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Internal Layout Assessment of a Lunar Surface Habitat

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Outline

Background

- Surface Habitat (SH) Overview
- SH Functionality

Internal Layout & Results

- SH Internal Layout
- Functional Changes Related to Mass Constraints
- Functional Overlaps
- Results

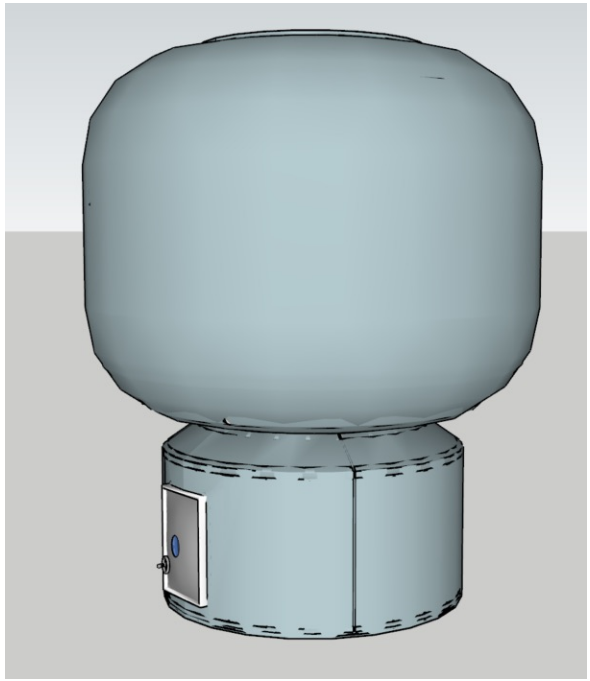
Forward Work

Conclusion

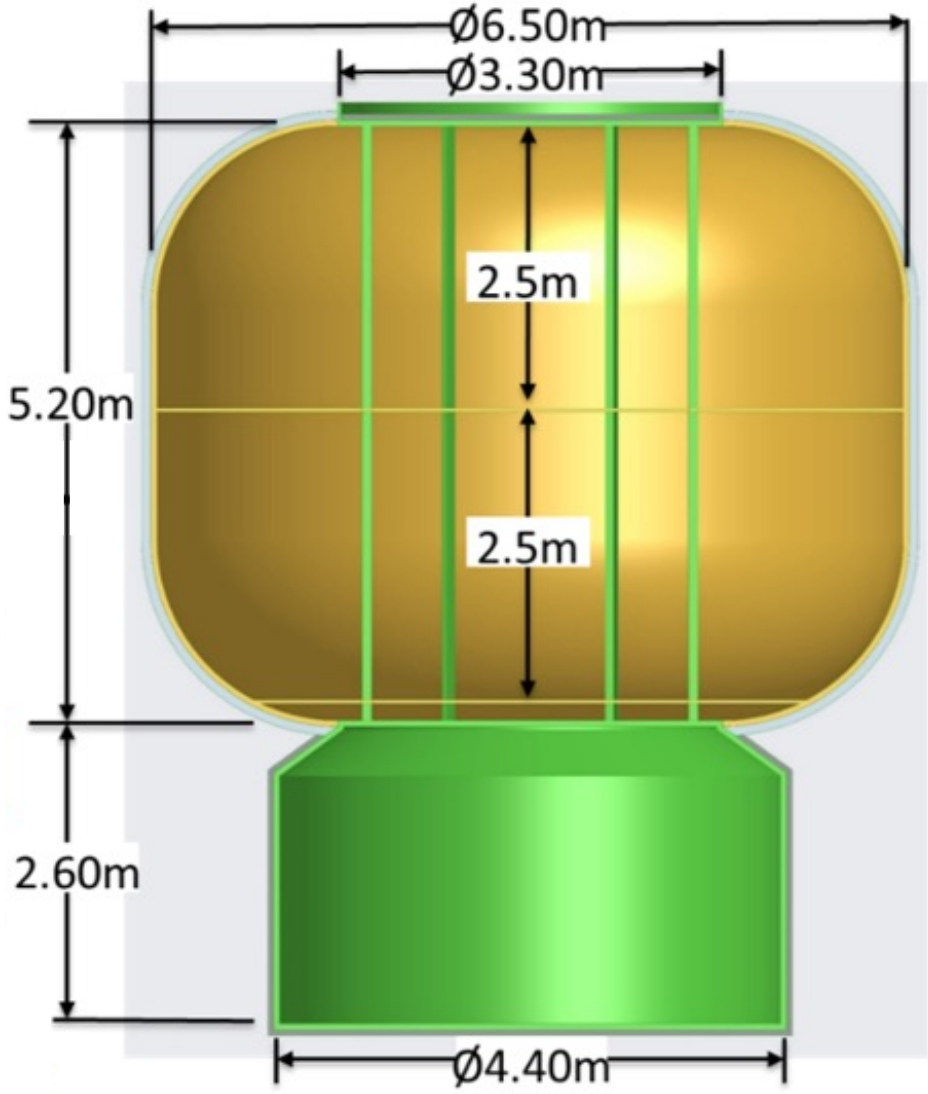
SH Overview

- **SH is a proof of concept derived from a set of Ground Rules & Assumptions, including but not limited to:**
  - 2 crew for 30 days
  - Allowable mass = 12 metric tons
  - Required set of habitability functions
- **Internal layout built using recommended minimal volume and dimensions for required functionality**
- **Included logistics stowage and closed-loop Environmental Control and Life Support System (ECLSS)**
  - Used dimensions of Collins ECLSS Pallets
- **Included extensive utilization**

Outer Mold – CAD Model



SH Dimensions – Hybrid-Inflatable



SH Functionality - Functions

Function	Volume (m^3)	Area (m^2)
Crew Habitation		
Access to Personal Stowage	2.60	1.08
Changing Clothes	2.40	1.00
Sleep Accommodation	3.64	1.82
Stretching	3.36	1.40
EVA Support		
Computer Display and Control Interface	2.24	1.12
Suit Component Testing and Repair	3.28	1.37
Temporary EVA Items Stowage	0.25	0.25
Exercise		
Exercise on a Resistive Device	3.60	1.50
Group Socialization and Recreation		
Group Movie Viewing	5.04	2.10
Group Tabletop Games	3.89	1.62
Personal Recreation	3.89	1.62
Human Waste Collection		
Emesis Waste Collection	2.18	0.91
Menses Waste Collection	2.18	0.91
Liquid Waste Collection	2.18	0.91
Solid Waste Collection	2.18	0.91
WMS Maintenance and Repair	2.18	0.91

Volumes have a standard height of 2.4 meters (except Sleep Accommodation, Temporary EVA Items Stowage, and Airlock Functions)

Function	Volume (m^3)	Area (m^2)
Hygiene		
Appearance Viewing and Body Inspection	2.54	1.06
Facial Cleaning	2. 54	1.06
Fingernail/Toenail Clipping	2.11	0.88
Full Body Cleaning	2.54	1.06
Hair Styling/Grooming	2.54	1.06
Hand Cleaning	2.54	1.06
Oral Hygiene	2.11	0.88
Shaving	2.11	0.88
Skin Care	2.11	0.88
Towel and Clothes Drying	2.11	0.88
Logistics		
Logistics Packing and Inventory Management	3.28	1.37
Maintenance and Repair		
Maintenance Workstation for Equipment Diagnostics	3.28	1.37
System Component and Electronics Repair	3.28	1.37
Meal Preparation		
Food Item Sorting	1.35	0.56
Food Preparation	1.35	0.56

Function	Volume (m^3)	Area (m^2)
Meal Consumption		
Full Crew Dining	3.89	1.62
Medical Operations		
Autonomous Ambulatory Care	2.68	1.12
Basic Medical Care (Space Motion Sickness, First Aid, etc.)	4.49	1.87
Computer Interface for Telemedicine and Data Entry	2.69	1.12
Mission Planning		
Mission Planning Computer Display and Control Interface Access	4.37	1.82
Mission Planning Work Surface Access	3.89	1.62
Team Meetings	4.37	1.82
Spacecraft Monitoring and Commanding		
Computer Interface for Teleoperation & Communication	4.37	1.82
Direct Window Viewing	1.35	0.56
Spacecraft Command and Control Interface	4.37	1.82
Translation Paths		
Crew Translation Paths	---	1.00m wide
Trash Management		
Trash Packing for Disposal	2.73	1.59
Utilization		
Internal Utilization Accommodation	---	---

SH Functionality – Combined Functional Spaces

Combined Functional Space	Area (m²)	Functional Category	ID*	Function
Stretching x 2 (one per crewmember)	1.40	Crew Habitation	1.1	Access to Personal Stowage
		Crew Habitation	1.4	Stretching
		Crew Habitation	1.2	Changing Clothes
Sleep x 2 (one per crewmember)	1.82	Crew Habitation	1.3	Sleep Accommodation
Medical Care	1.87	Medical Operations	11.1	Autonomous Ambulatory Care
		Medical Operations	11.2	Basic Medical Care
Exercise	1.50	Exercise	3.1	Exercise on a Resistive Device
Hygiene Station	1.06	Hygiene	6.1	Appearance Viewing and Body Inspection
		Hygiene	6.2	Facial Cleaning
		Hygiene	6.3	Fingernail/Toenail Clipping
		Hygiene	6.4	Full Body Cleaning
		Hygiene	6.5	Hair Styling/Grooming
		Hygiene	6.6	Hand Cleaning
		Hygiene	6.7	Oral Hygiene
		Hygiene	6.8	Shaving
		Hygiene	6.9	Skin Care
		Hygiene	6.10	Towel and Clothes Drying
Universal Waste Management System (UWMS)	0.91	Human Waste Collection	5.1	Emesis Waste Collection
		Human Waste Collection	5.2	Menses Waste Collection
		Human Waste Collection	5.3	Liquid Waste Collection
		Human Waste Collection	5.4	Solid Waste Collection
		Human Waste Collection	5.5	WMS Maintenance and Repair

Combined Functional Space	Area (m²)	Functional Category	ID*	Function
Wardroom Table	2.10	Group Socialization and Recreation	4.1	Group Movie Viewing
		Group Socialization and Recreation	4.2	Group Tabletop Games and Creative Recreation
		Group Socialization and Recreation	4.3	Personal Recreation
		Meal Consumption	10.1	Full Crew Dining
		Mission Planning	12.2	Mission Planning Work Surface Access
		Mission Planning	12.3	Team Meetings
		Spacecraft Monitoring and Commanding	13.2	Direct Window Viewing
Work Surface (Maintenance, Logistics, etc.)	1.37	Logistics	7.1	Logistics Packing and Inventory Management
		Maintenance and Repair	8.1	Maintenance Workstation for Equipment Diagnostics
		Maintenance and Repair	8.2	System Component and Electronics Repair
		EVA Support	2.2	Suit Component Testing and Repair
		EVA Support	2.3	Temporary EVA Items Stowage
		Trash Management	15.1	Trash Packing for Disposal
EVA Computer Station	1.82	EVA Support	2.1	EVA Computer Display and Control Interface
General Computer Station	1.82	Mission Planning	12.1	Mission Planning Computer Display and Control Interface
		Spacecraft Monitoring and Commanding	13.1	Computer Interface for Teleoperation, Communication and Tracking
		Spacecraft Monitoring and Commanding	13.3	Spacecraft Command and Control Interface
		Medical Operations	11.3	Computer Interface for Private Telemedicine and Data Entry
Galley-Food Item Sorting	0.57	Meal Preparation	9.1	Food Item Sorting
Galley-Food Prep	0.57	Meal Preparation	9.2	Food Preparation
Utilization	---	Utilization	16.1	Internal Utilization Accommodation
Translation Paths	---	Crew Translation	14.1	Crew Translation Paths
Systems & Storage Access	---	Maintenance and Repair	8.3	Sub-Systems Access

SH Functionality – Final Functional Areas

Combined Functional Space	Recommended Min. Area (m^2)	Area in Layout (m^2)
Stretching	1.40	2.68 (1.34/crewmember)
Sleeping	1.82	3.70 (1.85/crewmember)
Medical	1.87	3.43
Exercise	1.5	2.09
UWMS	0.91	1.04
Hygiene	1.06	1.04
Ward Table	1.62	2.23
Work Surface	1.37	1.30
EVA Computer Station	----	0.97
General Computer Station	1.82	2.10
Galley – Work Surface	0.56	0.95
Galley – Meal Prep	0.56	1.17
Utilization	----	5.07
Translation Paths, Ladder Access & Airlock/Suitport Access	-----	8.65
Systems & Storage Access	-----	5.79
Total	14.6	42.63
Total per Crewmember	7.3	21.31
Airlock	5.00	5.18

Resulting areas and volumes tend to be larger than the recommended minimum

Two functional areas that might be too small

	Recommended Min. Habitable Volume (m^3)	Habitable Volume In Layout (m^3)
Total	**35.2**	**127.70**
Total Crewmember	**17.6**	**63.85**

Internal Layout – Three Levels

Floor Heights

2.5m

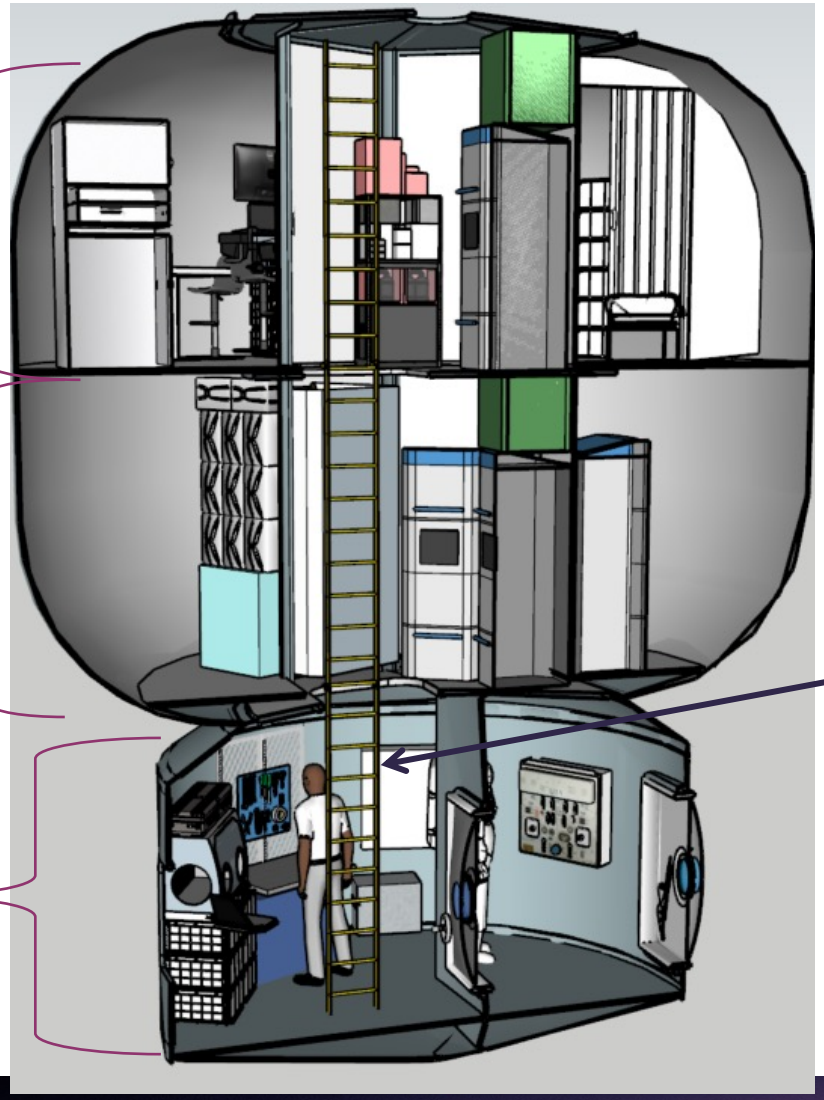
Area: 33.2m²

2.5m

Area: 17.2m²

2.6m

Area: 15.2m²

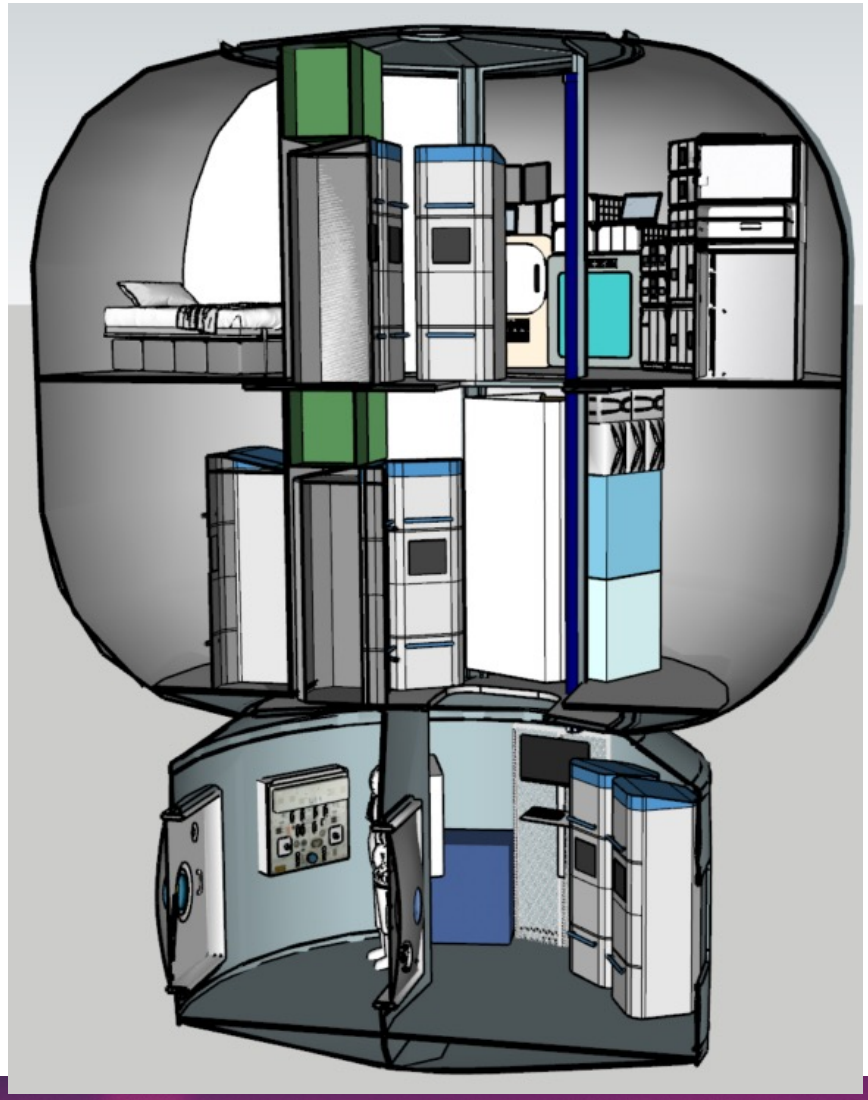


Level 3 – Crew Quarters, Galley, Ward Table, General Computer Station, Utilization, Storage, ECLSS & other sub-systems

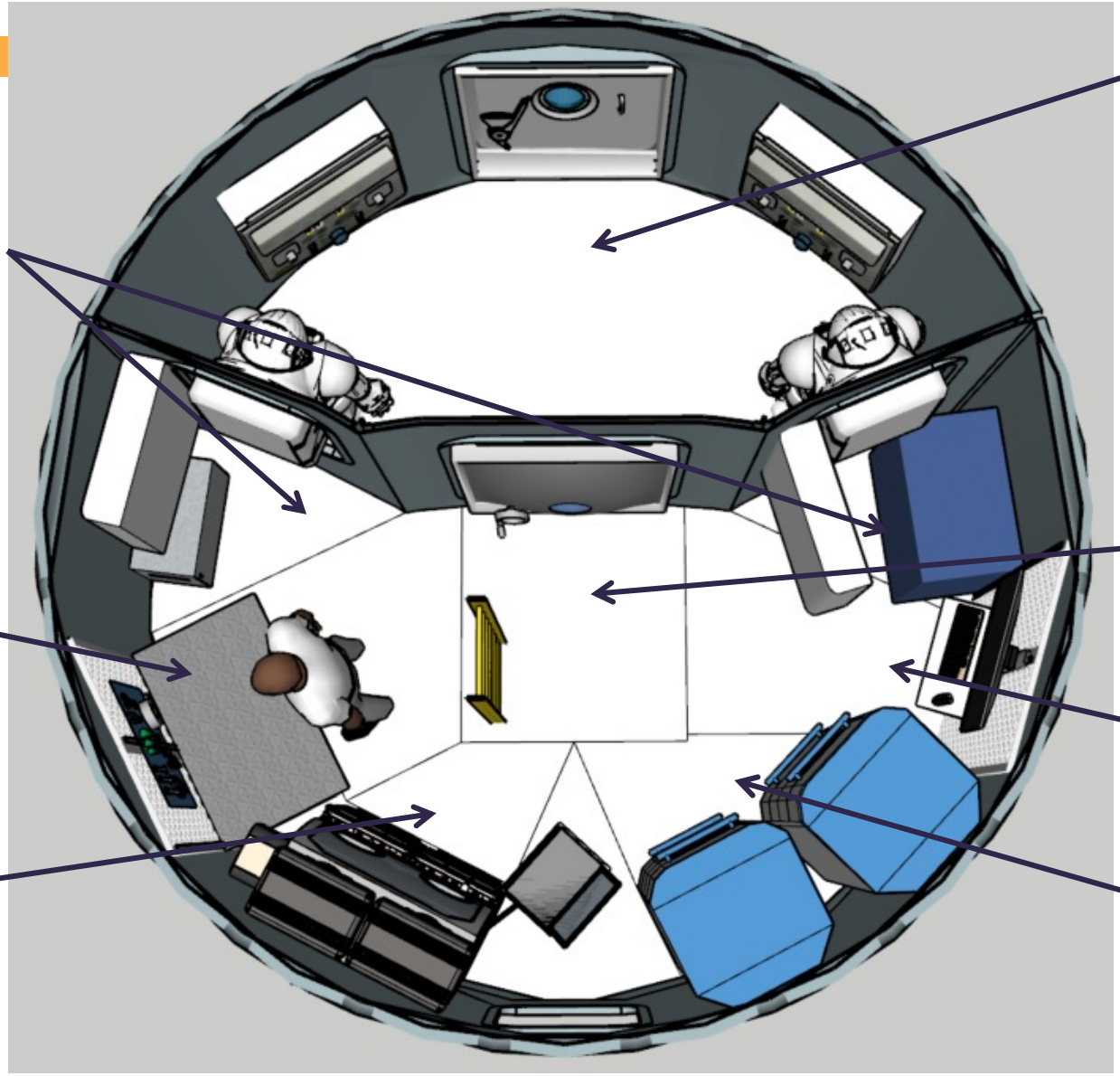
Level 2 – Hygiene, UWMS, Exercise, Utilization, ECLSS

Vertical Ladder

Level 1 – Airlock, Work Surface (Maintenance, Logistics, etc.), EVA Computer, ECLSS



Level 1



Airlock

Access to Suitports

Access to Airlock

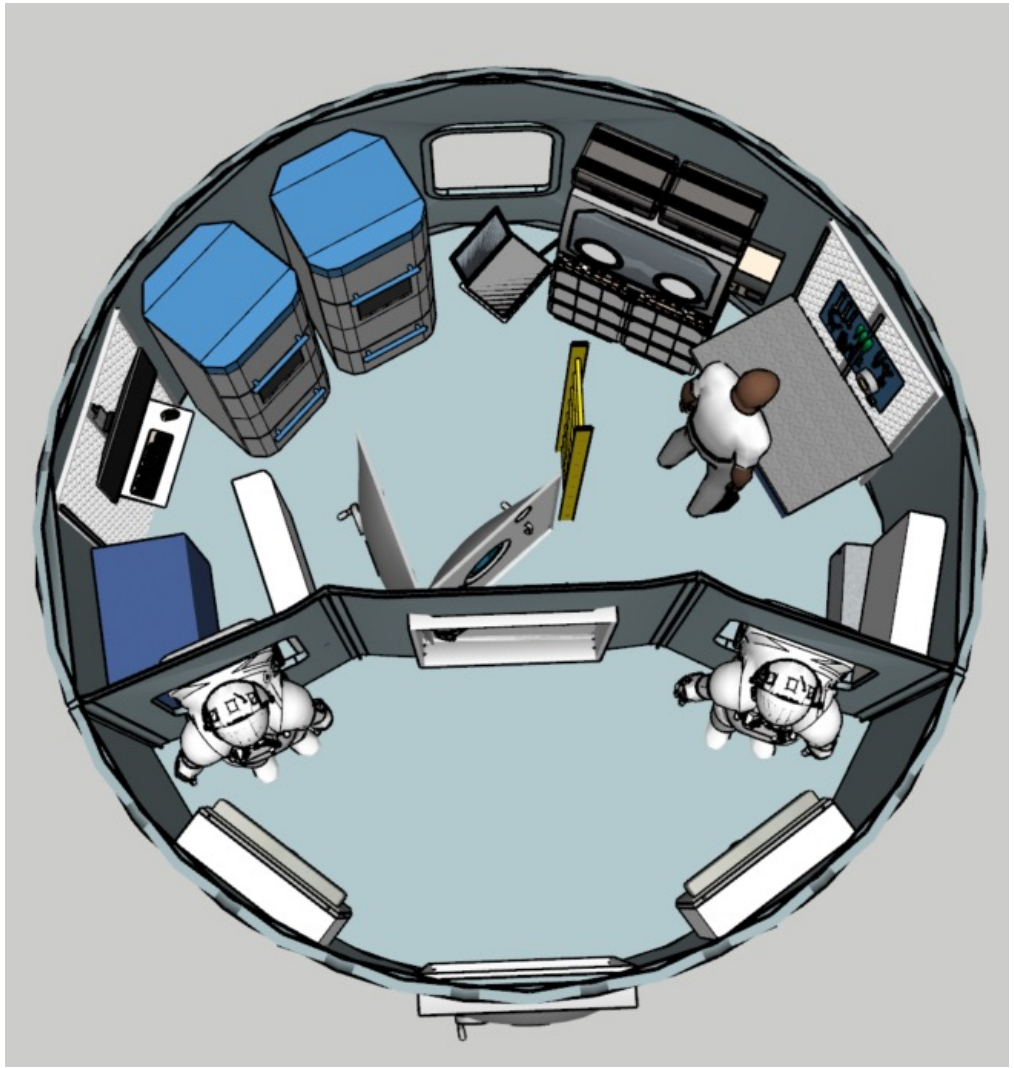
Work Bench for Maintenance, Logistics, etc.

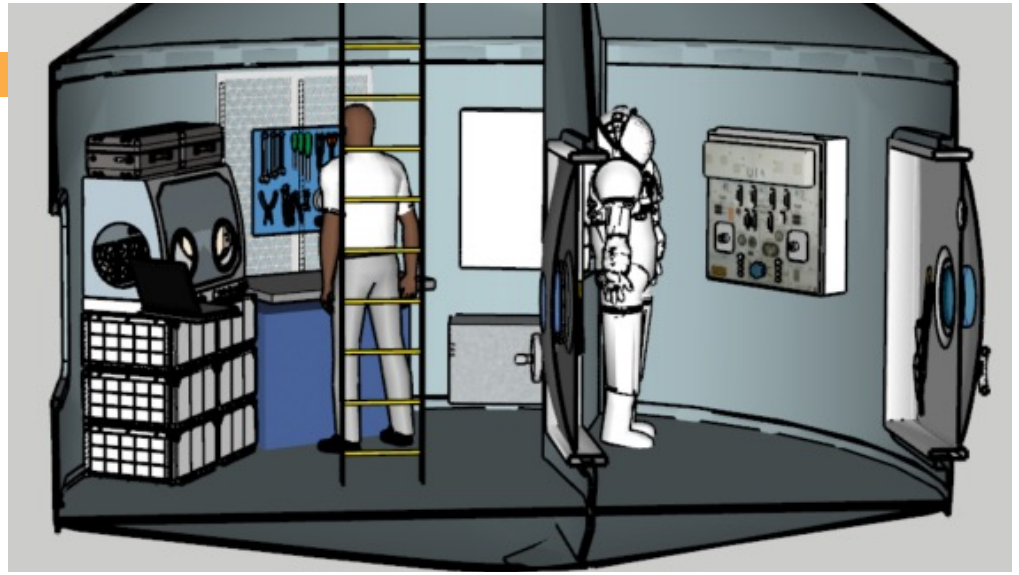
EVA Computer Station (can be used for Safe Haven & Medical also)

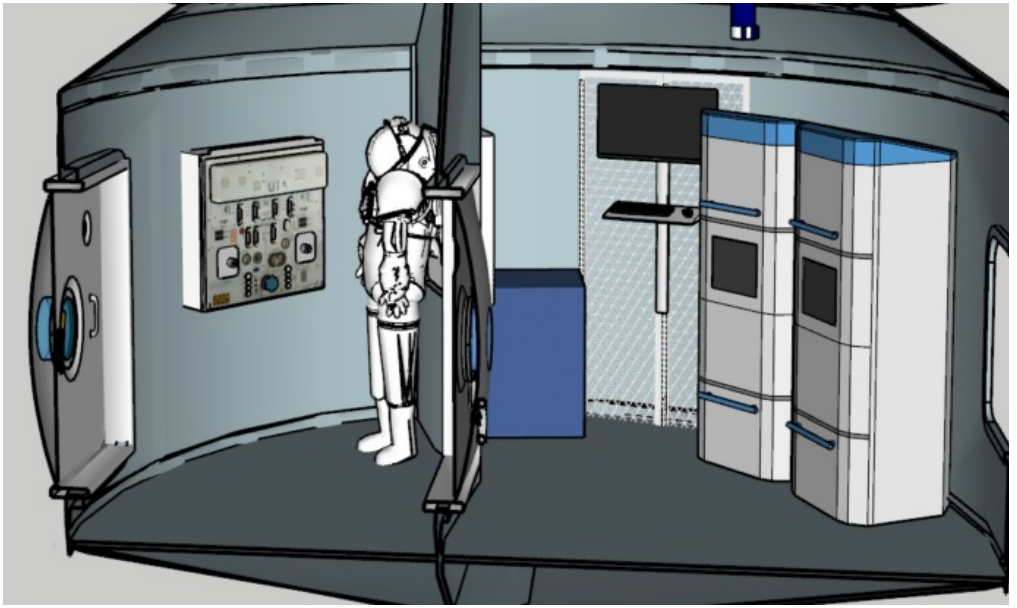
Utilization – Geo (located on Level 1 for possibility of a sample transfer port)

Sub-Systems Access (2 Pallets – OGA)

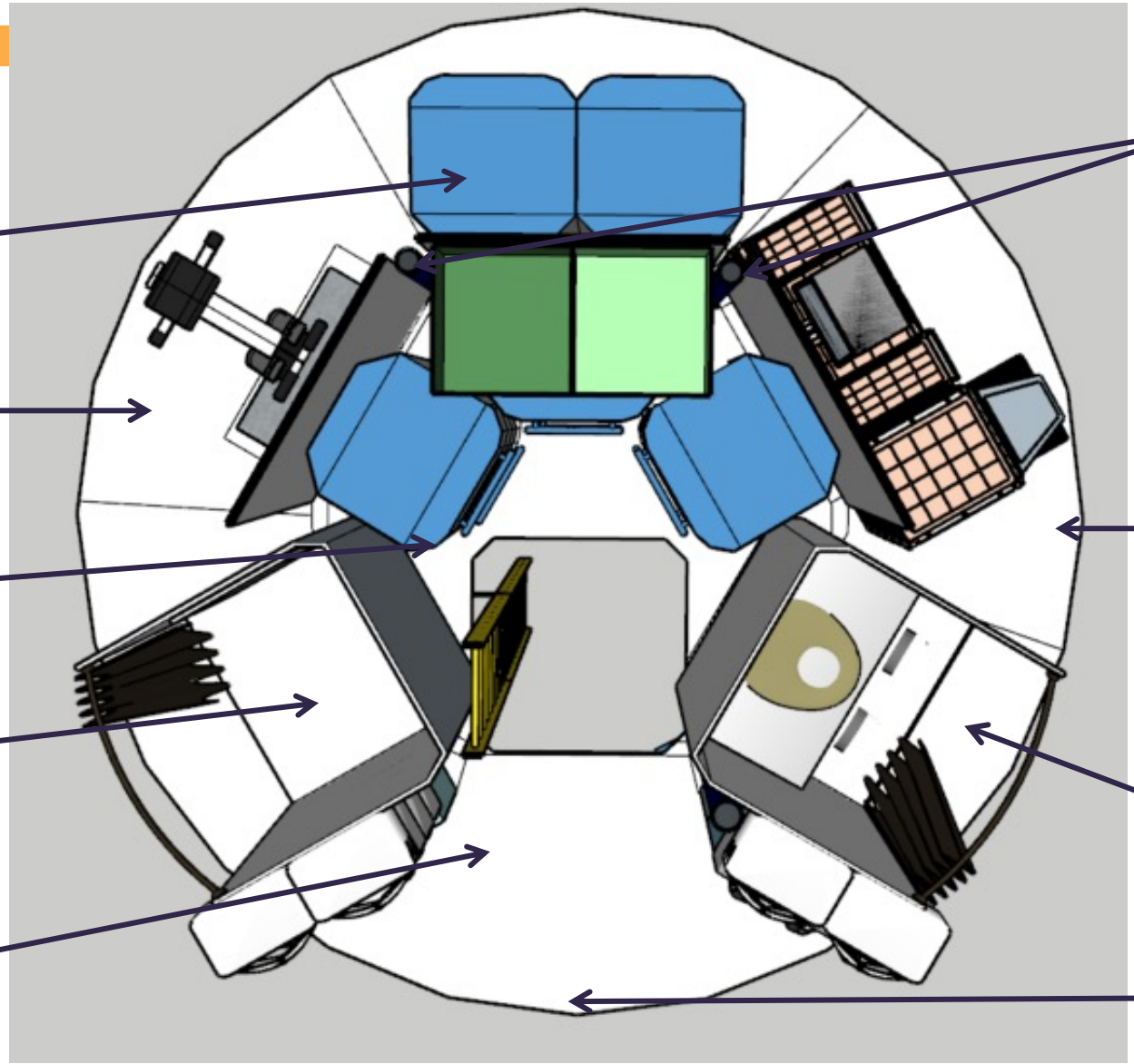
Level 1 cont.







Level 2



Access to Sub-Systems (2 Pallets – UP & BP)

Exercise

Inner Core: Access to Sub-Systems (3 Pallets – WPA)

Hygiene

Access to Water Tanks, Hygiene, UWMS & Ladder

Space for Piping & Cable Runs through Core

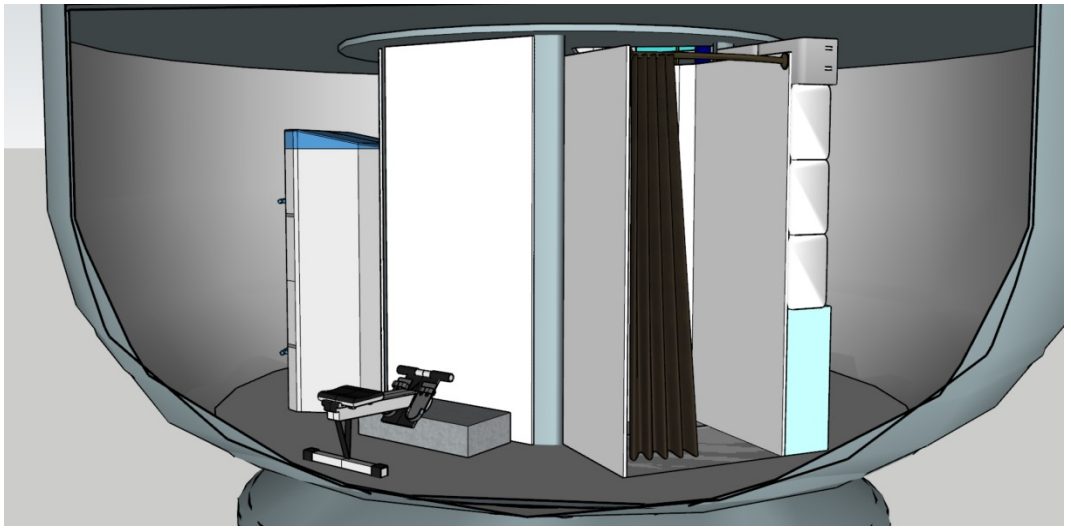
Utilization – Bio Lab

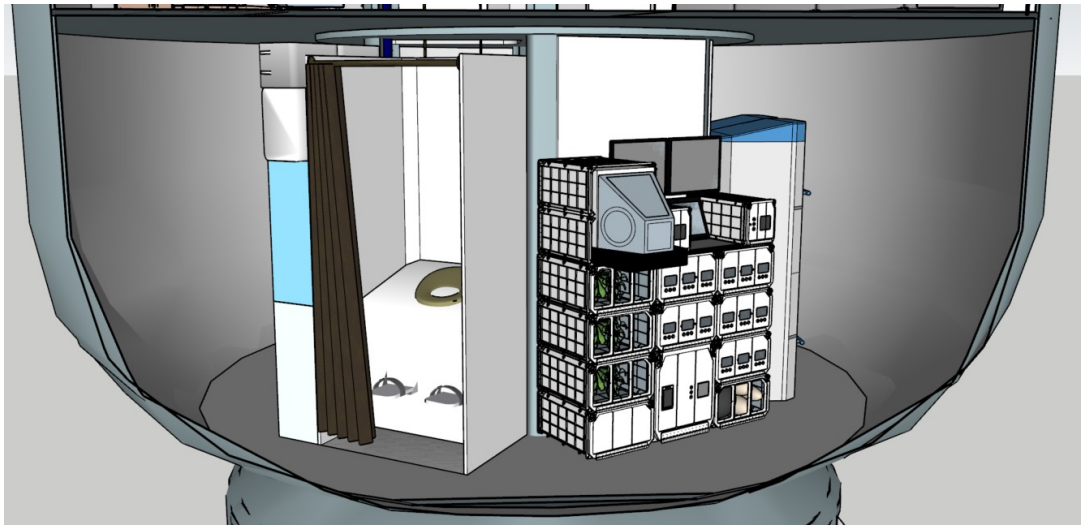
UWMS

Possible Window

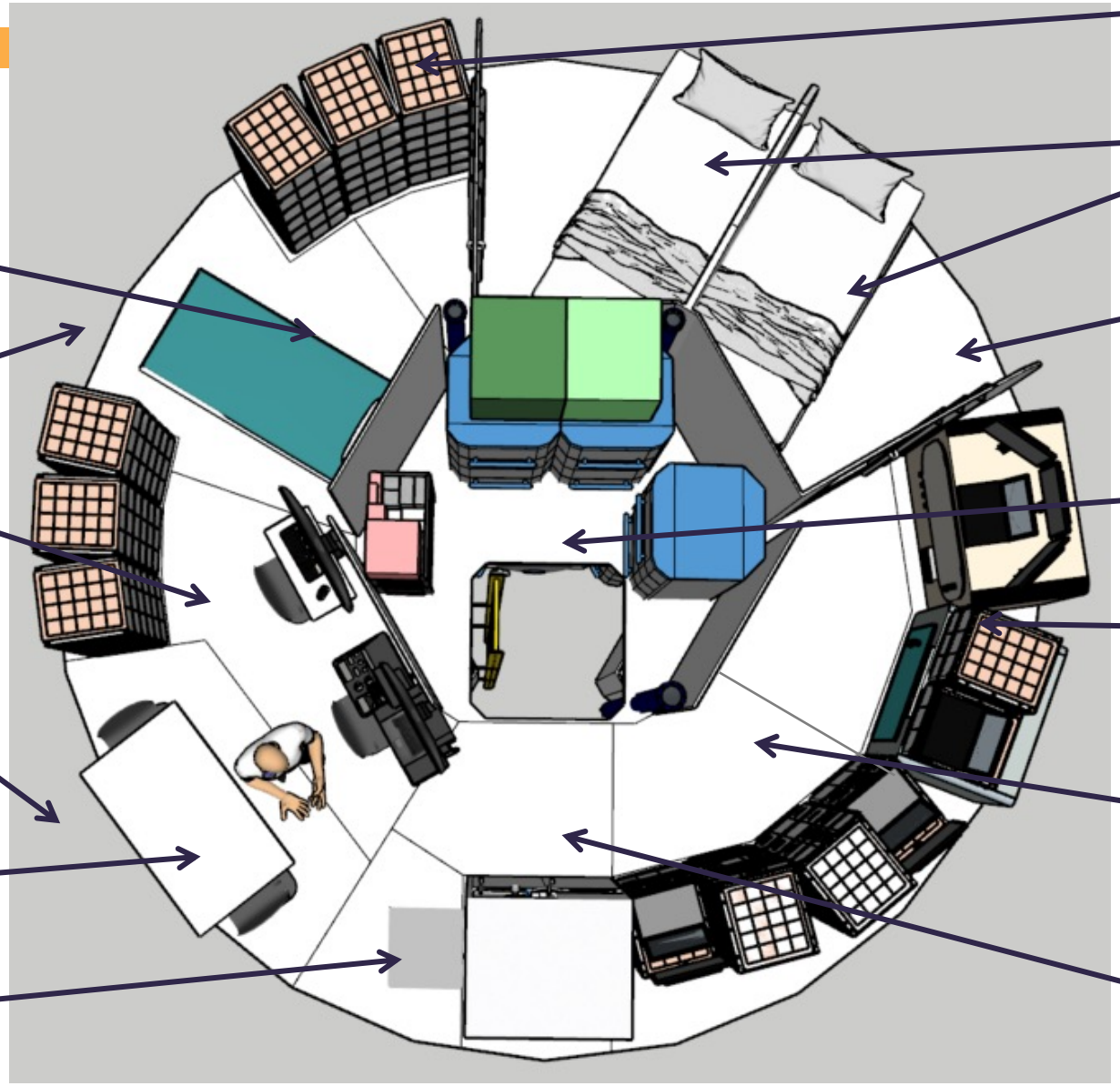
Level 2 cont.

- Orientation toward the core on the 2nd Level allows for additional clearance due to the curvature of the inflatable wall





Level 3



Access to Stowage in Middeck Lockers & Personal Quarters

Sleeping

Medical Area (stowable bed, possibility for privacy curtains)

Stretching & Possible Access to Personal Desk

Possible Windows

General Computer Station

Inner Core: Access to Sub-Systems (2 Pallets – ARS) & Ladder

Utilization – Physics Lab

Utilization – Human Research Lab

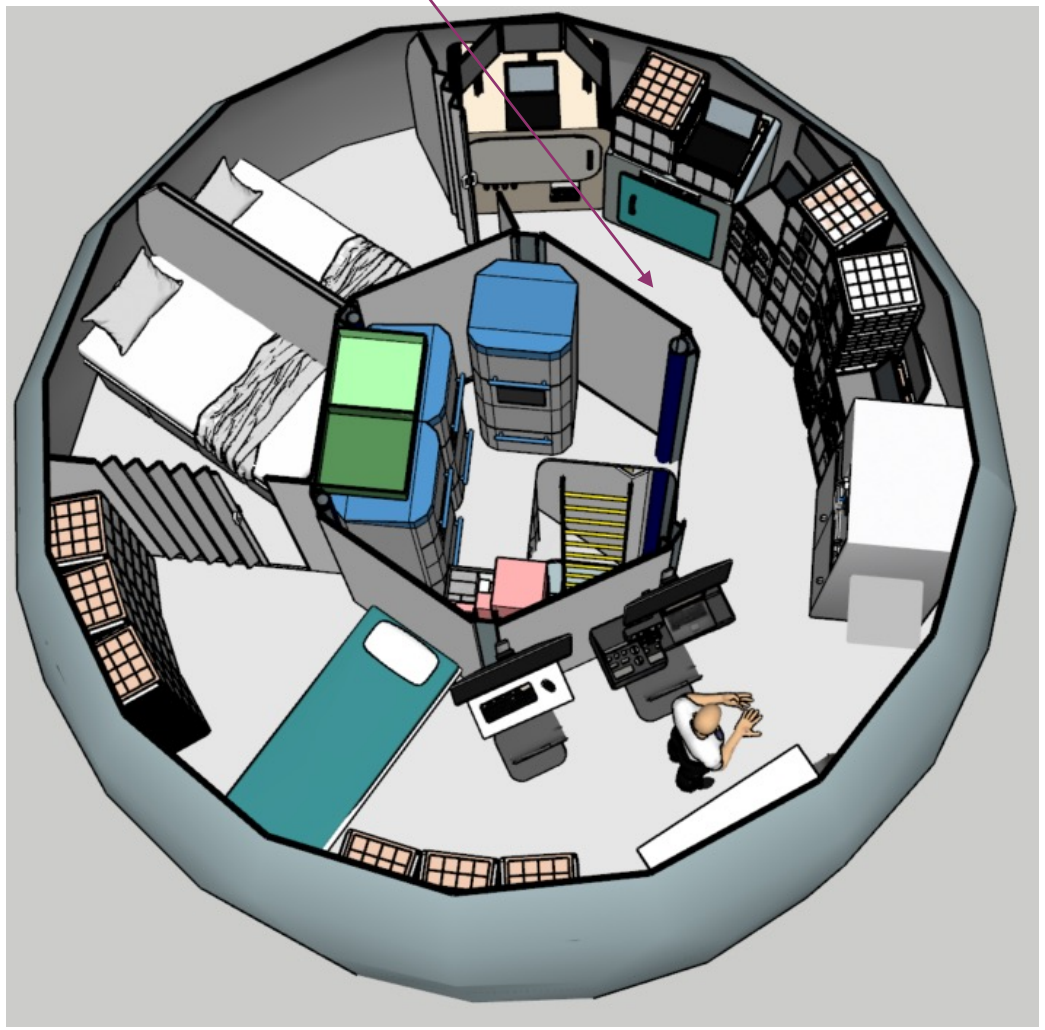
Ward Table

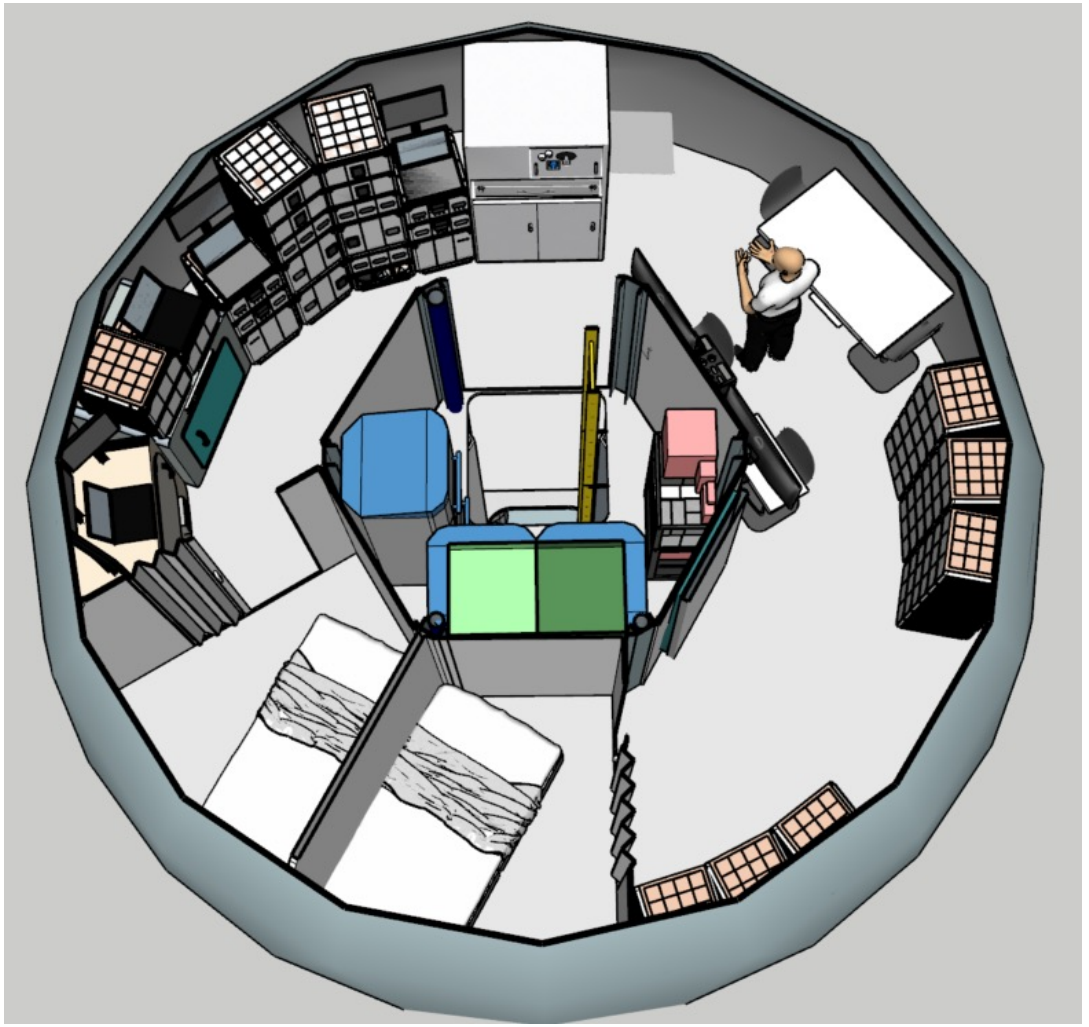
Galley – Food Item Sorting

Galley – Meal Preparation

Level 3 cont.

- Approx. 1m of clearance

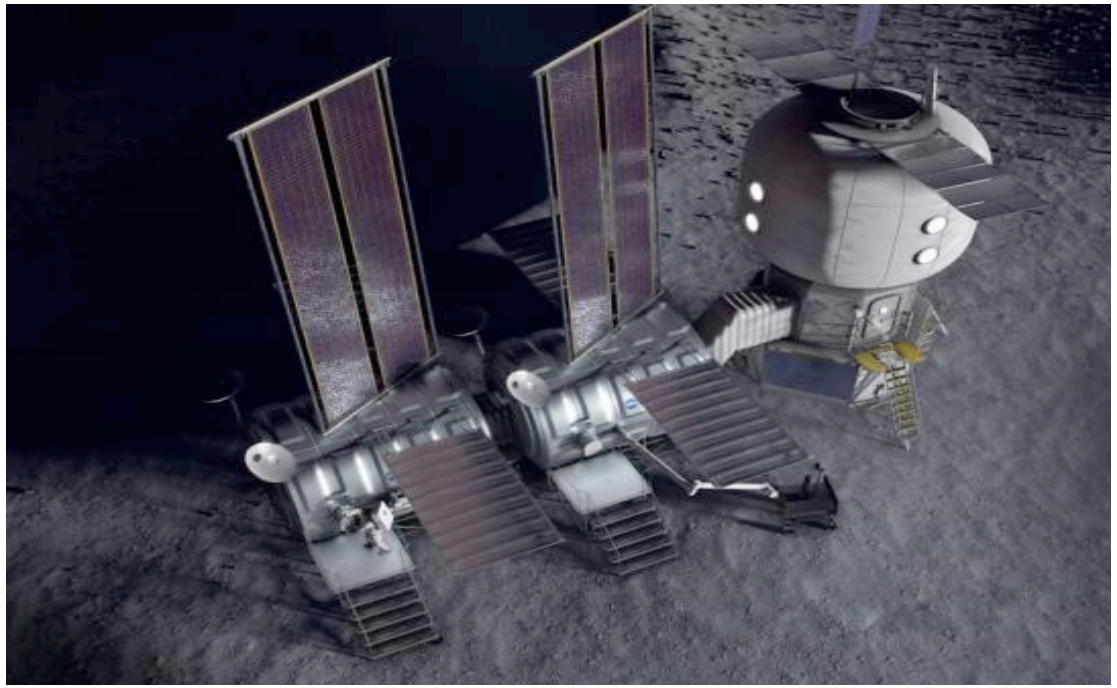




Mass Constraints

- **SH Ground Rule limits landed mass to 12 metric tons (capacity of anticipated range of HLS-class landers)**
- **Current mass estimates are in excess of 12 mt**

Forge Study Multi-Module Mobile Lab



Mass Reduction Options

1. **Eliminate some components and plan for future outfitting**
2. **Transfer functionality to other surface elements**
3. **Relax constraints on delivery mass**

Results: Key Takeaways & Layout Challenges

Crew Quarters

- Ability to house 4 crew in contingency situations
- Awkward dimensions
- Sound mitigation

Overlapping Functions

- Suitports and certain work stations overlap

Systems Access

- No direct access to Urine Processor, Brine Processor, and Water Processor Assembly pallets

Medical Area Privacy

- Crew quarters and logistics must be accessed by traversing through Medical Area

Utilization Allocation

- Physics, Geology, Biology, and Human Research Lab all included in layout but there was not enough space for the General Purpose Bench

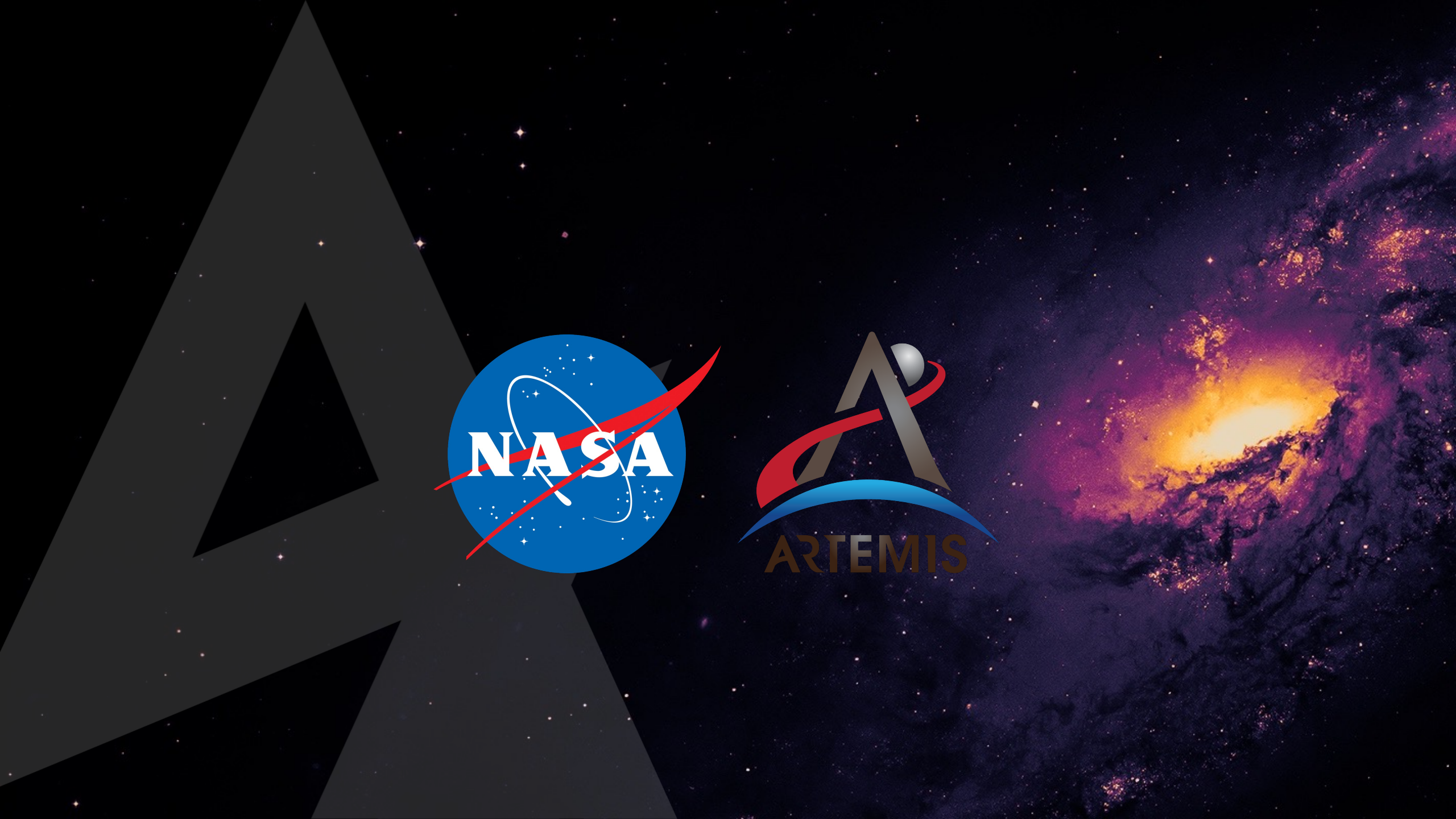
Maintenance & Repair Allocation

- Slightly less volume for recommended minimum

Forward Work & Conclusion

Future Studies

- **Tabletop Evaluation**
- **Virtual Reality**
- **Human-In-The-Loop**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