Development of an Inflatable Airlock for a Deep Space Gateway

Douglas A. Litteken[1] and Thomas C. Jones[2]
National Aeronautics and Space Administration

Abstract for Submission
American Institute of Aeronautics and Astronautics (AIAA) SPACE Forum
September 17-19, 2018 | Orlando, Florida

I. Abstract

Inflatable structures technology utilizes high-strength fabric materials and internal pressure to create a stiffened pressure vessel that can replace traditional metallic primary structure in a habitable spacecraft. The flexibility of fabric structures allows them to be compactly stowed for launch and expanded in space, providing significant launch volume savings. The unique construction and design flexibility of these structures can be customized for a variety of uses in space including landing bags, decelerators, long duration in-space and planetary surface habitats, and even airlocks. An airlock is often a required component of a crewed spacecraft to allow for maintenance and human exploration outside of the vehicle. Airlock designs in use today rely on complex hatches and seals connected by metallic walls. Recent developments towards the design of an inflatable airlock structure show feasibility and a significant launch volume savings over a traditional metallic design. This paper will provide a high-level summary of these projects and the current state-of-the-art in inflatable airlock development with additional references and detail about previous and on-going research, providing guidance for the design of a softgoods airlock system.

The use of inflatables in space has been in development since the 1960's for both habitats and airlocks. The first ever EVA was conducted by the USSR in 1965 using an inflatable airlock known as the Volga. This airlock was attached to the Voskhod 2 spacecraft and turned the vehicle into a dual chamber airlock. The airlock was successfully deployed, used and jettisoned after Alexey Leonov's historic spacewalk. Additional work on human-rated inflatable structures was not continued until the late 1990's when NASA-JSC led an effort to demonstrate these structures as feasible long-term pressurized elements with the TransHab project. The technology developed and pioneered during this project led to multiple patents and proven feasibility that inflatables could be used for large habitable structures. Following TransHab, Bigelow Aerospace continued the development of inflatable structures with technical support from NASA. This partnership eventually led to the successful flight certification, launch, attachment and deployment of the Bigelow Expandable Activities Module (BEAM) on the ISS in 2016.

Inflatable and expandable airlock structures have undergone various detailed feasibility studies and testing for over 15 years, most notably with the Advanced Inflatable Airlock (AIA), Dual-Chamber Hybrid Inflatable Suitlock (DCIS), Minimalistic Advanced Soft Hatch (MASH), and Lightweight External Inflatable Airlock (LEIA). During this time, full-scale articles have been built and pressure-tested, and mock-ups and demonstrators have been constructed and evaluated.

During the 2001-2003 timeframe, the AIA concept was matured through requirements development, conceptual design, subscale and full-scale engineering breadboards subjecting various test articles to deployment and pressure testing up to four times operating pressure. These tests proved the feasibility of successful deployment and structural integrity of an inflatable crewlock. Additional testing was performed in the ensuing years, as funding permitted, to further refine additional structural and deployment concepts and to understand the EVA crewmember interfaces, hatches and EVA support equipment interfaces that would be required for a fully functioning airlock. This work resulted in a refinement of the structural requirements and an accounting of the systems needed in an inflatable airlock.

In 2014, the MASH project developed an ultra-lightweight airlock concept with a fabric hatch that utilized a unique pressure vessel shape to minimize structural loads around a linear seal. The concept uses an automated zipper-like seal that allows for crew egress/ingress. Most of the development work on the project thus far has focused on the

[1] Structural Engineer, ES2, NASA Johnson Space Center, Houston, TX 77058, AIAA Member
[2] Research Engineer, MS 190, NASA Langley Research Center, Hampton, VA 23681, Senior AIAA Member

design, analysis and testing of the primary structure and the zipper-like seal system is in the preliminary stages of development with a successful proof-of-concept test.

As part of the 2017 LEIA effort, studies were conducted on EVA crewmember interfaces on the inside of an inflatable airlock. These efforts included the design of an internal secondary structure and placement of handholds and foot restraints to enable hatch opening, closing and translation through the airlock. Structural design, analysis and testing was completed on several secondary structure candidates. Crew interface testing was also completed using an inflatable crewlock mockup and the JSC Active Response Gravity Offload System (ARGOS) to simulate the movement of an EVA crewmember through an inflatable crewlock in microgravity. The results of these tests helped demonstrate the feasibility of utilizing an inflatable structure as an airlock and informed the required volume, hatch size, and configuration and location of translation aids for crewmembers in a microgravity crewlock.

The ISS Quest airlock uses a dual-chamber design with isolated compartments known as the equipment-lock and the crewlock. The equipment-lock houses the Servicing, Performance and Checkout Equipment (SPCE) items (suit batteries, consumables, etc.) while the crewlock has limited internal hardware and is the nominally depressurized compartment during US EVAs. While inflatable dual chamber airlocks have been studied, the current state of the art emphasizes an inflatable crewlock-type structure attached to a rigid equipment-lock type or habitat structure. Since a large portion of the hardware in the equipment-lock are rigid components and connectors that are installed on the ground - and an inflatable structure does not achieve full structural capabilities until pressurized in space - a depressurized fabric structure cannot provide the capabilities of a full *equipment-lock*. The use of an inflatable as a crewlock, however, provides all the required capabilities for EVA operations in a small launch package that offers significant volume savings over a metallic crewlock. The functions of a traditional equipment lock, including the SPCE, could be provided by a spacecraft's habitat module or node and not necessarily in a separate equipment lock. An inflatable crewlock would be attached to the vehicle and launched in a packed and compressed state, saving volume under the launch shroud and mass for the overall airlock element compared to a rigid crewlock.

Work is currently underway to continue development of an inflatable airlock with a variety of focus areas including the consideration of crew-induced loads and interfaces, the design and development of an internal sub-structure to provide translation aids and restraints, the thermal considerations of a fabric shell depressurized during an EVA, the micrometeorite environment in deep space, and the packaging and deployment of an inflatable airlock.