Design of a Microgravity Hybrid Inflatable Airlock

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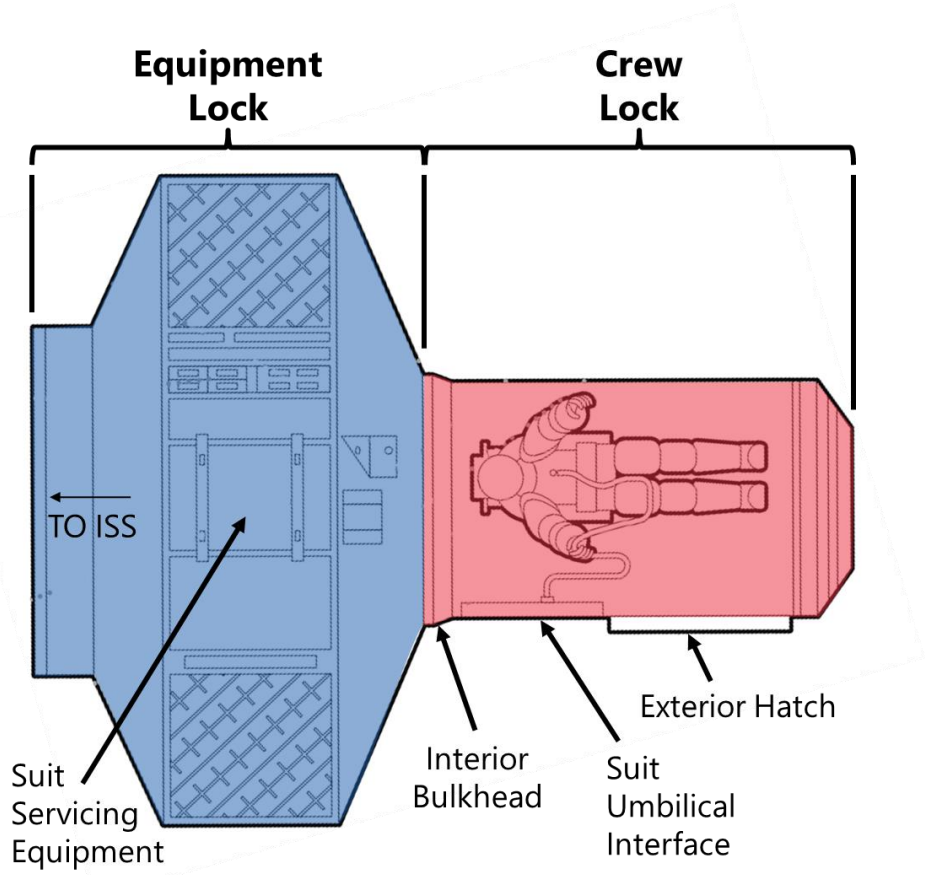
Microgravity Airlocks

- Airlocks provide an isolated volume for transfer between a pressurized vehicle and the vacuum of space
- For crewed flights, an extravehicular activity (EVA), or spacewalk, is typically conducted using an airlock to egress and ingress the vehicle
- On the International Space Station (ISS), the Joint Quest Airlock module is composed of two chambers, known as the 'Equipment Lock' and the 'Crew Lock'
- With a dual-chamber design, only the crew lock volume is depressurized during a nominal EVA, which minimizes the amount of gas lost during an EVA cycle



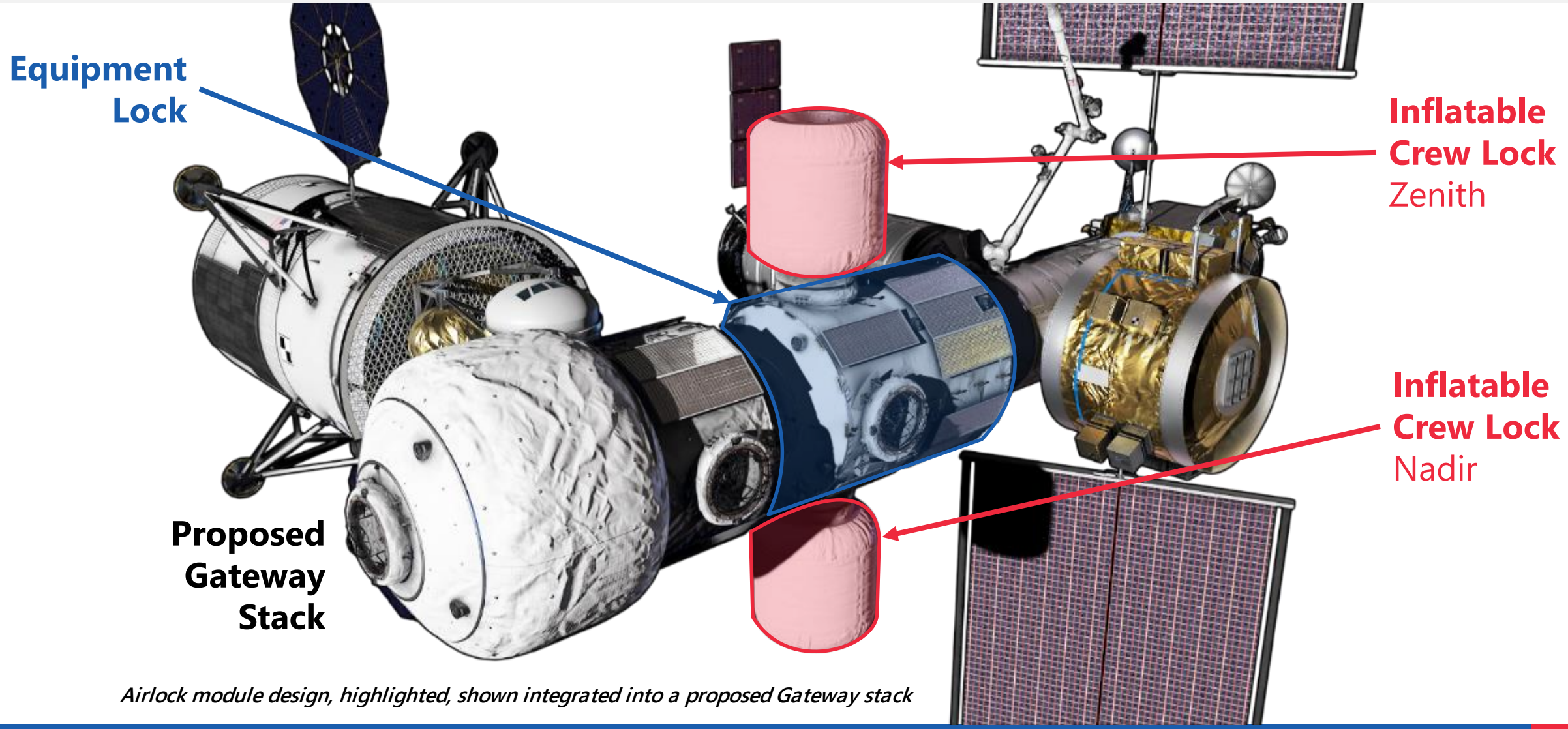
ISS Joint Quest Airlock module diagram showing the dual-chamber design

Gateway Requirements

- Gateway will be a spacecraft in orbit around the Moon that will provide access to the lunar surface, while providing ports for visiting vehicles, living quarters for crew members, and laboratories for research
- While the final configuration of Gateway continues to evolve, the need for EVA capability is fundamental for any future crewed spacecraft
- The hybrid airlock design presented here offers a feasible EVA capability for Gateway or any future microgravity vehicle
- The driving requirements for this design are agnostic of Gateway's final configuration and include assumptions to bound the design space

Requirement	Description
Vehicle Lifetime	15 year operating lifetime
Operating Pressure	14.7 +/- 0.5 psia
Hatch Size	Provide a 1100 millimeter minimum opening for suited translation
Docking Ports	Include at least one axial forward (passive) and one axial aft (active) docking port
Space Suit Stowage	Provide volume for 3 suits stored on board (2 used during EVA)
Suit Don/Doff	Provide don/doff capability for two crew members (including don/doff stands within the allocated volume)
Suit Interface	Provide umbilical interface assembly in Crew Lock
Secondary Egress	Provide a secondary egress method in the event of a failed hatch
Launch Vehicle	Fit on a vehicle with capability of 15,600 kilograms and 4.6 meter diameter fairing

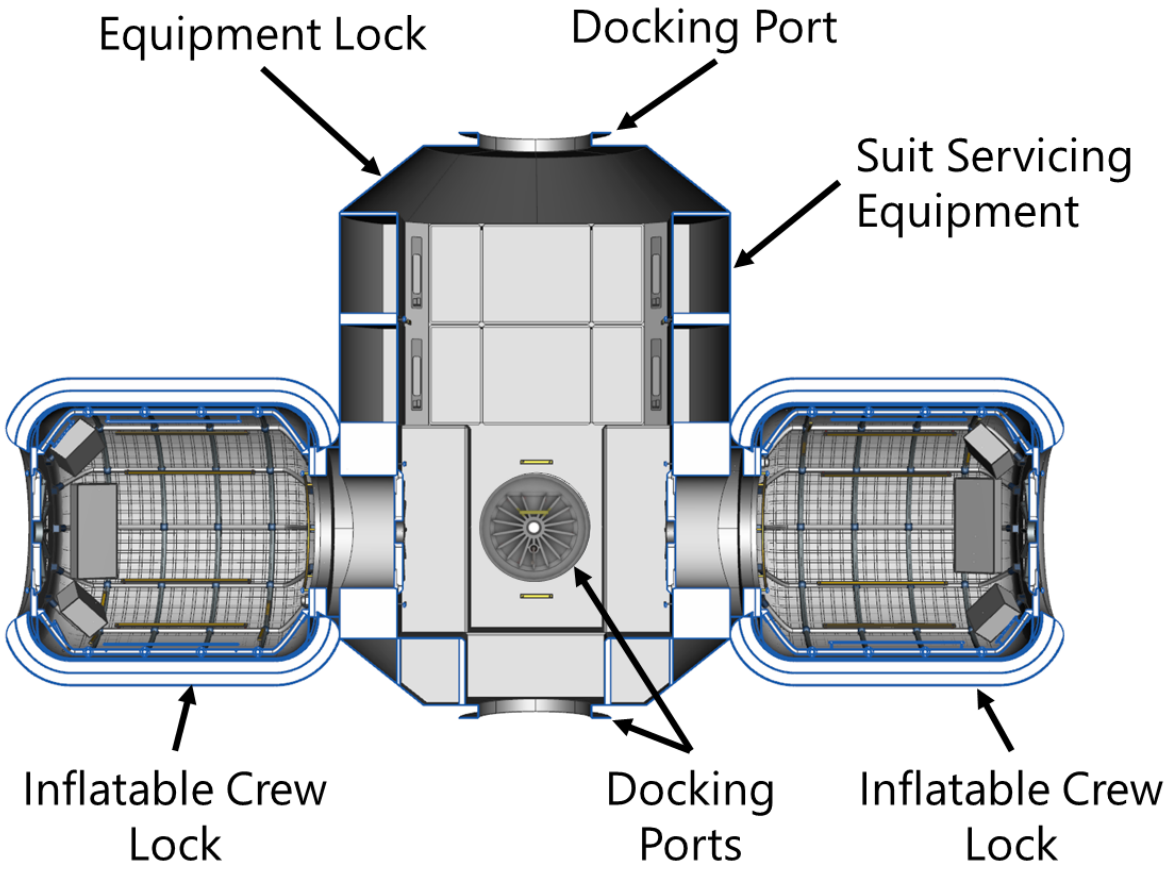
Hybrid Airlock Module Overview



Airlock module design, highlighted, shown integrated into a proposed Gateway stack

Hybrid Airlock Module Overview

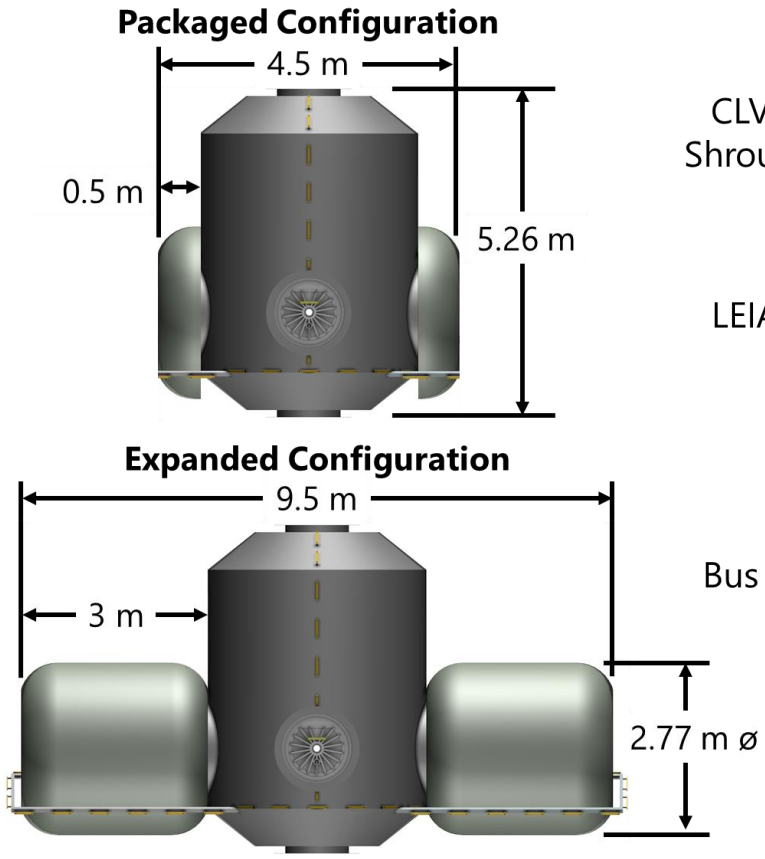
- Equipment Lock includes volume for suit storage, servicing equipment, don-doff stands, battery chargers, and maintenance items
- Equipment Lock acts as both a hardware stowage area to prep for EVAs and a docking node to allow for visiting vehicle traffic
- Dual Crew Locks are identical volumes that offer suit umbilical connections, support equipment such as cargo bags, tool bags, handrails, lights, etc
- Dual Crew Locks offer an emergency capability in the event of a hatch failure



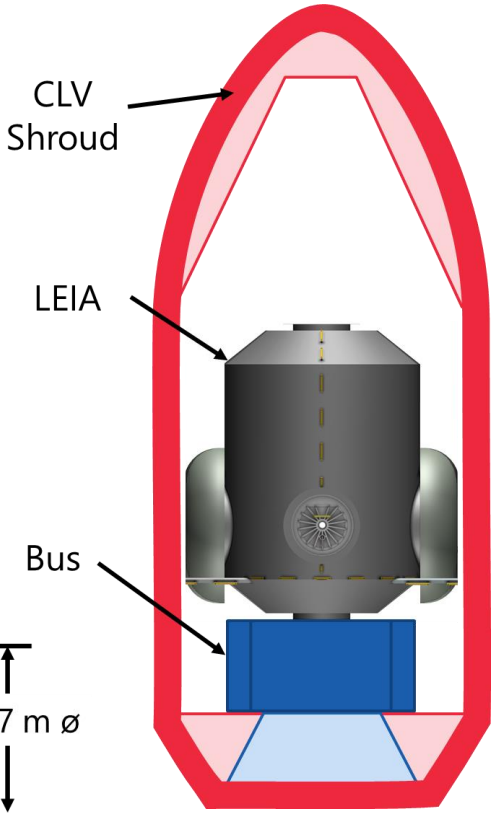
Cut-away view of the airlock module, showing the Equipment Lock and dual inflatable Crew Locks

Packaged & Expanded Configuration

- Structural sizing was completed on the airlock module with assumptions on other system masses, resulting in an estimated **8.1 metric ton** total vehicle mass
- The hybrid airlock can be packaged and fit inside of the Space Launch System (SLS) Block 1 as a co-manifested payload with Orion
- The airlock can also fit inside of a commercial launch vehicle (CLV) with a 4.6 meter fairing and 15,600 kg lift capability
- If flown on a CLV, a commercial bus is required to get the airlock module to the Gateway orbit



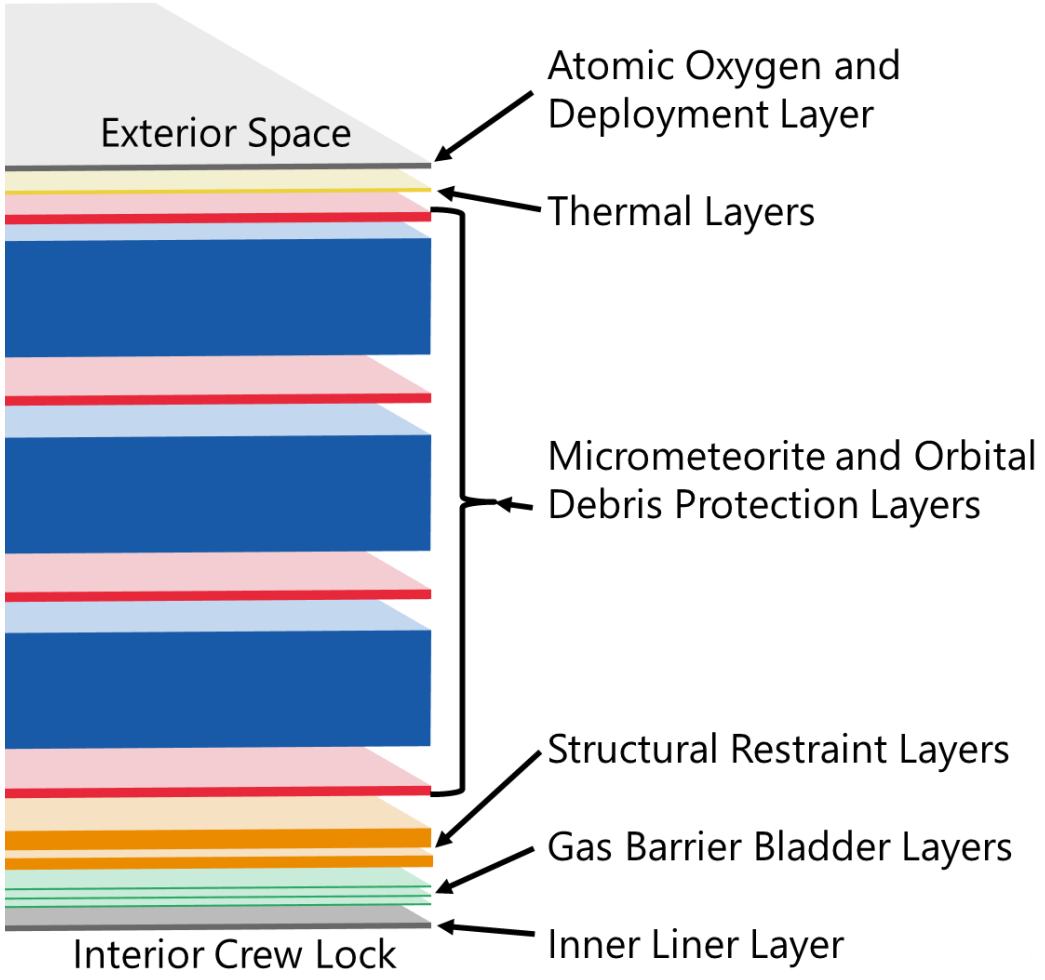
Overall dimensions in both packaged and expanded configurations



Launch configuration with attached bus in a CLV shroud

Crew Lock Softgoods Structure

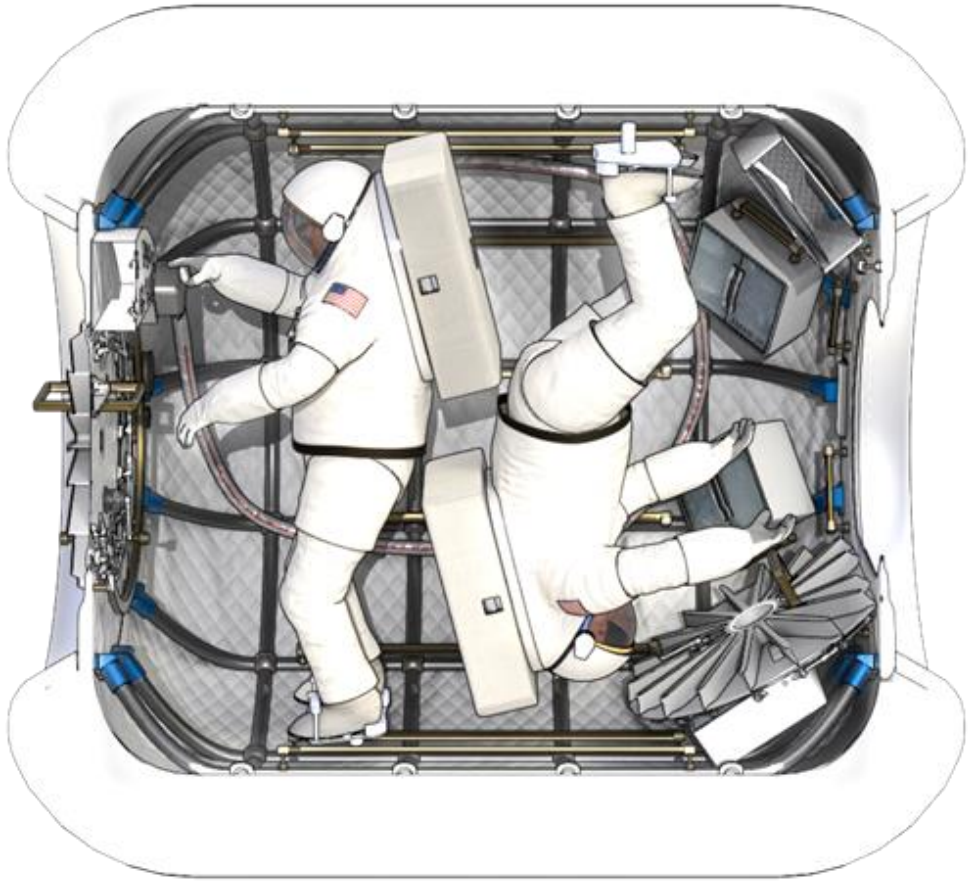
- Inflatable crewed structures are composed of a stack up of fabric layers that provide atomic oxygen protection, thermal insulation, micrometeoroid and orbital debris protection, structural stiffness, and a gas barrier
- The flexibility of these materials provide high packing ratios and significant launch volume savings over metallic structures, while still providing all required structural functions
- Modern inflatable structures were developed through the TransHab program in the 1990's, which led to the first habitable inflatable module on ISS in 2016, known as the Bigelow Expandable Activity Module (BEAM), still in operation today



Softgoods shell layer stack-up

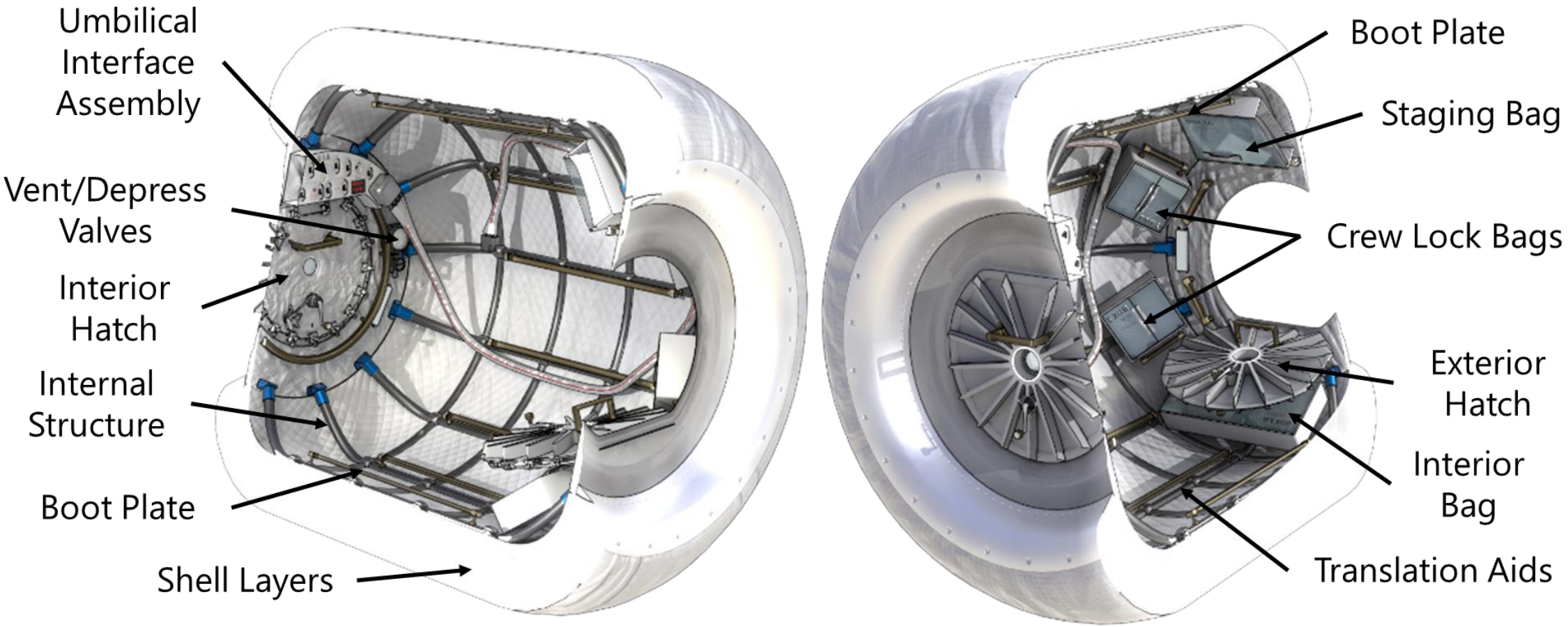
Crew Lock Internal

- Each inflatable Crew Lock has **9.7 m^3** pressurized volume, which is a 76.4% increase compared to the ISS Crew Lock
- The increased size is required for crew operation of the exterior bulkhead, since the space suit has limited mobility in the vertical direction, the hybrid Crew Lock design allows for the exterior hatch to be operated in the front plane of the crew member while in a standing position
- The volume allows for two suited crew members to work back to back, while still allowing for movement and rotation of the crew members with respect to each other, a significant increase in mobility compared to the ISS Crew Lock



Cut-away view of fully outfitted Crew Lock with two suited crew members at the start of an EVA

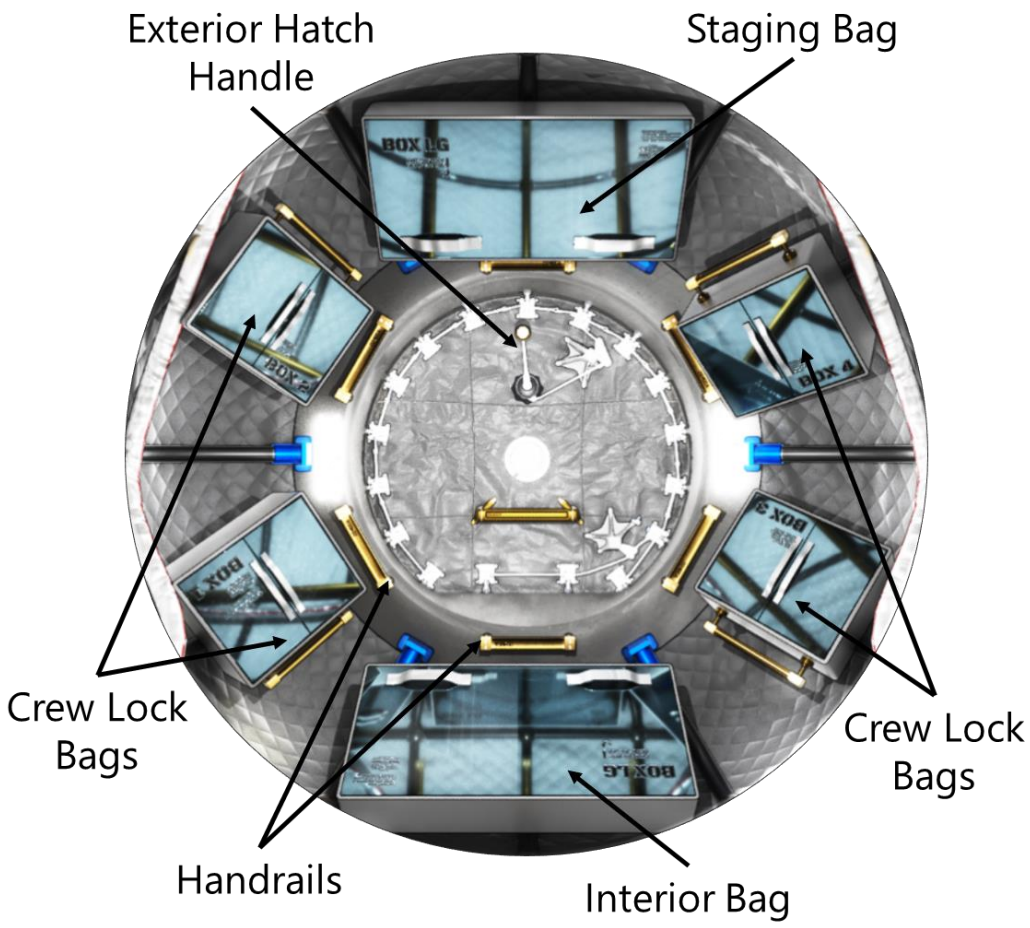
Crew Lock Internal



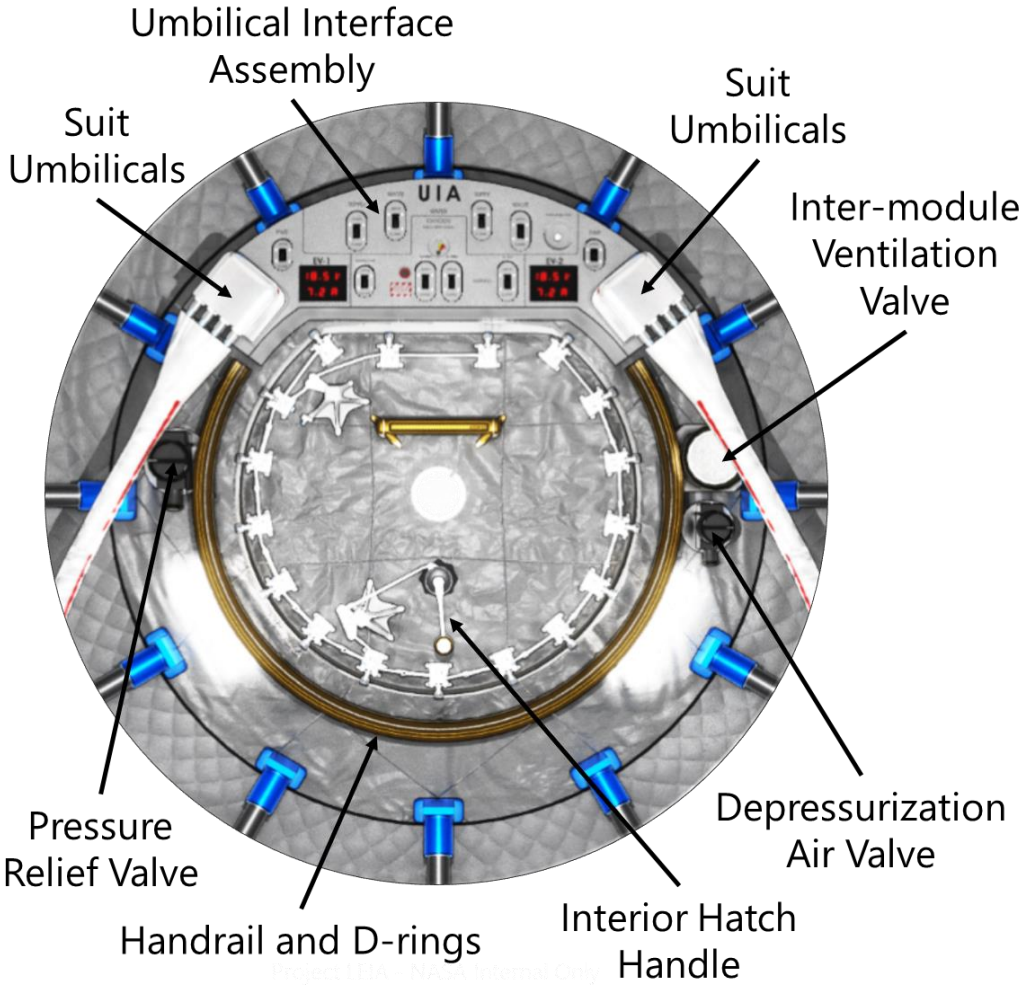
Cut-away view of Crew Lock with critical components identified

Crew Lock Internal

Exterior Bulkhead View

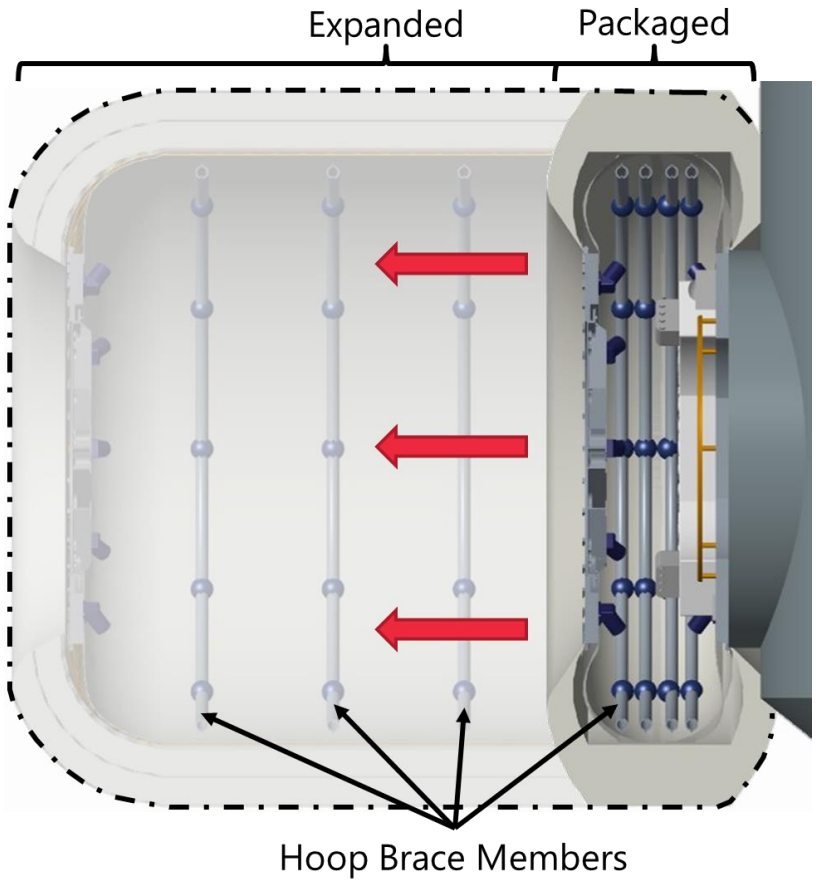


Interior Bulkhead View



Crew Lock Inflation

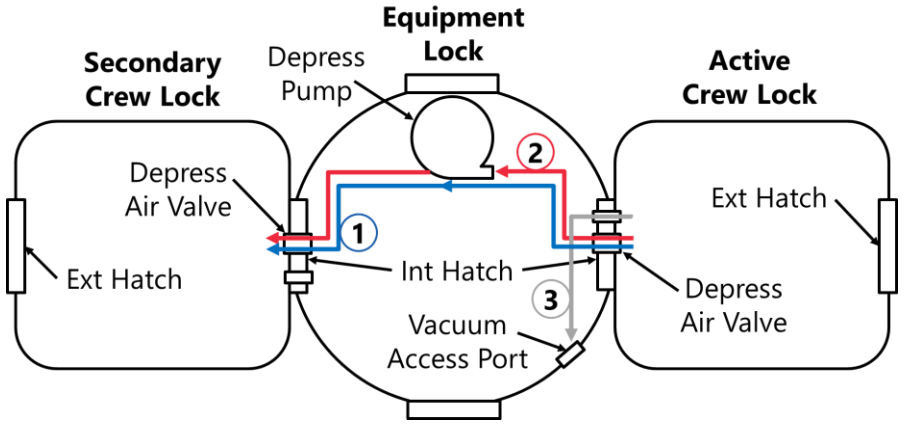
- Each Crew Lock is pressurized using a recharge tank assembly (RTA) that is included in the initial launch package and can be replaced by visiting vehicles
- 1 Nitrogen and 1 Oxygen tank are included
- The RTA connection and plumbing is housed in the Equipment Lock and provides air for both Crew Locks, although only one Crew Lock is planned to be used at a time
- Each Crew Lock is pressurized individually and includes structural components that are pre-integrated with the softgoods structure
- After initial inflation, the crew will enter the Crew Lock and complete installation of all equipment



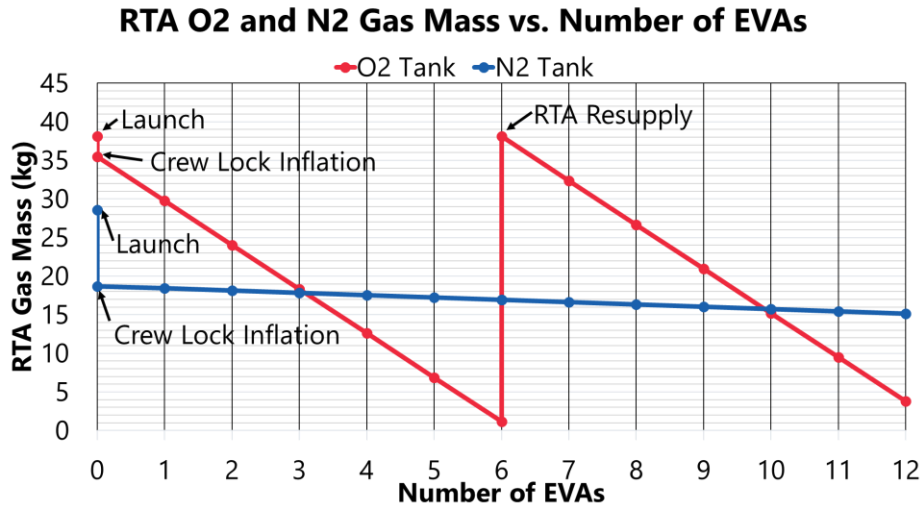
Crew Lock in packaged and expanded configurations with structural hoop brace members pre-integrated into softgoods shell

Crew Lock Air Save

- To recycle air during EVA cycles, one Crew Lock can be used as an air save bag, using the nominal depress cycle described:
  - 14.7psi to 7psi: Active Crew Lock depress valve is opened and air moves to secondary Crew Lock
  - 7psi to 2psi: Depress pump reduces pressure down to 2psi
  - 2psi to vacuum: Remaining air is dumped overboard to vacuum
- Using average ISS EVA gas usage, the proposed air save method allows for 6 EVAs to be completed using the initial tank of O2 before a refill is required

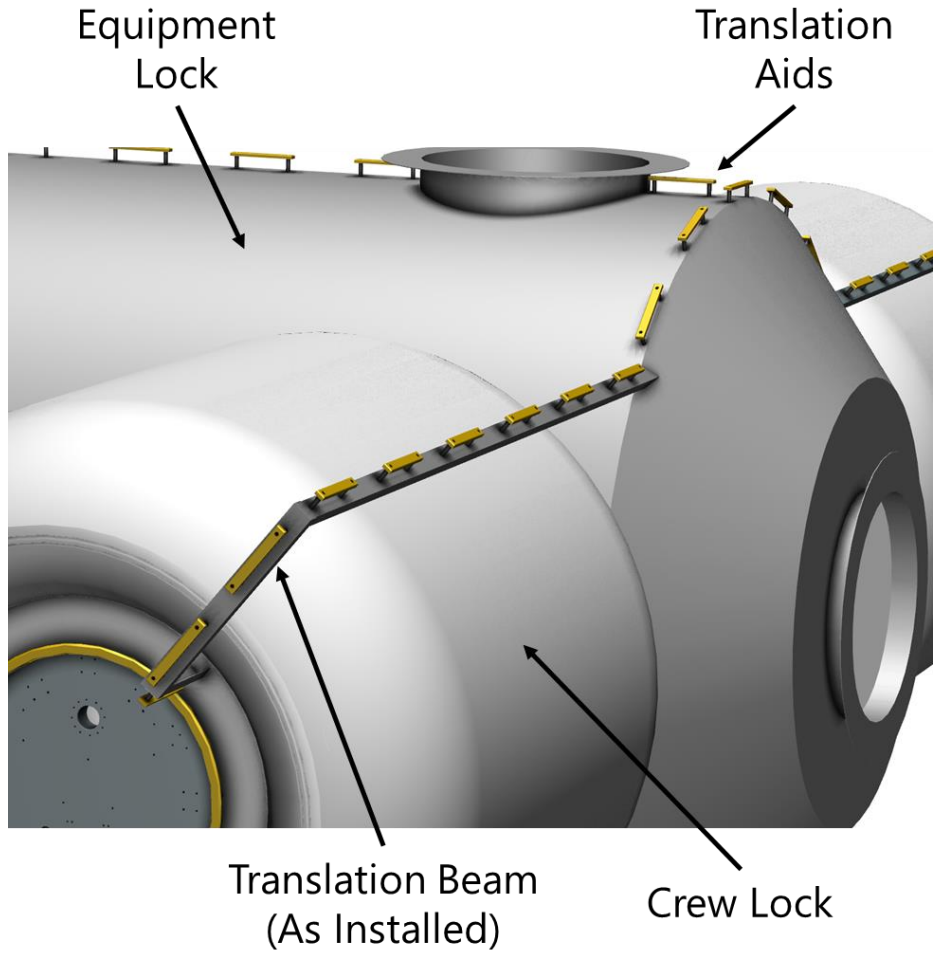


Graphical representation of active Crew Lock depress cycle



Crew Lock External

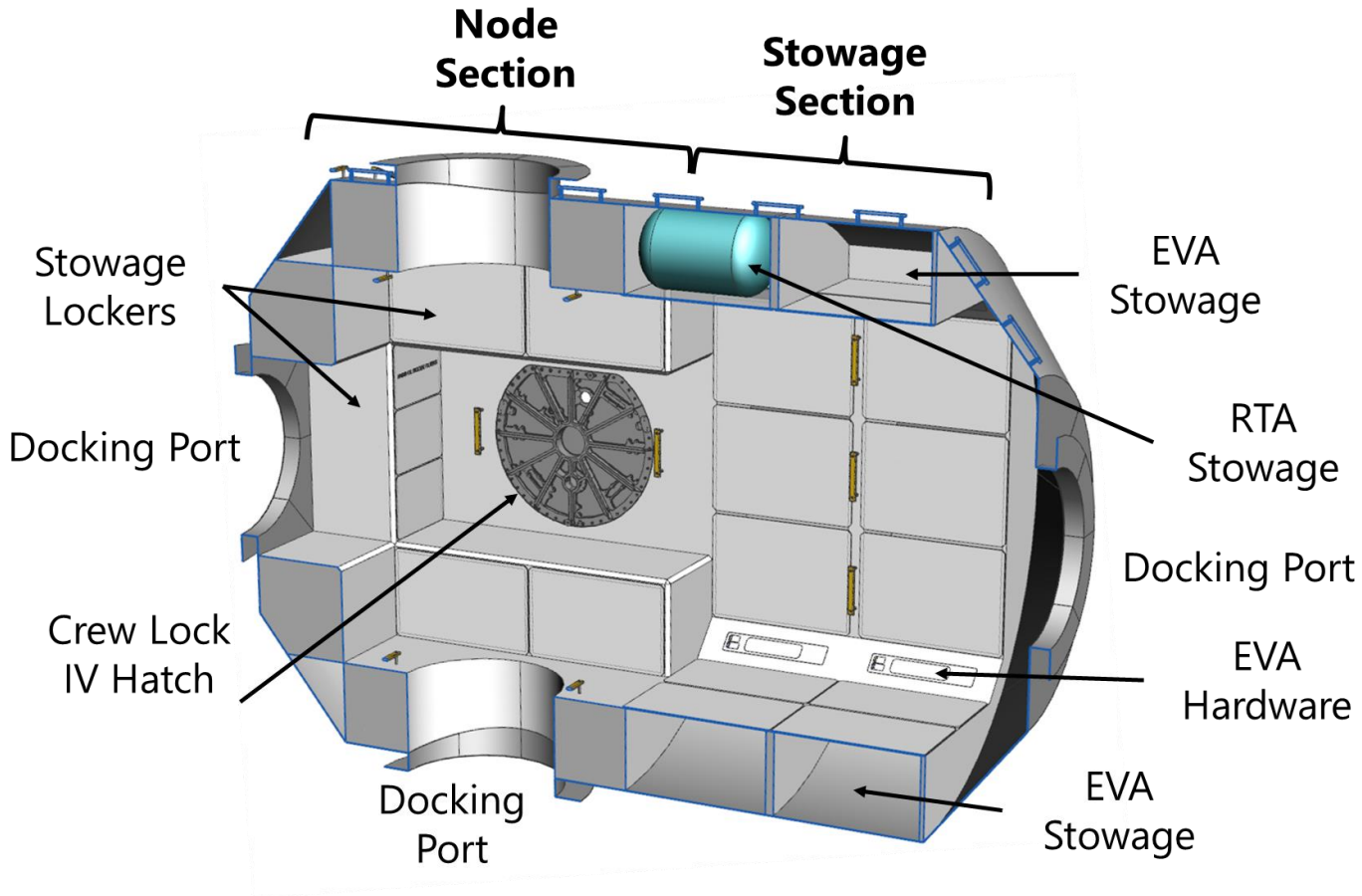
- External mobility needs to be considered for crew members to translate from the Crew Lock external hatch to the EVA worksite
- Because of the nature of the softgoods shell, which will be unpressurized during an EVA, a secondary structural beam needs to be used to translate from the hatch to the equipment lock
- A translation beam would be installed after inflation of the Crew Lock that connects the Crew Lock bulkhead to the equipment lock structure
- This beam provides translation aids, tether attachment points, and EVA worksite interfaces



Concept for Crew Lock external translation beam

Equipment Lock Internal

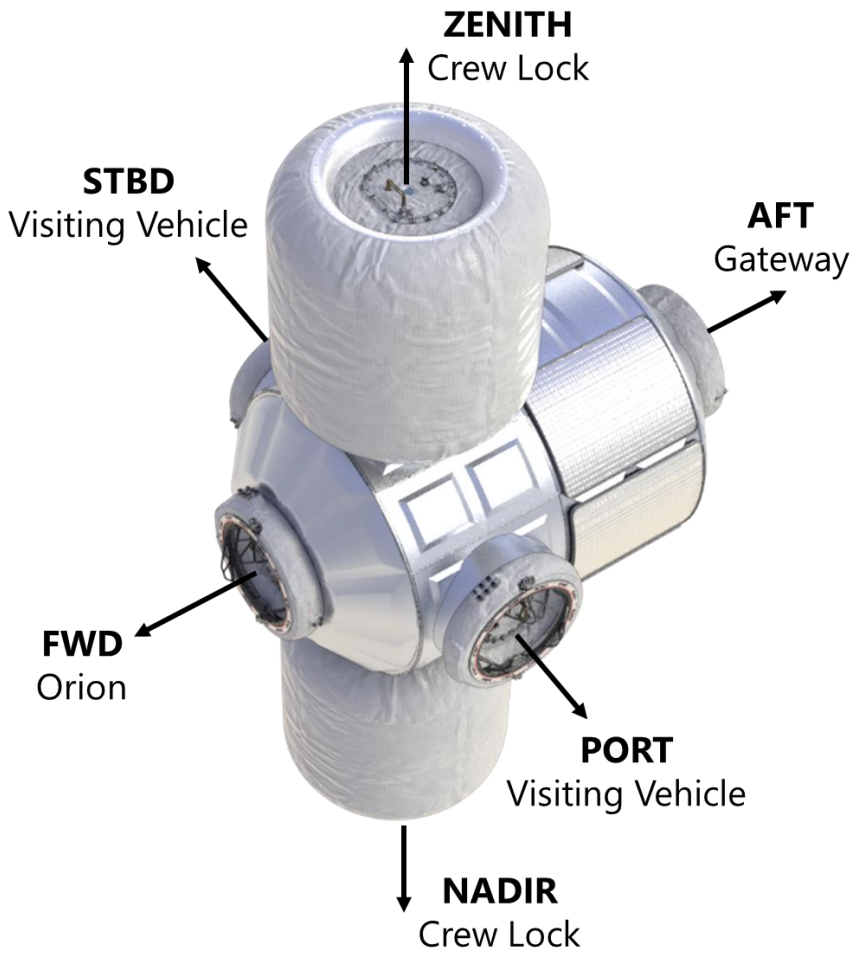
- The Equipment Lock has a total habitable volume of **27.3 m³** split between two sections
- The node section is similar to a docking node with six total ports, two for Crew Locks, two for visiting vehicles, and two axial ports for connection to Gateway
- The stowage section is similar to the ISS Equipment Lock with hardware for suit maintenance, battery chargers, consumable refills, RTAs, and suit component storage



Cut-away view of equipment lock with both sections identified

Conclusions & Forward Work

- Continued development is required to get the hybrid airlock into a flight ready design, but the feasibility of the concept has been shown to be successful
- The combination of a metallic Equipment Lock and inflatable Crew Locks take advantage of each structure's qualities to provide an optimized solution
- The increased capability of an Equipment Lock with docking ports can accelerate the Gateway buildup by combining multiple module needs into one
- The hybrid inflatable airlock presented here is a viable option for microgravity airlock needs and should be pursed in future architecture designs



Notional orientation of hybrid airlock docking ports

Questions?

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