage (autonomous and crew supported)
    - Impact detection sensors (EVA/IVA)
    - Damage detection
      - Thermal imaging
      - Penetrating 3-D Imagers
      - Serpentine imaging robots (w/ inner liner removal)
      - External camera inspection (fixed, translating, and free flyers)

BEAM Expansion on ISS
Ground Testing Inspection Needs

- Development Testing - Possible opportunities to include NDE sensors for some tests
- Modal Testing
  - WLE, DIDS, and Acoustic Emission
  - Sensors can be installed internal/external
- Micrometeoroid/Orbital Debris Hypervelocity testing
  - Impact detection (at impact)
  - Impact location methods
- Leak Testing (at operational pressure)
  - Leak detection/location
- Damage Tolerance Testing
  - Impact detection when damage imparted
  - Damage inspection methods
Ground Testing Inspection Needs

- Burst Testing
  - Fabric strain/load measurement methods
  - Non-invasive measurement methods
- Creep/Burst Testing
  - Long term strain/load measurements
  - Change in properties prior to ultimate burst
- Thermal Vacuum Testing (sub-scale)
  - Thermal imaging in the folded and deployed states
- Thermal Vacuum Testing (full scale)
  - Thermal imaging in the folded and deployed states
- Rapid Depress/Ascent Testing (sub-scale)
  - Imaging in the folded and deployed states
Inspection Hardware Needs

• Desired Characteristics
  • Small
  • Lightweight
  • Low-power
  • Accurate
  • Sensitive
  • Inexpensive
  • Durable
  • Ease of use
  • Multi-functional

• Potential solutions?
  • Contact us!
  • We have upcoming ground test opportunities and can work with you to develop flight hardware
Questions?

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Inflatable Habitat Strain Measurements

- Current strain monitoring techniques for inflatable structures utilize optical measurement systems on fabrics and traditional foil strain gauges on metallic components.
- Photogrammetry/digital image correlation (DIC) uses a dual camera system and speckle pattern to measure the strain on the fabric restraint layer.
- DIC system is very accurate and provides good results, but is limited to a small surface area.
- DIC system only works for ground tests when the restraint layer is visible; it does not work in the space environment with MMOD and thermal layers.