Lunar Inflatable Habitat Development

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While surface habitats are necessary for planetary exploration missions, inflatable, lightweight habitats are critically needed. This is because inflatable habitats reduce the logistic issues of transporting a large volume to the surface of the moon as well as the launch weight. By including engineering development that directly feeds into the lunar surface system architecture, we are focusing on providing surface inflatable habitat concepts for delivery, emplacement/deployment, outfitting, and operations for lunar operations to make the missions more reliable, safe, and affordable. Before we can achieve this, many technical issues must be understood.

In January 2008, scientists jointly partnered through NASA, the National Science Foundation (NSF), and ILC Dover, Frederica, Del., to deploy an inflatable habitat in Antarctica (figure 1). Deployment took fewer than 50 minutes. Performance data (e.g., temperature, pressure, humidity, carbon dioxide concentration, power monitoring, and weather station) were subsequently measured, recorded, and monitored remotely by scientists at Johnson Space Center (JSC) throughout the 2008 Antarctic season. These scientists also investigated various operational scenarios, including packing efficiency, deployment, harsh environment performance (e.g., cold, ultraviolet, flex, crew interface), and integrated electronics. The NSF is currently working to extend deployment of the habitat as part of the Arctic Program.

Fig. 1. *(a) Inflatable habitat deployed in Antarctica. (b) Inflatable habitat during Antarctic winter.*

In August 2008, NASA White Sands Test Facility (WSTF) pressure-tested an 88-in.-diameter woven inflatable module to 45 psig (25% of ultimate burst pressure) and remotely severed a woven structural member using a linear-shaped charge (figure 2). Not only did the global inflatable module maintain its structural integrity during testing, but no measurable change in load was measured at the webbing-to-bulkhead interface, including at the interface of the severed webbing. This demonstrates that not only is the woven inflatable design

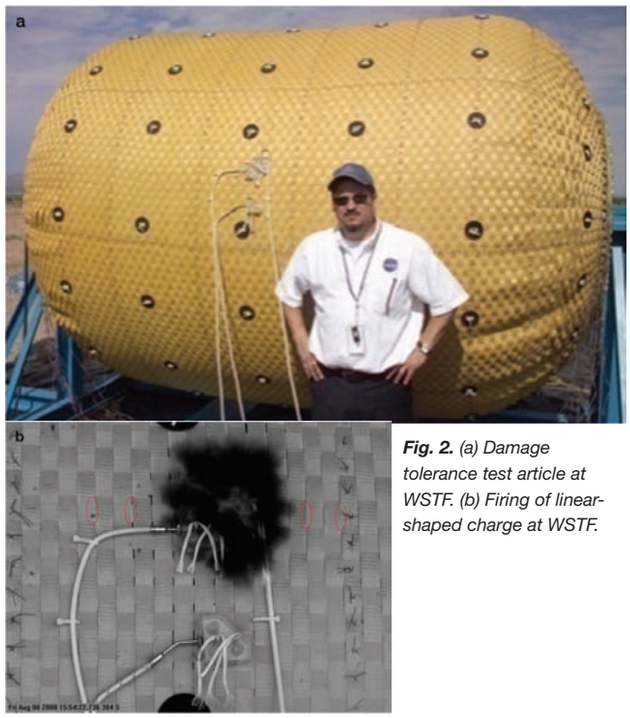

Fig. 2. *(a) Damage tolerance test article at WSTF. (b) Firing of linear-shaped charge at WSTF.*

tolerant to damage, but that the damage has a local effect that gets redistributed to adjacent members.

NASA is currently refurbishing the damage tolerance test article and integrating it with a 40-in. hatch that has a 48-in. frame. The integrated test article will be tested to lunar surface pressures times a 1.25 factor of safety (11.25 psig = 9.0 psig * 1.25). Various clevises, strain-gauged and calibrated to measure load during testing, will be used to verify analytical predictions. This integration will demonstrate the integration of a large penetration into an inflatable module. Boeing Phantom Works, Seal Beach, Calif., and NASA fabricated the hatch and frame. WSTF began Phase I pressure testing in the summer of 2009. This Phase I module (figure 3) will serve as a target during subsequent deployment and mating testing scheduled for fiscal year 2010 (FY10).

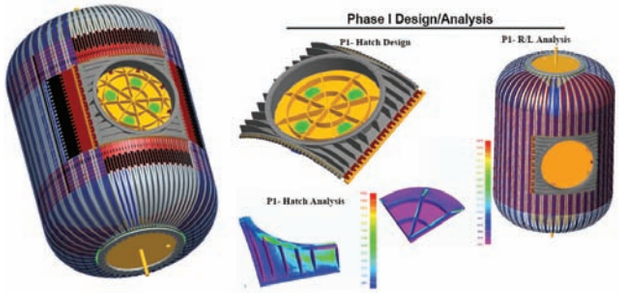

Fig. 3. *Inflatable structure: hatch integration Phase I.*

For Phase II, NASA will design, analyze, fabricate, and test a full-scale, 28-ft-diameter Constellation Trade Set-1a torus habitat with integrated hatch penetration (figure 4). The product is a full-scale expandable structure with a 40-in.-diameter hatch. The objectives are: to design, fabricate, and integrate a hatch into the full-scale inflatable torus module; to scar the internal core longerons and hatch frame for a future addition of a hatch deployment system; to inflate in a 1g environment; to inflate the module to 11.25 psid (lunar and Mars surface pressures 9.0 psig *

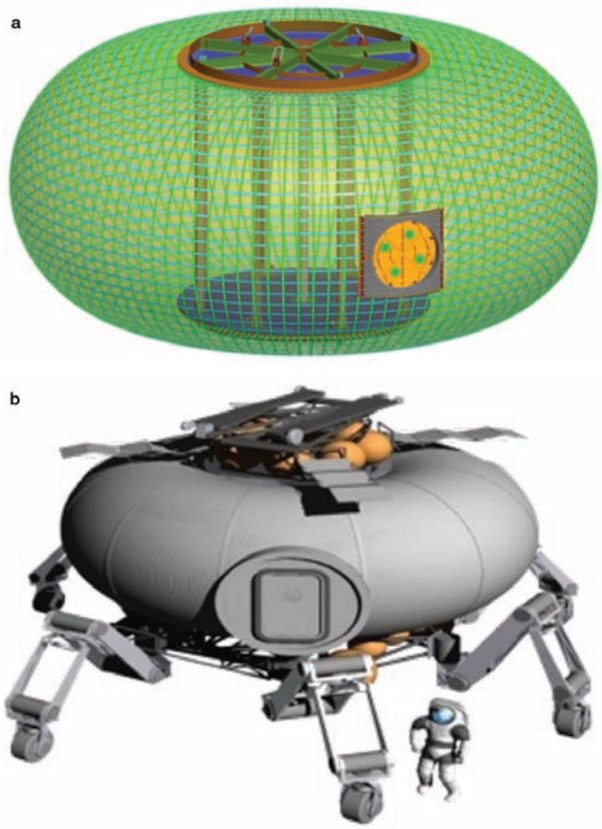

Fig. 4. *(a) Phase II test article. (b) Constellation trade set 1a torus habitat.*

1.25 Proof); and to compare the hatch frame and bulkhead clevis strain measurements with analytical predictions. Fabrication of the Phase II test article started in the summer of 2009 with pressurization testing at WSTF thereafter.

Phase III will use the Phase I and II modules for deployment and mating testing to ensure a Technical Readiness Level of 5-6. Phase III is currently scheduled for FY10 with funding forthcoming.

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