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Damage Tolerance Testing of a NASA TransHab Derivative Woven Inflatable Module

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Current options for Lunar habitat architecture include inflatable habitats and airlocks. Inflatable structures can have mass and volume advantages over conventional structures. Inflatable structures are perceived to carry additional risk because they are at a lower Technical Readiness Level (TRL) than conventional metallic structures. One of the risks associated with inflatable structures is understanding the tolerance to component damage and the resulting behavior of the system after the damage is introduced. The Damage Tolerance Test (DTT) is designed to study the structural integrity of an expandable structure during and subsequent to induced damage.

The TransHab Project developed an experimental inflatable module developed at Johnson Space Center in the 1990's. The TransHab design was originally envisioned for use in Mars Transits but was also studied as a potential habitat for the International Space Station (ISS).

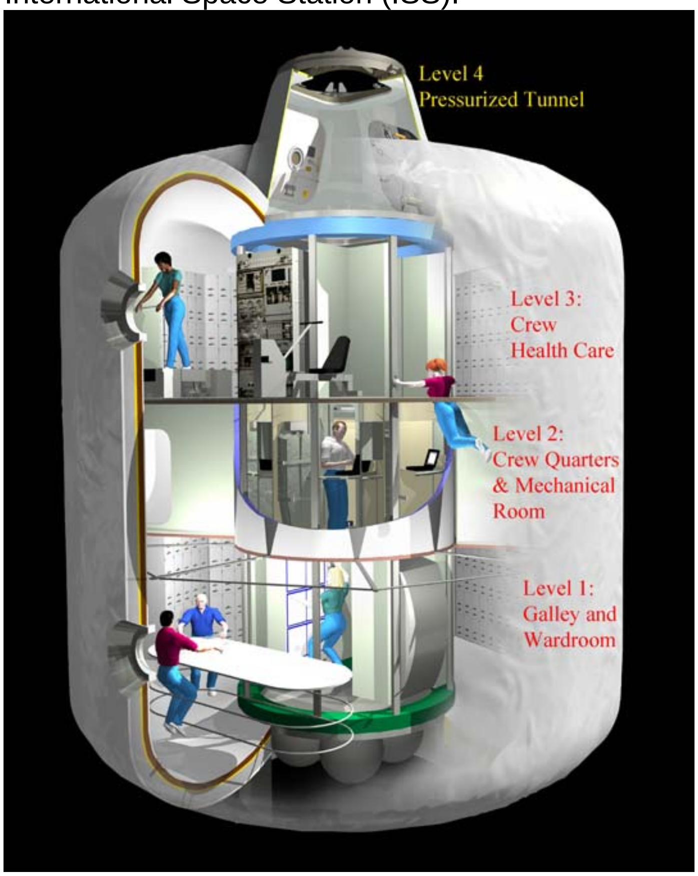

Figure 1: Cut-away of TransHab Inflatable Module

The design of the TransHab module was based on a woven design using an Aramid fabric. Testing of this design demonstrated a high level of predictability and repeatability and good correlation with analytical predictions of stresses and deflections. Based on JSC's experience with the design and analysis of woven inflatable structures, the Damage Tolerance Test article was designed and fabricated using a woven design.

The Damage Tolerance Test Article consists of a load bearing restraint layer, a bladder or gas barrier, and a structural metallic core. The test article restraint layer is fabricated from one inch wide Kevlar webbing that is woven in a basket weave pattern. Underneath the structural restraint layer is the bladder or gas barrier. For this test the bladder was required to maintain pressure for testing only and was not representative of a flight design. The bladder and structural restraint layer attach to the structural core of the module at steel bulkheads at each end. The two bulkheads are separated by a 10 foot center tube which provides the structural support for the module when in a non-inflated state as well as resists a portion of the axial load when pressurized. The longitudinal members of the structural restraint layer are attached to the bulkheads using a series of clevises that are bolted to the bulkheads. Strain gages are placed on the clevises that can measure change in load when the structural restraint is inflated. The test module is 88 inches in diameter and 120 inches in height.

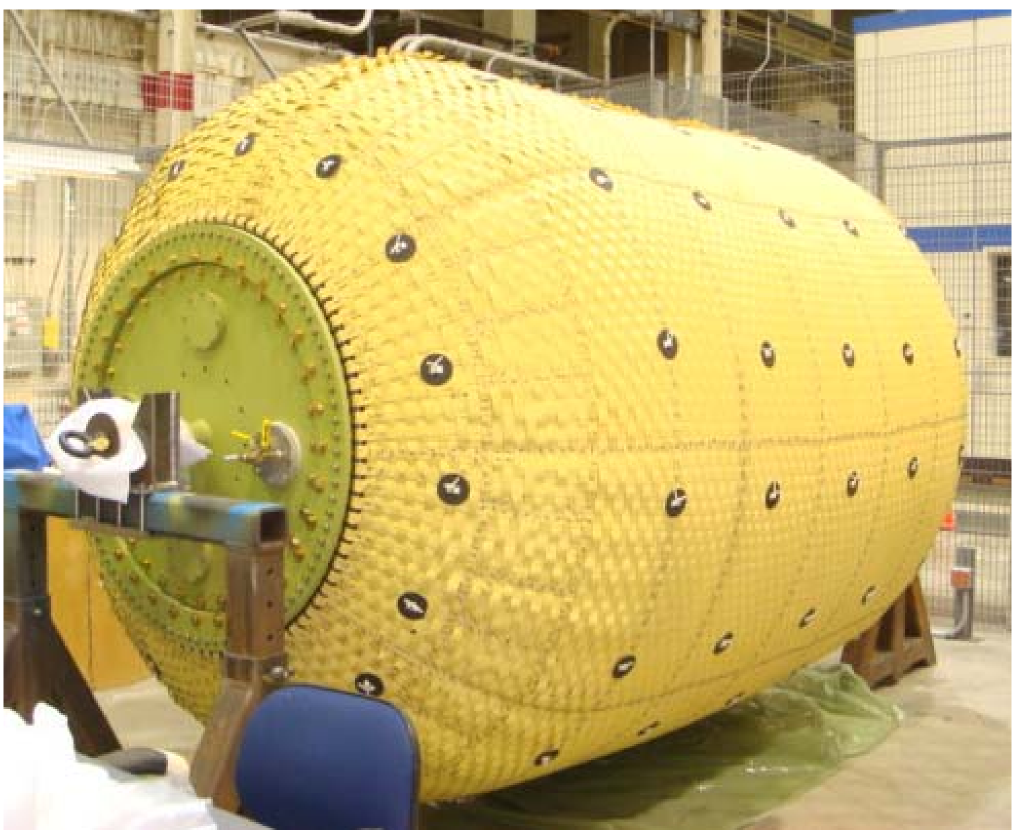

Figure 2: Low pressurization of the Damage Tolerance Test (DTT) Article

The objectives of the DTT are to (1) verify the structural integrity of the assembled and pressurized structure when a section of the structural restraint layer is cut by a foreign object, and (2) verify the load distribution of the structural restraint layer during pressurization, before and after the structural restraint layer is severed. For this test, a longitudinal structural restraint strap will be severed using a linear shape charge. The linear shape charge was designed specifically for this application to cut only a single longitudinal strap, while not damaging the bladder. An array of strain gages were located at the bulkhead mounted clevises where the longitudinal restraint layer straps are attached.

The DTT article was inflated to 45 psig, 25% of the ultimate design pressure, and one of the one-inch wide longitudinal structural members was severed. Strain gage measurements of loading in an array of longitudinal straps were taken throughout pressurization of the module to 45 psig, before firing of the linear shape charge, and after firing of the shape charge and separation of the strap. During testing not only were the original objectives met but better than expected results occurred. This paper will discuss space inflatable structures, damage tolerance analysis, test results, and applicability to the Lunar architecture.