HESTIA

Kyle Kesling
Taylor Phillips-Hungerford
Jan. 10, 2017

SICSA

HESTIA: A Centralized Trunk
Earth based analog for a 90 day Mars mission for a crew of 4

Assumptions:

- ECLSS system is equivalent in volume to 4 racks
- Designs to be constrained by current structure
- Designs to be constrained for Earth habitat analog
- Secondary structure to support all interior structures
- Emphasis on subsystems integration
- 90 day mission with NO EVA
- Single, small airlock for non “mission” activities
- Current HVAC and fire suppression systems to be integrated into design (providing ELCSS functionality)

A Centralized Trunk: This HESTIA concept aims to reduce the complexity of the systems by creating a single “systems trunk” though the center of the habitat. This allows for more unique spacial separation, pulling the major systems off the periphery and placing them into a centralized group. This grouping limits the overall length of individual utilities, providing a combined trunk rather than having them spread along a wall. The utilities are centered and based in the ECLSS on the first floor. This allows for the shortest access for water return systems, tanks, air pressure and power to all of the major end uses. The result dictates that the major systems are stacked, creating hubs on each floor, centralizing the workflow and providing dual means of egress on all floors.

Systems running through the trunk:

- Potable water
- Sewage
- Electricity
- Data
- Compressed Air

Secondary Structure: The secondary structure is composed of 80/20 columns anchored to the floor and ceiling by a leveling ring of 80/20. This removes the need for several custom structures and unifies the amount of structural support delivered by the columns. The columns are spaced 20 degrees apart, this allows for a useful chord length (roughly 1 meter) while maintaining flexibility in accommodating built in obstacles on the chamber wall. Per Contra, the main purpose of the secondary structure in this design is to support a soft, modular storage solution as the central trunk feeds all the systems of the habitat. The bags are a 0.5 by 0.5 by 0.5 meter volume that hook onto the screen panels that are fastened to the columns.

Down and Dirty: The ground floor is set up around the ECLSS structure, creating a large volume in the center of the space. In order to maximize the volume closest to the water and power, a hygiene compartment, aeroponics, and sink are molded into the structure. Sandwiching this construction are two 1,100 liter water tanks, supplying direct access to the systems that require on-demand water. This aids in keeping the two most massive elements at the lowest point in the habitat, aiding in EDL by enabling a lower center of gravity. Roughly 50% of the perimeter is allocated to the sciences, providing ample work surfaces for labs, long term experiments, tool storage, controlled environments, sample return clean room options and maintenance. The remainder of the perimeter allow for the stowage of deployable gym equipment, suit spares, and waste containment envelopes. The airlock provides the only egress into the chamber, however, once inside all floors have two modes of emergency egress provided by the main ladder and the emergency rungs installed on the secondary structure over the cargo access.

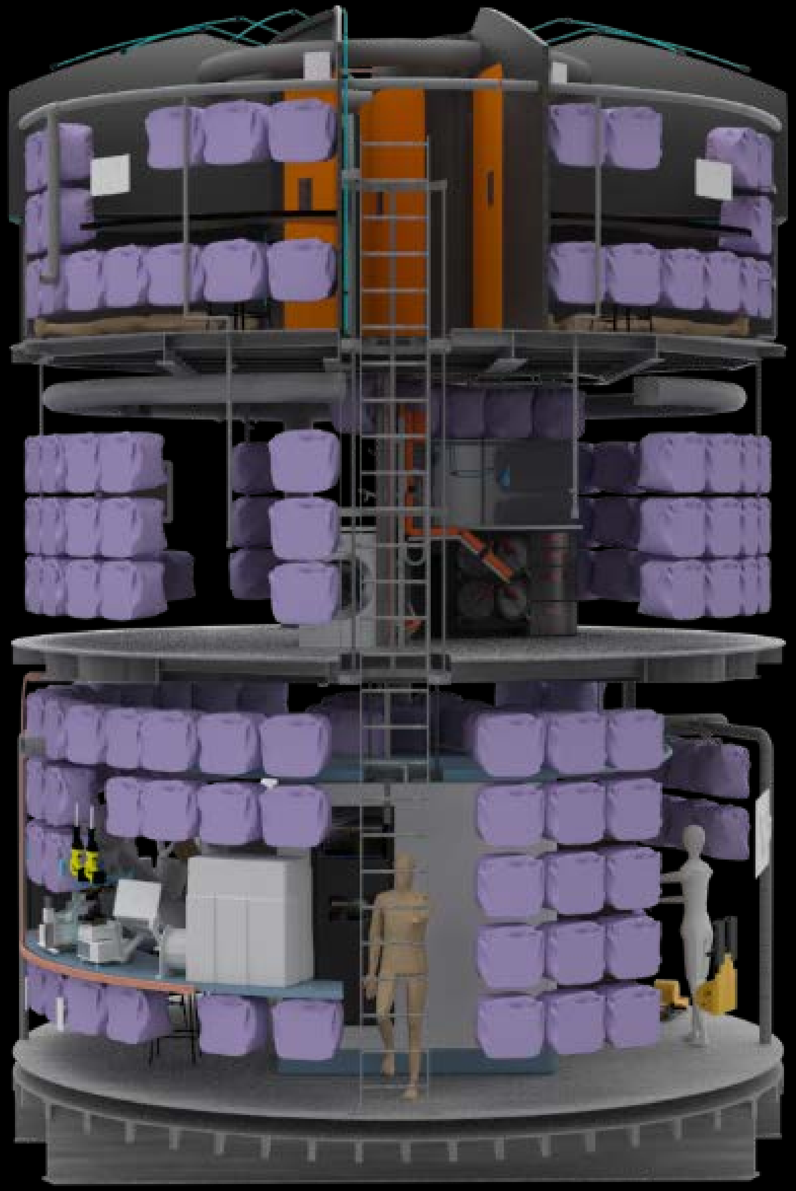
NASA requires each crew member to maintain a 2.5 hour a day gym routine, thus the allocation of a significant portion of the available floor space. The first floor accommodates this by separating the primary science/work surfaces and the gym/hygiene/human research area with the ECLSS monolith. The structure creates a large visual barrier as well as providing a high level of white noise to wash out some of the ambient noise that comes from a treadmill and a die grinder (fed from compressed air tapped off the central ECLSS structure).

Food and Fun: The second floor holds very few of the utility heavy systems. Thus the volumes can be reduced while still providing utility for the crew. The second floor supplies the galley, pantry, long term food storage, med-bay, cold storage, wardroom, command control, and RMS station. There are centralized sinks, allowing water to be run, independently to the galley and the med-bay. The slender forms that divide the galley and wardroom space from the medical area yield a reduction of mass. To take advantage of this, the walls, ceiling and floor are to be outfitted with roughly 5,100kg of 5 cm thick radiation bricks to provide shielding. This allows the entire floor to be protected during a solar particle event, giving the crew access to food, water, entertainment, and medical, while the reduced footprint of utilities provides ample floor space for sleeping if the event lasts for more than a rotation. The daily consumables are crushed in a galley mounted waste compactor which sends any wayward water back into the trunk while the bricks of solid waste get stored in the floor of the dust porch or in cargo bags stacked against the exterior wall of the habitat. The wardroom table can be configured in either a small, cafe style surface or deployed out, providing room for four.

The focus is on open space. The first floor, where the crew spends the majority of their working hours, is cramped due to the triple duty of laboratory, gym and maintenance. The second floor, while providing several of the key mission capabilities, caters to R&R with relatively large open floors, a large window and “open plan” style kitchen. Medical privacy is supplied by a deployable curtain to separate crew and patient during exams or treatment. The command and control center is situated on the opposite side of the habitat from the wardroom and galley with no line of site. This separates the functions and creates a work zone that is differentiated from the community area, dining table, and the command center by breaking up the line of sight with the medical area.

Rinse and Repeat: The third floor is reserved for crew quarters and hygiene. The second toilet is centrally co-located with the shower, divorced with a divider and separate entrances. As this is in the middle of the habitat, providing means of egress and maintaining four individual compartments of equal proportions proved impractical. The rooms are of equal net volume, however, the bed structures and overall room layouts vary in pairs. To maximize living space, the beds are arranged as bunks with an asymmetrical divider that separates the rooms. The top bunk’s divider is curved over the bed creating more visual volume for the crewmate on the other side of the wall. The hygiene area is recessed into one pair of rooms, while the passageway protrudes into the second pair of rooms. This evens out the reduction of habitable space in the private quarters and increases the corridor, providing almost a direct line of sight to either of the egress points, or to see if someone is using the lavatory. The rooms are provided with power and light, allowing space for sanctioned personal experiments, personal down time and a place to sleep. Through analysis of “A day in the life,” crew members spend between 33-59% of a given 24hr day, activities ranging from sleeping, down time, logs, and hygiene. This has been a driving factor in the provision of such substantial volume for the crew quarters.

HESTIA: A Centralized Trunk

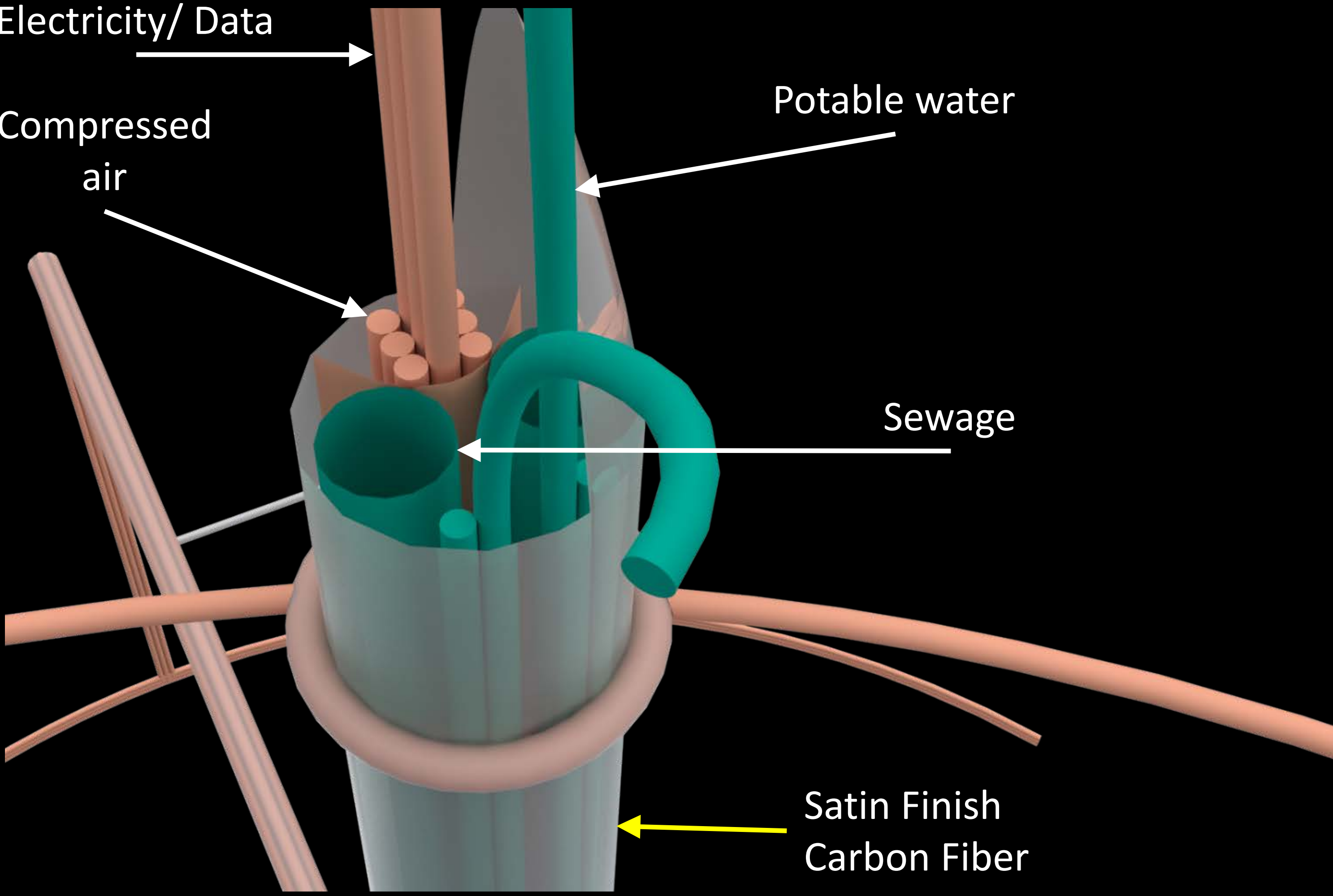


January 10th, 2017

Kyle Kesling

Taylor Phillips-Hungerford

Major Systems Trunk



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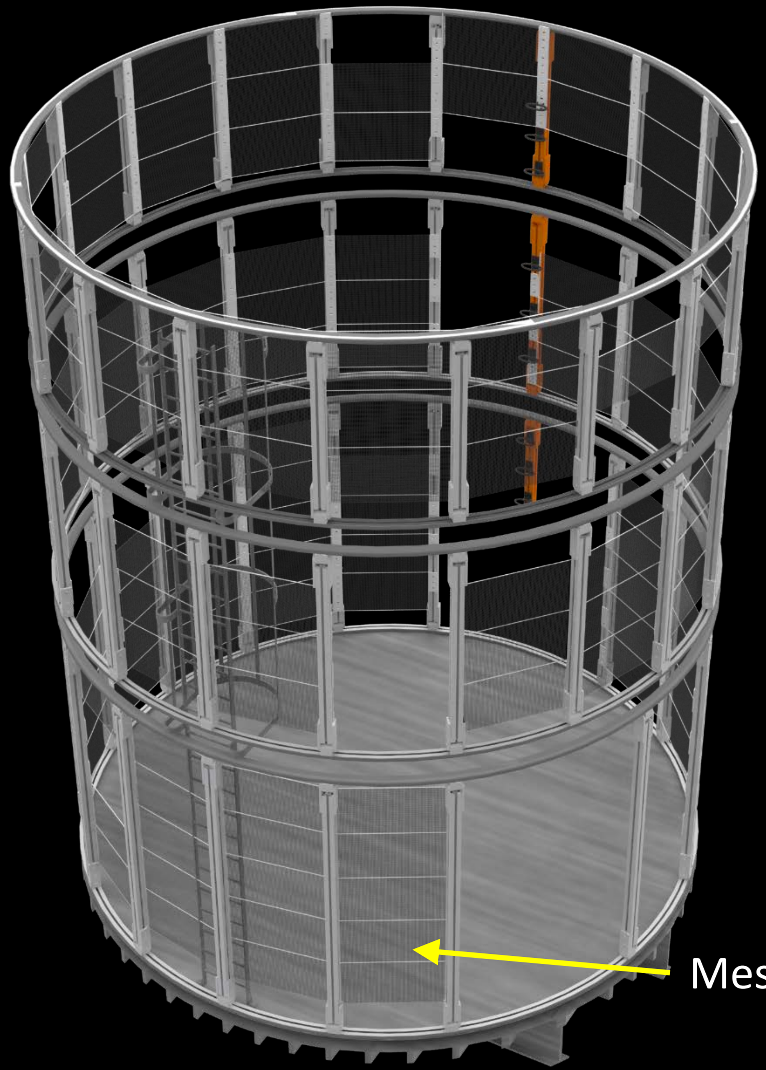
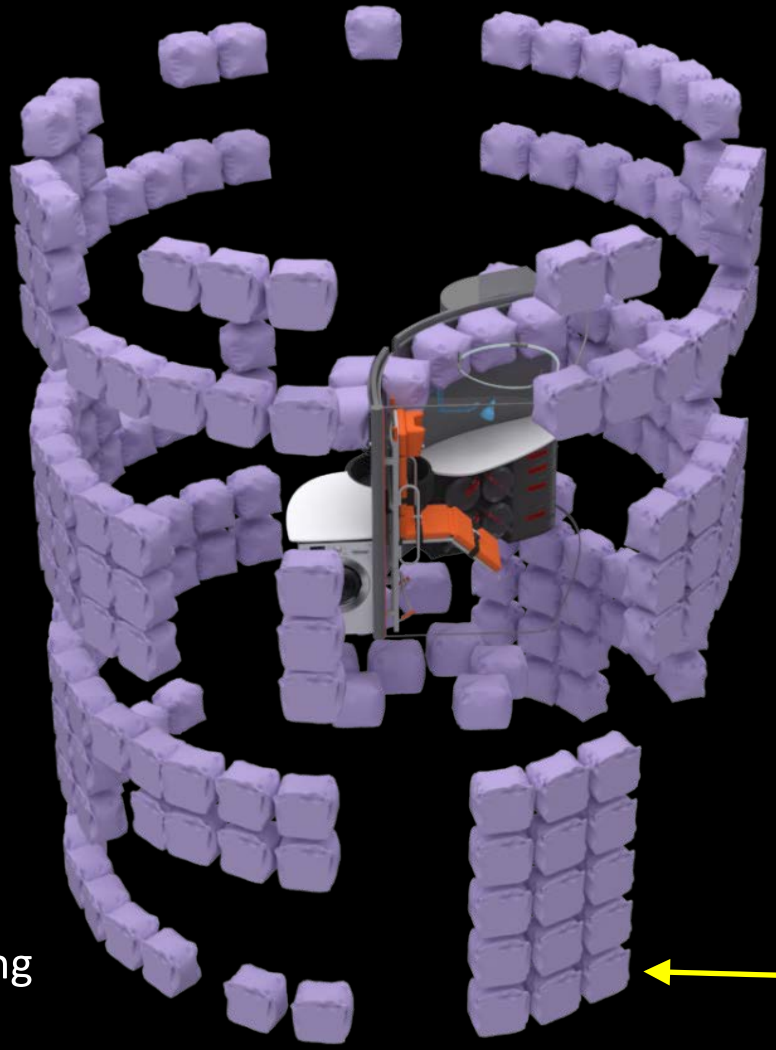
Secondary Structure: Good Ol' 80/20



Mesh Paneling



- 212 (0.50 x 0.50 x 0.50) m bags
- ~ 4 bags equivalent in galley and medical area
- 2 x 1100 kg water tanks
- Minimum Volume: ~ 27 m^3

Multi-colored Woven Polyethylene

1st Floor: Down and Dirty

Cargo bags color-coated as denoted in bubble diagram

Science/Maint.

ECLSS

Sink

Hygiene

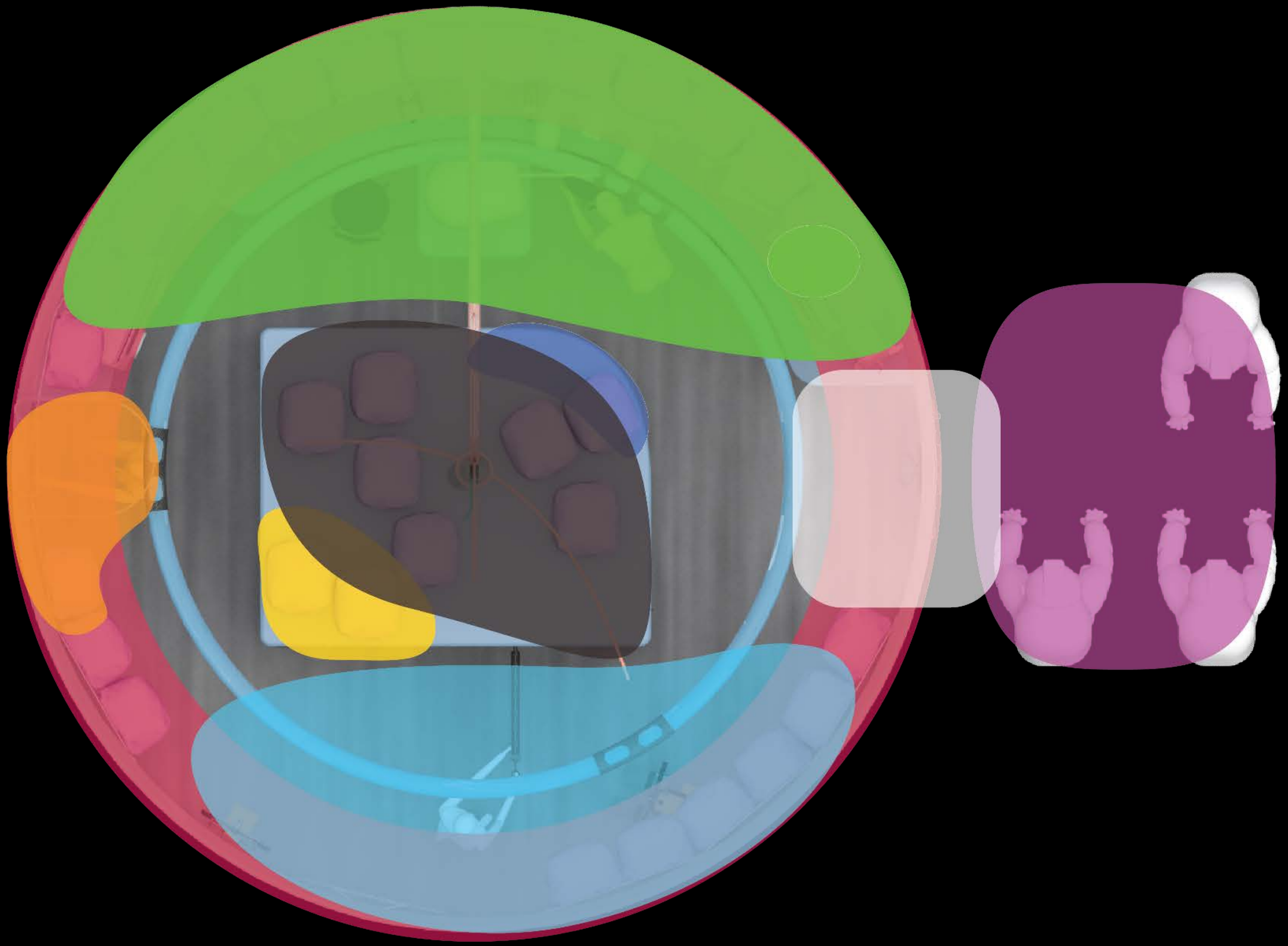
Gym

Egress

Stowage

Egress/EVA access

External Storage



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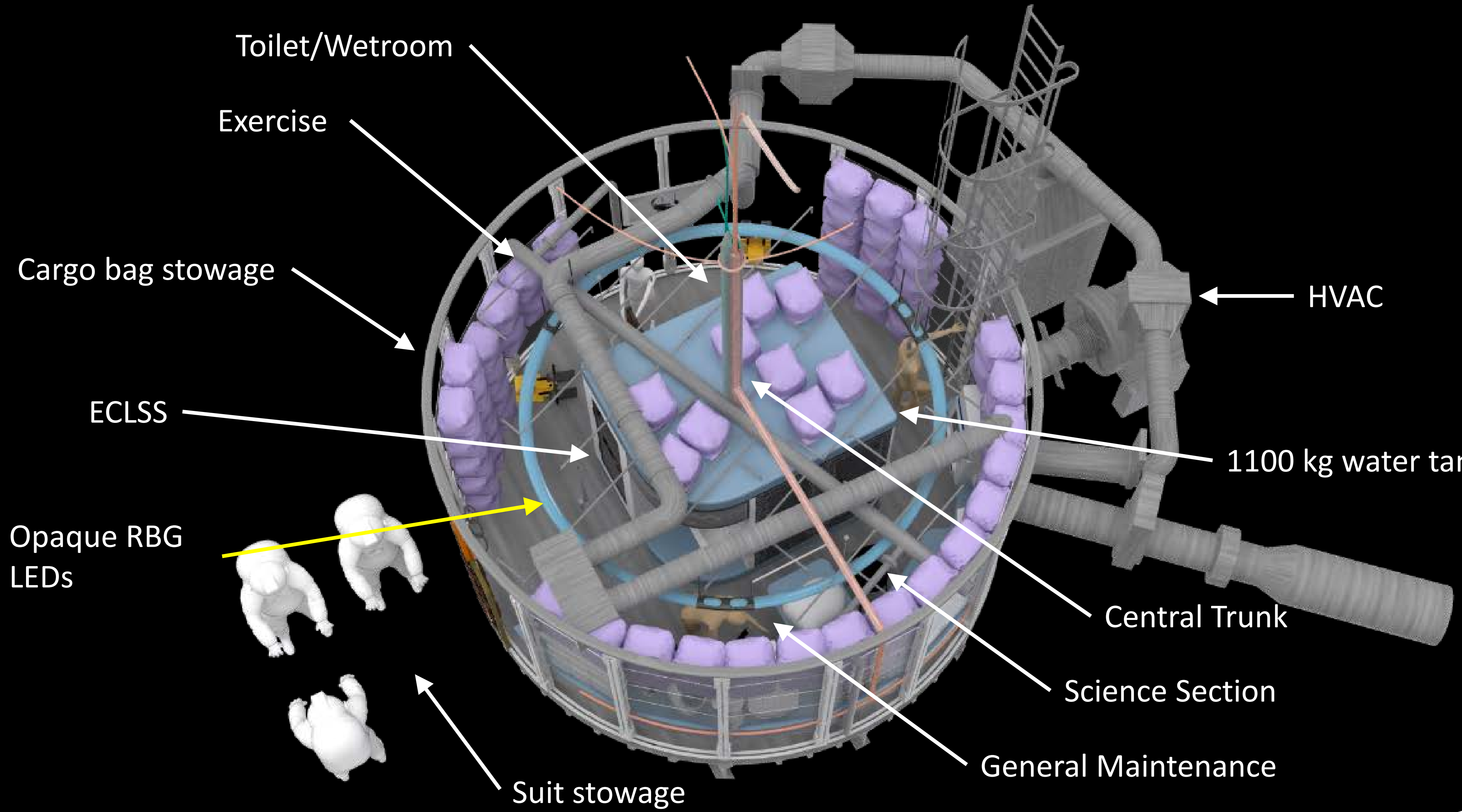
1^{st} Floor: Down and Dirty



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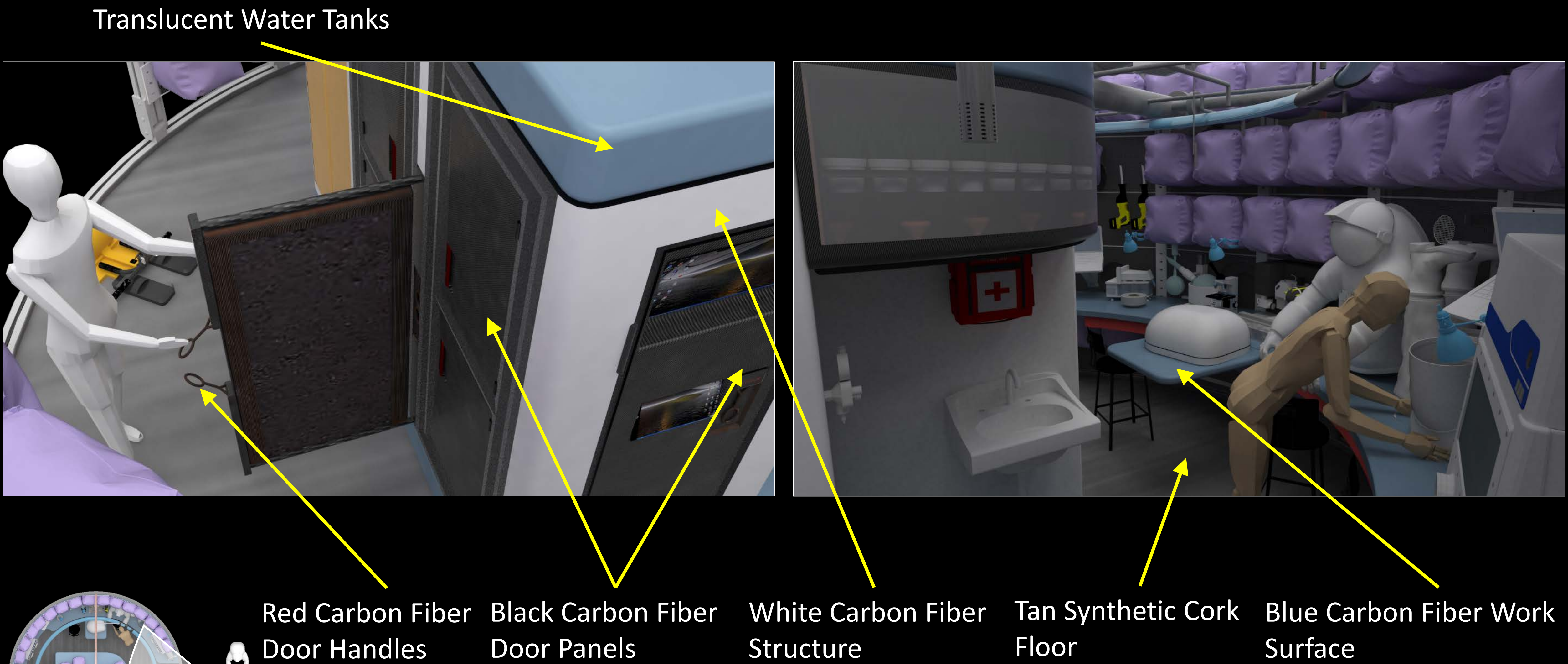
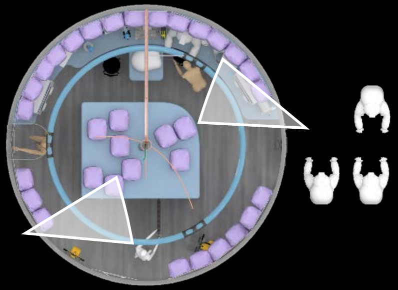
1st Floor: Down and Dirty





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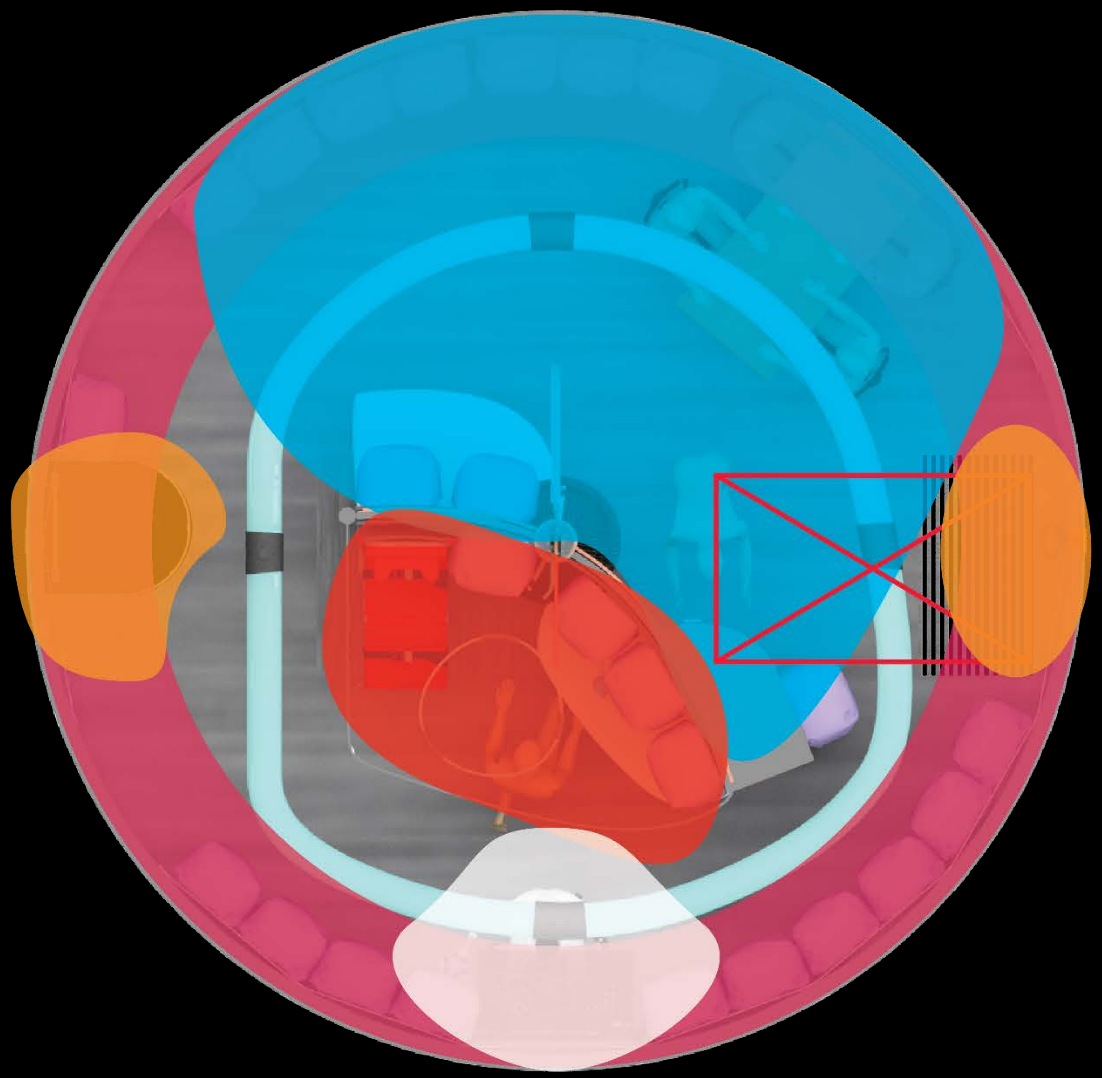
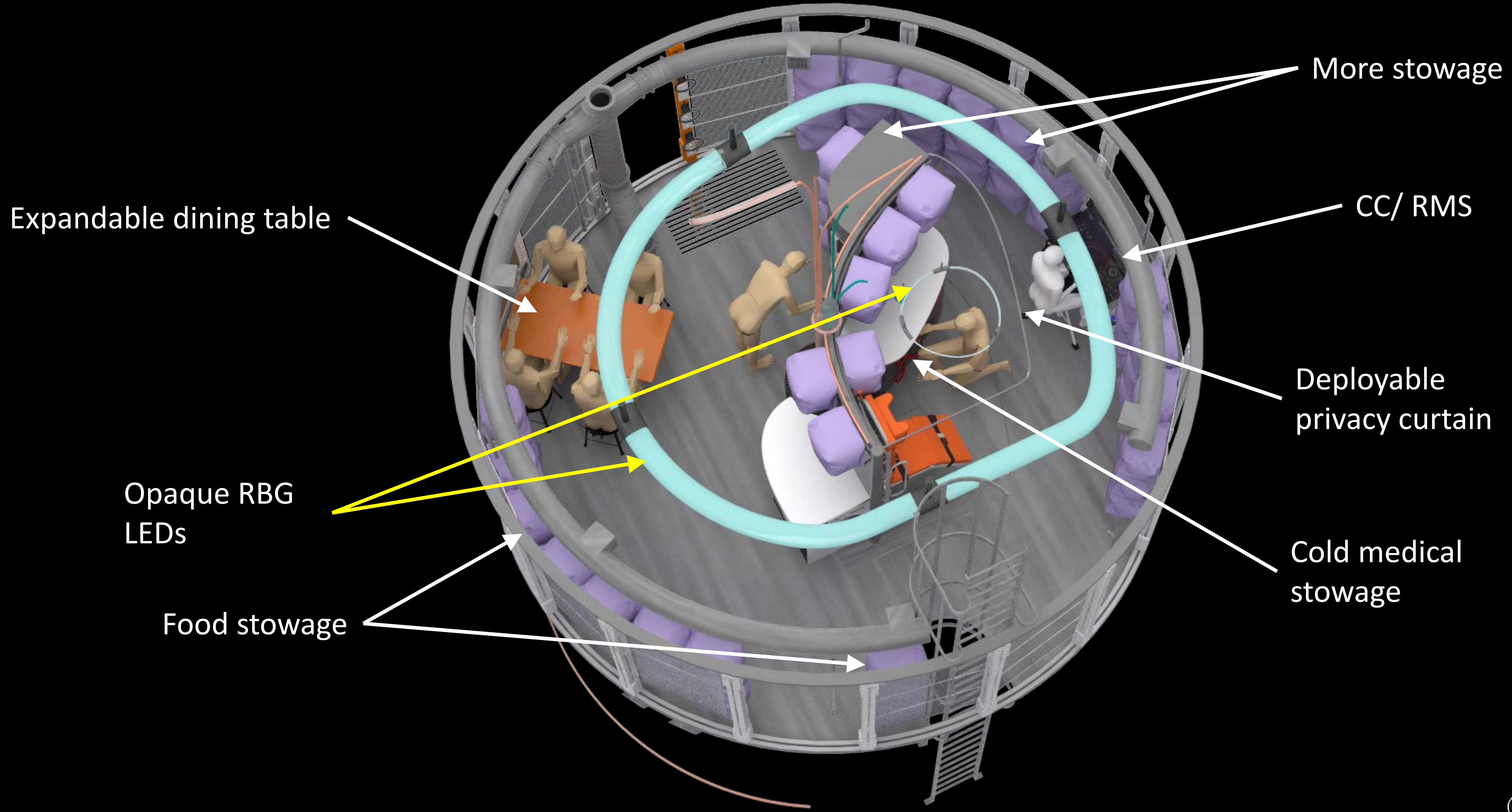
2nd Floor: Food and Fun

Cargo bags color-coated as denoted in bubble diagram

- Galley/Wardroom
- Medical
- CC
- Stowage
- Egress



2nd Floor: Food and Fun



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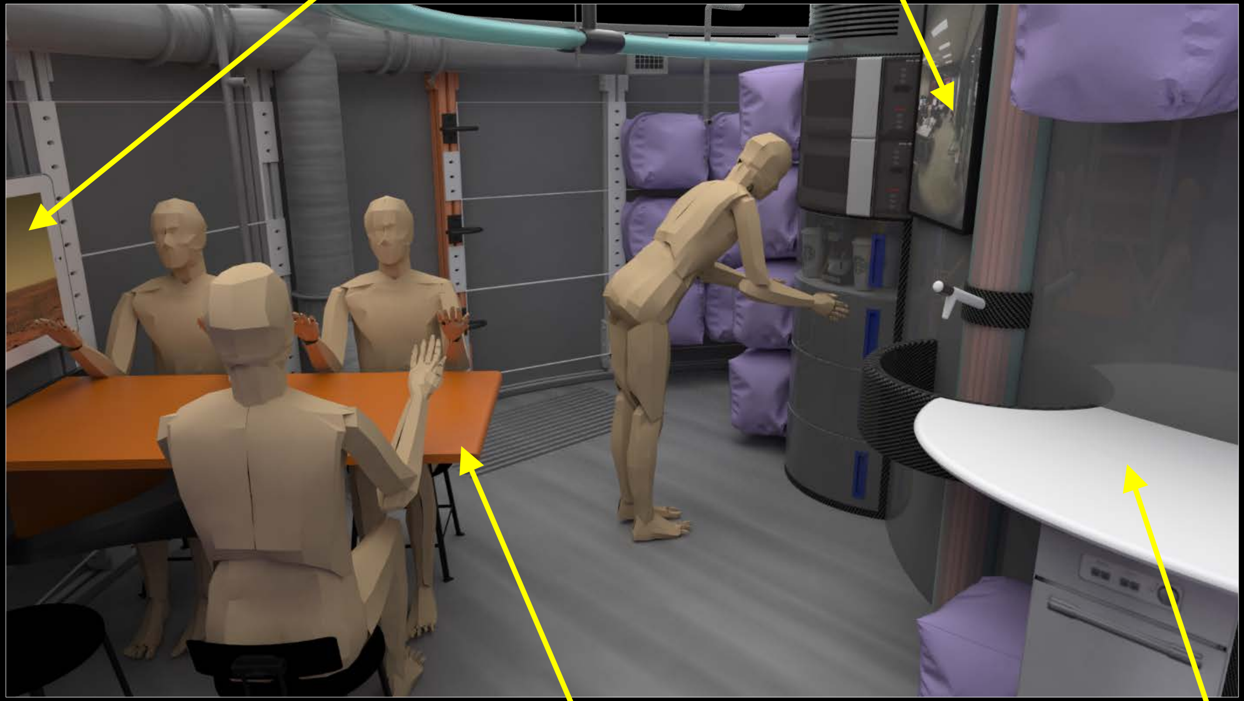
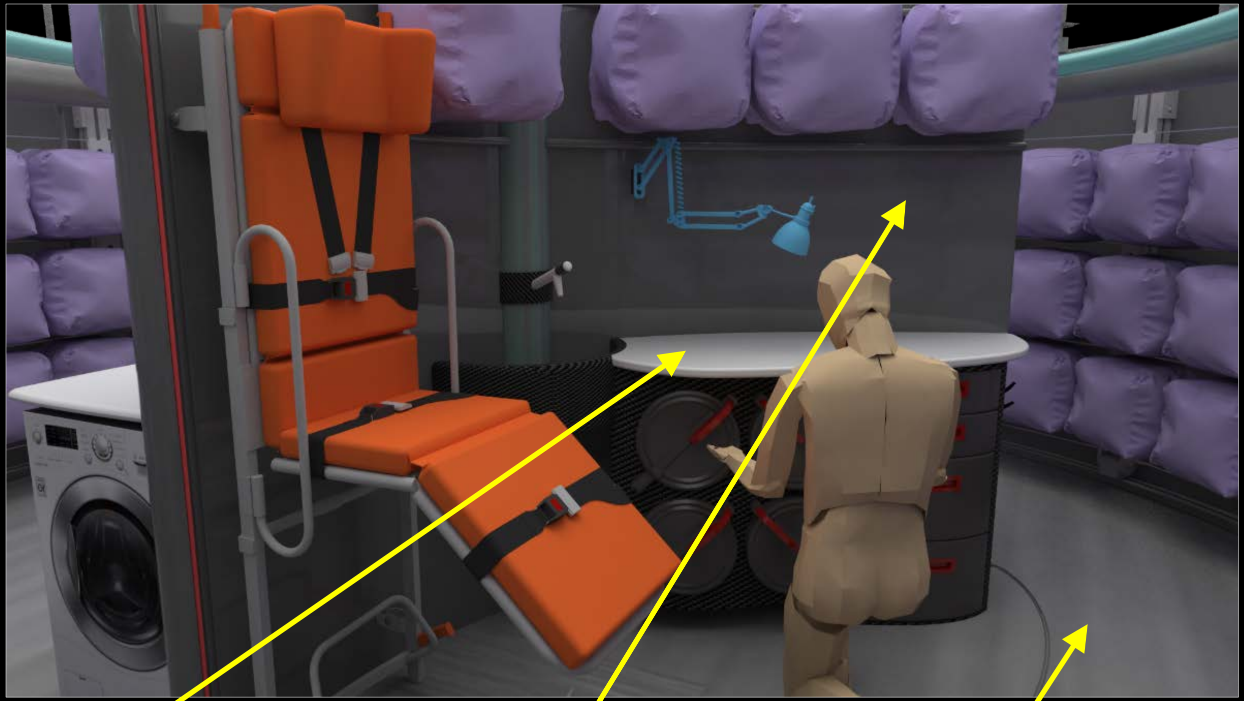
2nd Floor: Food and Fun

Window-Analog Computer Screen

Computer Screen



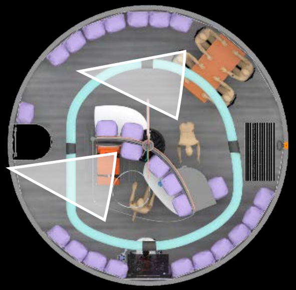


Light Orange Walnut Dining Table

White Carbon Fiber Kitchen Work Surface

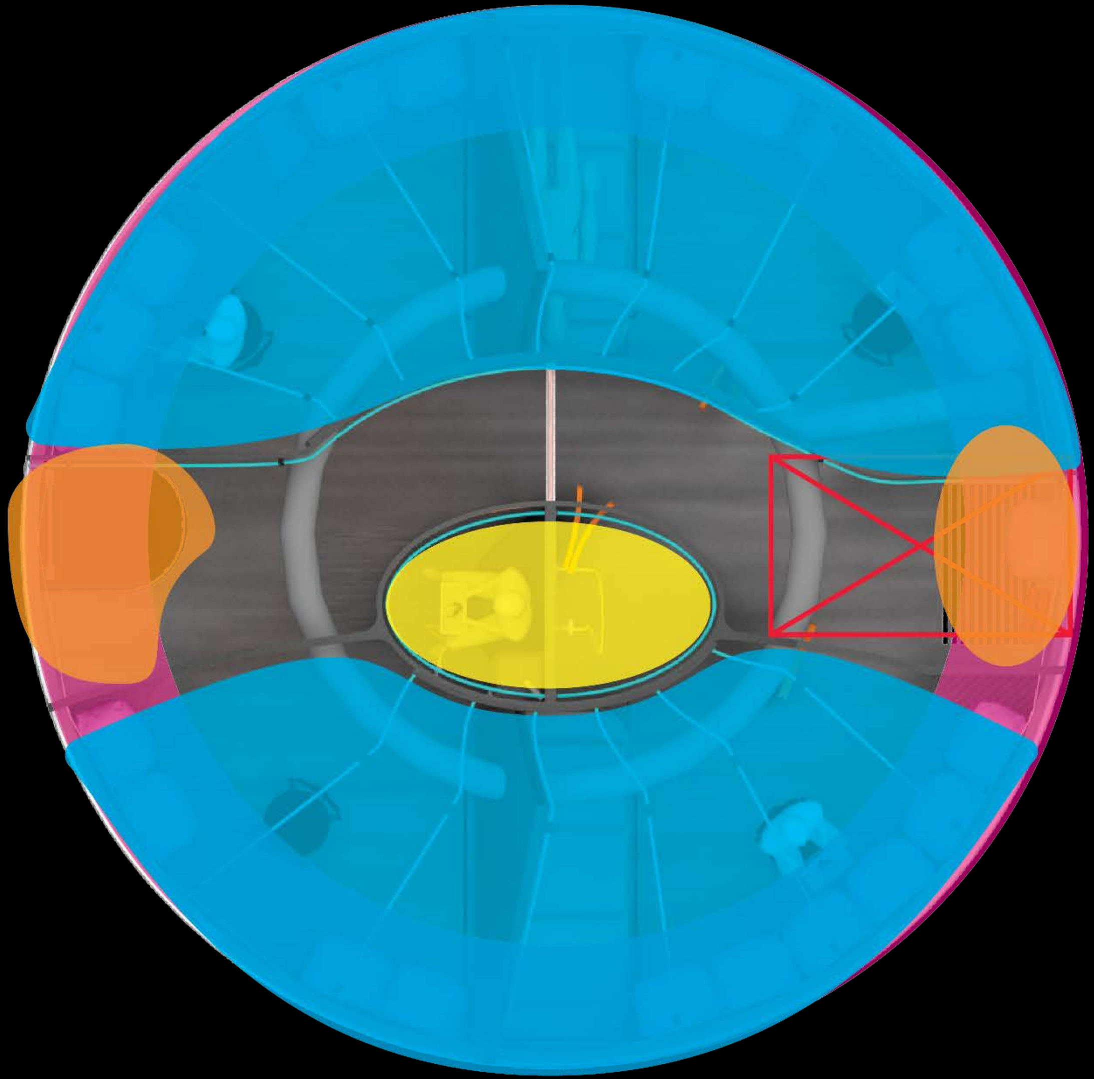
Black Carbon Fiber Structure

Tan Synthetic Cork Floor

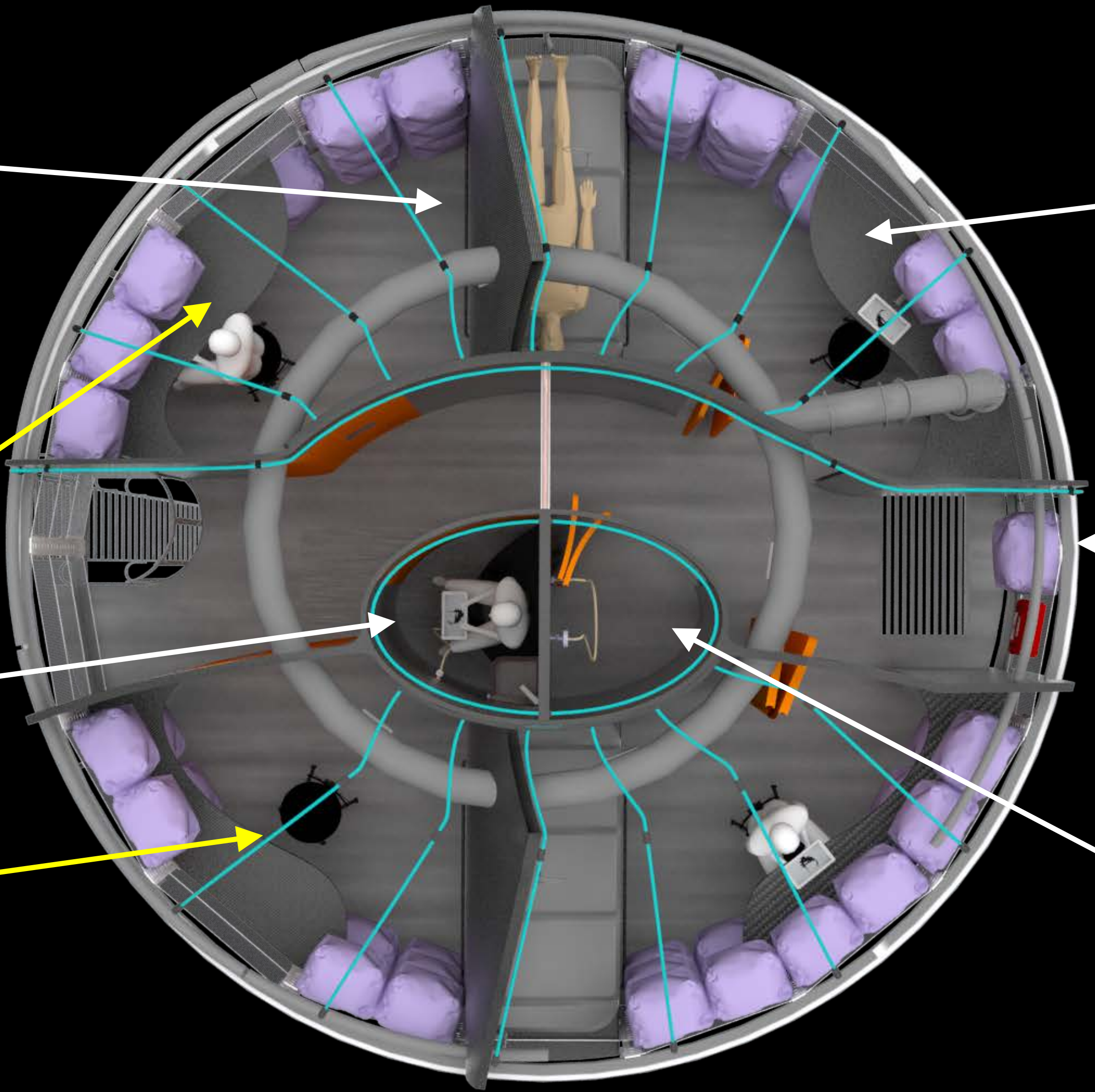


3rd Floor: Rinse and Repeat

Cargo bags color-coated as denoted in bubble diagram

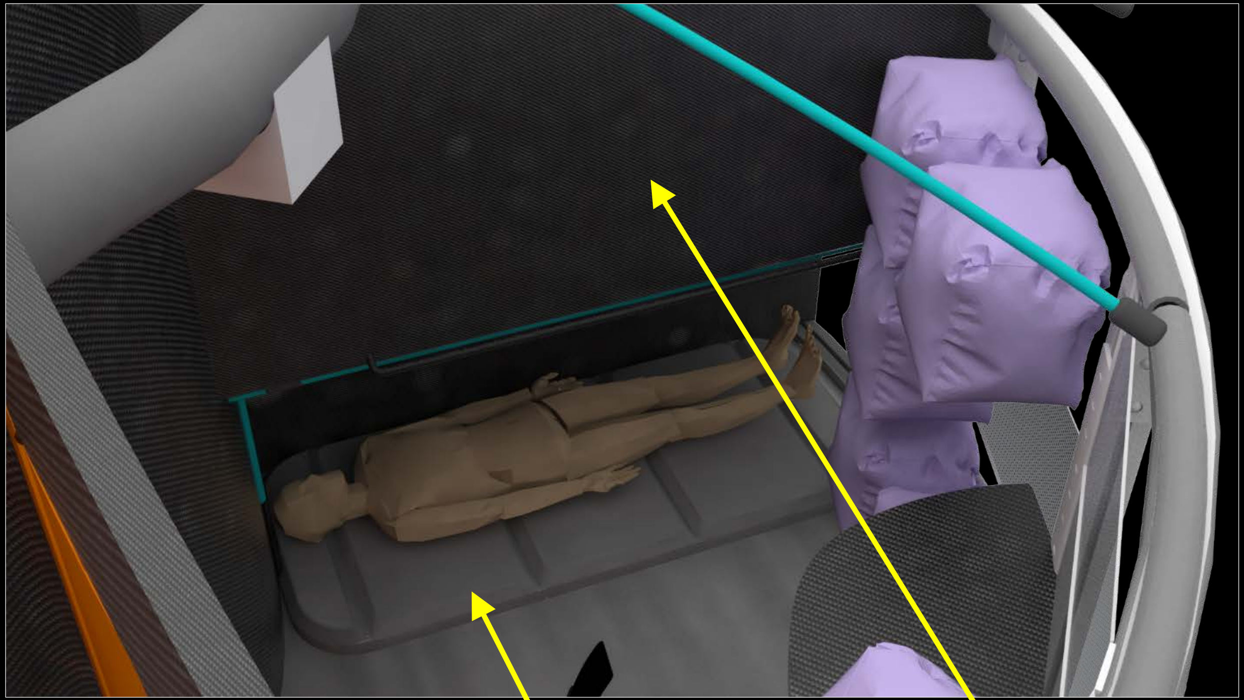


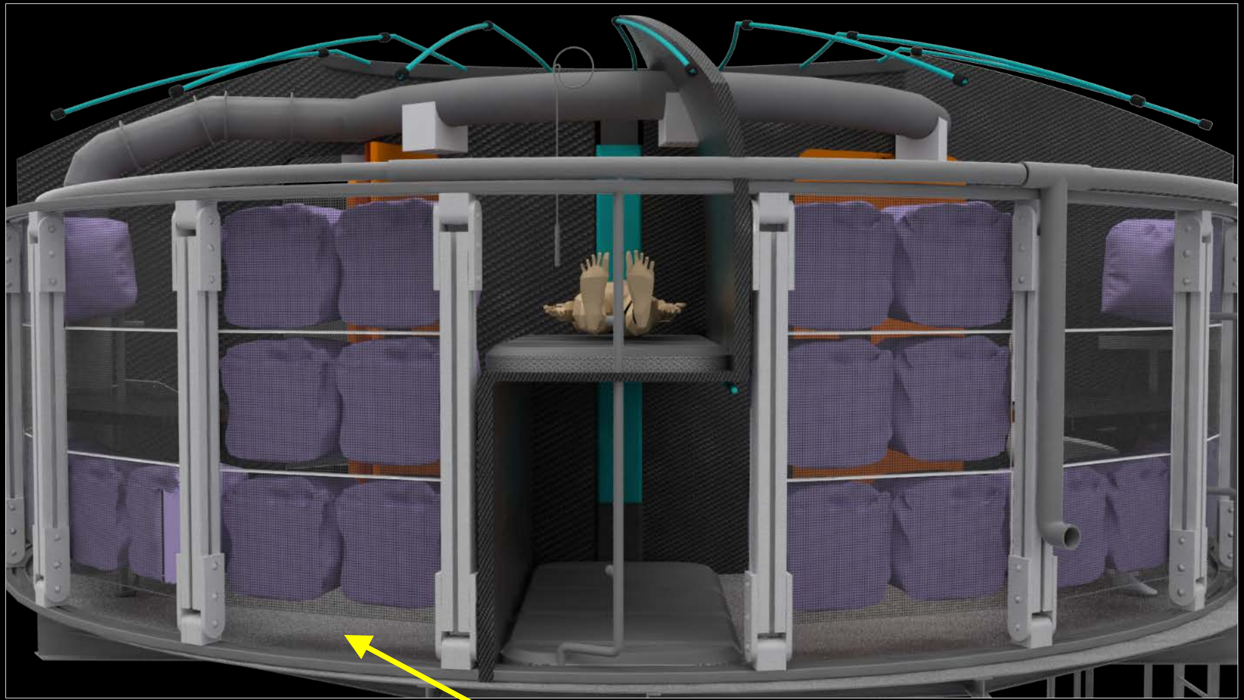
3rd Floor: Rinse and Repeat

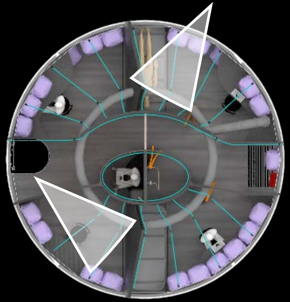


* Possible additions: Extra fire sprinkler in the passageway

3rd Floor: Rinse and Repeat







Blue Memory Foam Mattress

Glossy Carbon Fiber Structure

Tan Synthetic Cork Floor

Cheers!

Kyle Kesling is a native Texan who has been fascinated with space travel ever since his first visit to NASA as a child. He was always looking up at airplanes in awe as giant pieces of metal flew across the sky. This fascination led Kyle to join rocketry in high school and pursue a bachelor's degree in Aerospace Engineering from the University of Texas at Austin. While receiving his undergraduate degree, Kyle was a part of the Mars Research Group, which furthered his interest in space travel. Kyle Kesling is currently pursuing his master's degree in Space Architecture from the University of Houston. As a thesis, Kyle plans on designing a transit vehicle that will one day be used to travel to Mars. Kyle is currently employed as a contractor with Intuitive Machines working with Axiom Space in designing their future commercial space station. After graduate school, Kyle plans on getting a job that will still allow him to look up in the sky in awe, but this time not at airplanes, but at a creation of his own that was used to send the first humans to Mars.

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Taylor Phillips-Hungerford is currently enrolled in the Sasakawa International Center for Space Architecture master's program at the University of Houston. He was classically trained in the trade of design, from a very technical course at WIT in Boston to a very conceptual course at CSM in London. He was also classically trained in vocational labor from construction to landscaping, from laying water pipes in early winter to changing fan belts in the dead of winter. His design aesthetic stems from the virtues of honest form follows function practiced by I. M. Pei and Dieter Rames, and the day to day hands on vocational upbringing. This has led to a collaborative project fleshing out Buzz Aldrin and Larry Bell's Mars cycler and permanent settlement concept as well as a Space Architect Contractor position at Axiom Space and Wyle Laboratories, INC. designing for human centric space crafts.

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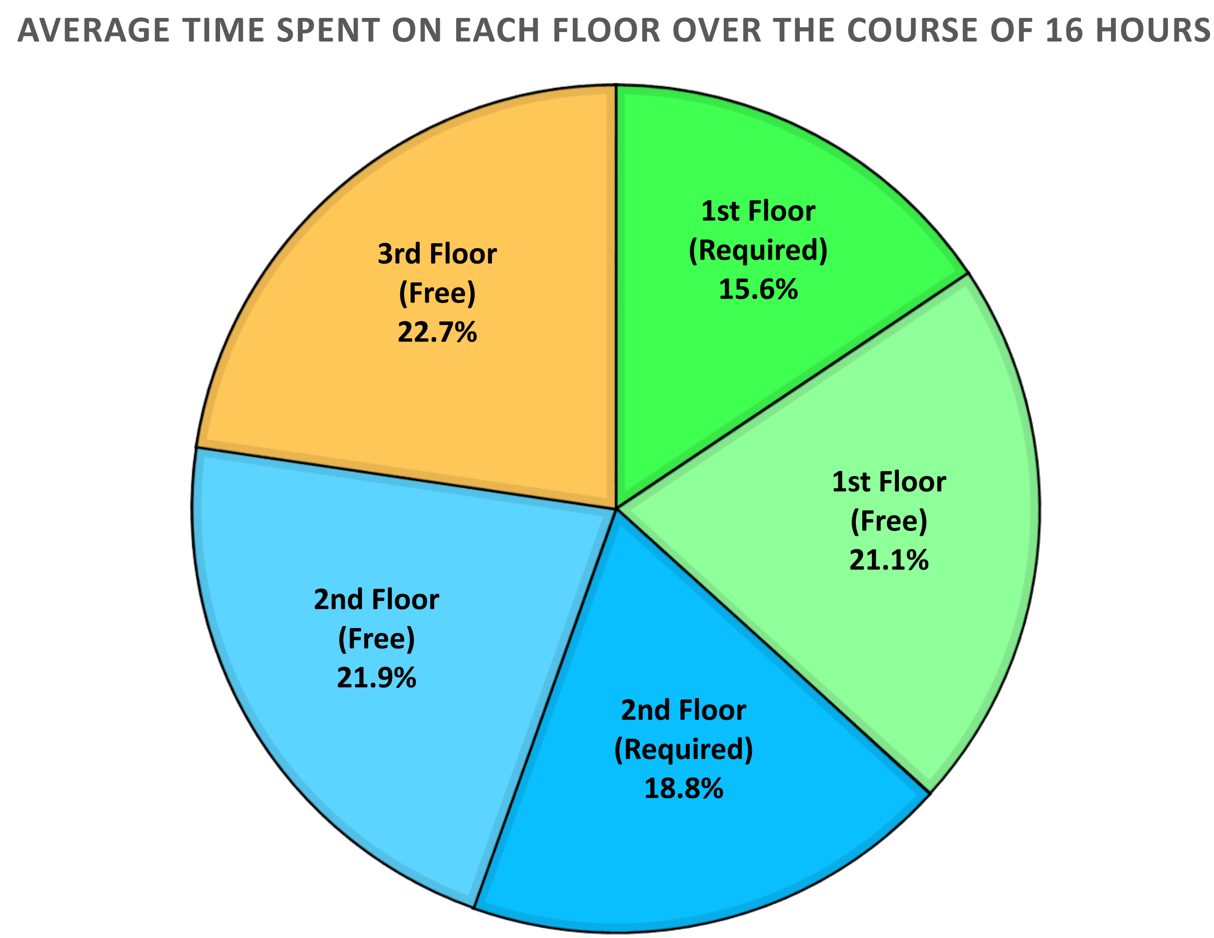
APPENDIX

TIME	CM1 - Biologist	CM2 - Physician	CM3 - Geologist	CM4 - Mechanic/Engineer
6:00 - 6:30 AM	CQ	CQ	CQ	CQ
6:30 - 7:00 AM	CQ - records questions	CQ - records questions	Medical blood test	Uses Toilet
7:00 - 7:30 AM	Breakfast	Breakfast	Breakfast	Breakfast
7:30 - 8:00 AM				
8:00 - 8:30 AM	Listens to NASA's response	Listens to NASA's response	Sets up soil samples	Repairs hardware on rover #2
8:30 - 9:00 AM	Performs soil sample analysis	Sets up rover # 1 for sample return	Performs soil sample analysis	
9:00 - 9:30 AM		Resistive workout		
9:30 - 10:00 AM				Cardio workout
10:00 AM - 10:30 AM			Writes up soil analysis report	
10:30 - 11:00 AM	Writes up soil analysis report	Private Medical Call		Runs software analysis on rover # 2
11:00 - 11:30 AM		Repairs Trunk Leak/Clean Trunk	Medical - eye and bp tests	
11:30 AM - 12:00 PM	Cardio workout		Resistive workout	Repairs Trunk Leak/Clean Trunk
12:00 - 12:30 PM				
12:30 - 1:00 PM	Cleans 1st floor wet room			
1:00 - 1:30 PM	Lunch	Lunch	Lunch	Lunch
1:30 - 2:00 PM				
2:00 - 2:30 PM	Checks plant growth	Replaces pantry with food	Rover # 1, sample return	Writes report on trunk repair
2:30 - 3:00 PM		Cleans 3rd floor shower and toilet		
3:00 - 3:30 PM	Resistive workout			Runs diagnostics/ performs final testing on rover # 2 for tomorrow's sample return
3:30 - 4:00 PM		Cardio workout		
4:00 - 4:30 PM				
4:30 - 5:00 PM	Cleans up/ Changes Clothes	Cleans up/ Changes Clothes	Cardio workout	Writes report on rover # 2's repairs
5:00 - 5:30 PM	Sets up soil samples	Sets up soil samples		Resistive workout
5:30 - 6:00 PM	Receives minor cut on arm	Treats crew member with minor cut	Cleans up/ Changes Clothes	
6:00 - 6:30 PM	Begins soil sample analysis from rover # 1	Cleans area/ Writes up injury report	Begins soil sample analysis from rover # 1	
6:30 - 7:00 PM				Cleans up/ Changes Clothes
7:00 - 7:30 PM	Dinner	Dinner	Dinner	Dinner
7:30 - 8:00 PM				
8:00 - 8:30 PM	Game Night	Game Night	Game Night	Game Night
8:30 - 9:00 PM				
9:00 - 9:30 PM				
9:30 - 10:00 PM	Personal Time	Personal Time	Personal Time	Personal Time
10:00 PM - 6:00 AM	SLEEP	SLEEP	SLEEP	SLEEP


AVERAGE TIME SPENT ON EACH FLOOR OVER THE COURSE OF 16 HOURS
1st Floor (Required) 15.6%
1st Floor (Free) 21.1%
2nd Floor (Required) 18.8%
2nd Floor (Free) 21.9%
3rd Floor (Free) 22.7%

Spacecraft Habitation Crew Functions

Reminder: *Not all crew functions require dedicated workstations - some can be combined and some are accomplished with equipment items, while others may require multiple workstations and/or facilities. Mission duration and mission objectives drive degree*

Yellow – include
Gold – don't preclude
Red – assumed no room to include

HESTIA simulation of a Mars surface habitat

Functional Category	Crew Function	Description	HESTIA Suggestion	Function Location (3'o clock = dust porch
Hygiene Activities	Full Body Cleansing	Washing of the entire body of an individual crew member	Enclosed shower-like volume; separated from toilet volume	3F/C3
	Hand/Face Cleansing	Washing of an individual crew member's hands or face	Traditional sink/faucet, mirror arrangement. Include surfaces/points for holding washcloth, soap, etc. May or may not have privacy enclosure to close off from cabin; should include access doors to full body cleansing and urination/defecation	1F/C2 2F/C 3F/C9
	Personal Grooming	Individual personal care tasks such as shaving, brushing teeth, combing hair, etc.	Co-locate with hand/face cleansing, include counter surface area for grooming materials and stowage area for housekeeping and shared items	1F/C2 3F/C9
	Urination/Defecation	Discharge and containment of liquid and solid bodlily wastes	Enclosed toilet room with odor control and acoustic insulation; opens to hand/face cleansing and grooming volume.	1F/C8 3F/C9
Personal Activities	Sleep	Private environment to allow individual crew member sleep	Place inside a private crew quarters; sleep on horizontal surface, elevated minimum of 2' above floor	3F/12&6
	Private Communication	Crew member video and or audio conversation with visual and auditory isolation from other crew	Place inside private crew quarters; possible from both sleep and sitting position; requires CQ to have both visual and auditory partitions as well as data interfaces	3F/12&6
	Private Recreation/Leisure	Individual crew member unstructured, non-mission, self-directed activity	Place inside private crew quarters; include both a desk space for seated tasks and sufficient open floor space to move unencumbered in any direction (e.g. Kinnect based video game)	3F/12&6
	Dressing/Undressing	Changing of IVA clothing	Place inside private crew quarters AND inside personal grooming volume; include overhead reach	3F/12&6
	Personal Data Entry/Access	Individual crew member data device access on private (non-mission, non-shared) IT devices	Place inside private crew quarters; implies computer network securitity	3F/12&6
Exercise Countermeasures	Aerobic Exercise	Individual crew member aerobic conditioning	Requires both treadmill and ergometer; additional rower is optional	1F/C6/6
	Resistive Exercise	Individual crew member resistive conditioning	Requires equivalent to ARED	1F/5
	Physical Rehabilitation	Individual crew member recovery from dehibilitated condition	May also include stretch bands	1F/5
	Bone Conditioning	Individual crew member bone loading	Met by combination of ARED equivalent and treadmill	1F/C6/6 1F/5
	Sensorimotor Conditioning	Individual crew member sensorimotor exercise	Met by presence of treadmill	1F/C6/6
	Exercise Monitoring	Physiological monitoring of individual crew member exercise countermeasure effectiveness	Requires appropirate monitoring devices and room to mount in exercise area and/or medical or life science area	1F/7
Medical Care	Preventative Medical Care	Routine medical evaluation and intervention	Requires ISS-equivalent or better medical capability	2F/C6
	Medical Monitoring	Physiological monitoring of individual crew member health	Met by above medical equipment	2F/C6
	Emergency Medical Care - don't preclude	Contingency medical intervention due to injury or illness	Requires medical workstation to be a dedicated volume not shared with other tasks and deployable privacy curtains; should also include equipment for transfer of injured crew to other spacecraft	2F/C6
Crew Dining	Meal Prep	Preparation of food items for crew member consumption	Level of capability varies depending on fresh food augmentation; minimal is ISS rehydrator and food warmer; enhanced versions consider how to prepare freshly grown meats and vegetables for immediate consumption; other enhancments include stabilizing fresh food for use in multi-week rover expeditions	2F/C9
	Fresh Food Augmentation - don't preclude	Production of fresh food items (e.g. plant or animal growth) to supplement prepackaged food items	Minimum solution should include sufficient fruits and vegetables for a weekly crew salad; enhanced solutions may increase frequency and/or add additional plants or animals; consider demonstrating a meat concept (perhaps tilapia or salmon)	1F/C2
	Eating	Group and individual crew meal consumption	Includes utensils, trays, surfaces, cups, etc. and galley table; Mars location implies need for chairs	2F/2
	Meal Cleanup	Disposal of food waste products and cleaning and stowage of reusable meal equipment	Stowage for housekeeping / cleaning supplies and trash stowage sized to accommodate 1-3 days worth of meal trash	2F/C9
Group Activities	Group Recreation/Leisure	Group crew member unstructured, non-mission, self-directed activity	One or more locations in the spacecraft where all four crew can play, inclusive of physical activity, board cames, movie/video watching, cards, conversation, etc.	2F/2
	Crew Meetings	Multi-person crew mission-related meetings	One or more locations in the spacecraft where all four crew can conduct work related meetings without displaying prohibited content in the background; at least one location should be appropriate to each type of mission operational activity (e.g. research, EVA, spacecraft system commanding, etc.)	2F/2
	PAO Events and Multi-Person Video Communication	Multi-person crew video and audio communication with the ground or other space assets	One or more locations in the spacecraft where multiple crew can communicate with Earth or other space vehicles without broadcasting prohibited content in the background (e.g. no direct view of medical activity or proprietary research)	2F/2
Maintenance, Fabrication, and Repair - how much?	Housekeeping	Routine component replacement, cleaning, or adjustment of spacecraft subsystems	Include pantry stowage for general housekeeping items as well as point of use stowage near areas requiring frequent housekeeping (e.g. cleaning fluids and rags in galley)	2F/C4
	Electrical Maintenance, Repair, and Fabrication	Corrective action to diagnose and restore degraded functionality of electrical components or produce new/replacement items	Extensive electronic and electrical capability including PCB fabrication, soldering, circuit testing, etc.	1F/2
	Mechanical Maintenance, Repair, and Fabrication	Corrective action to diagnose and restore degraded functionality of mechanical components or produce new/replacement items	Tools, fixtures, and parts for repair of electric motors, mechanisms, releases, and other mechanical devices	1F/2
	Soft Goods Maintenance, Repair, and Fabrication	Corrective action to diagnose and restore degraded functionality of soft goods components or produce new/replacement items	Miniaturization of EC Soft goods lab; thermoplastics capability should be able to fabricate inflatables, flexible tubes of varying diameters, patches, seals, etc.; sewing shop should be able to fabricate suit replacement segments, rebuild gloves, repair boots, fabricate IVA clothes, cargo bags, curtains, etc.	1F/2

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Gold – don't preclude
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HESTIA simulation of a Mars surface habitat

Functional Category	Crew Function	Description	HESTIA Suggestion	Function Location (3'o clock = dust porch
	Structural Maintenance, Repair, and Fabrication	Corrective action to diagnose and restore degraded functionality of structural components or produce new/replacement items	Basic metal and plastics machine shop capabilities, including metal bending, rolling, cutting (sheet, bar stock, tube, etc.) grinders, saws.; 3D printing (metal and plastic); lathe and mill; small IVA welding (larger welding capacity EVA)	1F/2
	Software Maintenance, Repair, and Fabrication (Coding, CAD, Diagnostics, etc.)	Corrective action to diagnose and restore degraded functionality of software modules or produce new/replacement code	High performance CAD and computaitonal analysis workstation; software integrated development environment (IDE), hardware/avionics integration (miniature SAIL-like capability)	1F/2
Commanding	Subsystems Access and Control	Crew member commanding and monitoring access to spacecraft subsystems	Include dedicated displays and crew interfaces; should facilitate 1 and 2-person operation and allow 4 crew to observe at same time.	2F/6
	Spacecraft Piloting - don't preclude	Crew member manual or supervisory piloting of mobile spacecraft assets	Should not conflict with robotic asset operation; usage may include Hab control of nearby MMSEV or ATHLETE, or remote checkout of MAV, taxi, or Mars Transfer Vehicle	2F/6
	Activity Planning/Scheduling	Onboard crew planning or scheduling of human or robotic tasks	Does not need to be a dedicated station - could pull up from any computer interface	2F/2
	Teleoperations, Robotic Supervision, and Remote Commanding - don't preclude	Crew member teleoperated or supervisory control of robotic or other remote assets	Similar to piloting station, but capable of monitoring of swarm robotic assets (e.g. multiple robots in parallel)	2F/6
Translations	Cargo Transfer to/from Visiting Vehicles or Attached Modules - don't preclude	Cargo Transfer across exterior pressure vessel hatches to/from Visiting Vehicles or Attached Modules, inclusive of hatch size, placement of open hatches, hatch operation, and visibility across hatches	Accommodate 2 docked logistics modules at all times. Hatch size should maximize cargo transfer efficiency - recommend 40x60-inch as minimum hatch size. If connecting tunnel is greater in length than side-step length, tunnel height should be same as cabin deck.	1F/3
	Crew Transfer to/from Visiting Vehicles or Attached Modules - don't preclude	Crew Transfer across exterior pressure vessel hatches to/from Visiting Vehicles or Attached Modules, inclusive of hatch size, placement of open hatches, hatch operation, and visibility across hatches	Accommodate 2 docked MMSEVs at all times. Hatch size should accommodate pressurized suited crew transfer, including one crew member carrying incapacitated crew member - recommend 40x60-inch as minimum hatch size. If connecting tunnel is greater in length than side-step length, tunnel height should be same as cabin deck.	1F/3
	IVA Crew Translation	Crew translation from point to point within the pressure vessel, including across interior hatches, between workstations and subsystems, and past other crew members and cargo	Translation space should accommodate suited crew member carrying incapacitated crew member; all interior vertical and horizontal hatches/doorways recommend 40x60-inch as minimum size.	ALL
	IVA Cargo Translation	Autonomous, teleoperated, and manual cargo translation from point to point within the pressure vessel, including across interior hatches, between workstations and subsystems, and past other cargo and crew	Accommodate transfer of largest IVA inert item (e.g. rack, machinery, pallet, robonaut, etc.); for all interior vertical and horizontal hatches/doorways recommend 40x60-inch as minimum size.	ALL
	IVA Restraint and Positioning Aid	Rails, tie downs, manipulators, seats, foot straps, thigh bars, enclosures, and other devices to aid in translation, positioning, or restraint of crew or cargo	Mars gravity calls for use of seats for crew; rails, tie downs, manipulators, and other devices may be required for cargo	WINCH INSTALLED
	Cargo Staging / Configuration / Sorting / Assembly	Temporary positioning of cargo items for sorting, assembly, rearrangement, or preparation to transfer to other locations	Strategically reserve open floor space near key translation points. Airlock, docking hatches, vertical translations are primary examples.	1F/3
	Crew Access to Workstations/Crew Stations	Physical access to spaceceraft facilities designed for crew use	Reserve operator volume that does NOT protrude into translation paths	1F/9-3 2F/C9 2F/C6 2F/2
	Crew Access to Subsystems Equipment	Physical access to spacecraft subsystem components	Reserve access volume behind/around equipment for cables and other ducting/plugs as well as access volume to install/remove and inspect subsystems	1F/C3 2F/C6 2F/C12 3F/C3 3F/C9
	Crew Access to Stowage	Physical access to spacecraft logistics stowage locations	Ensure sufficient room to not only access and remove/replace stowage items, but to also read labels and identify the proper stowage unit	ALL
	Crew Access to Trash/Waste	Physical access to spacecraft trash or waste containment locations	Consider logical trash locations to store small amounts of trash at point of use (e.g. 1-2 meals worth of trash in galley) and odor-controlled aggregation points for batch relocation of trash to logistics module	2F/C9

Spacecraft Habitation Crew Functions

Reminder: *Not all crew functions require dedicated workstations - some can be combined and some are accomplished with equipment items, while others may require multiple workstations and/or facilities. Mission duration and mission objectives drive degree*

Yellow – include
Gold – don't preclude
Red – assumed no room to include

HESTIA simulation of a Mars surface habitat

Functional Category	Crew Function	Description	HESTIA Suggestion	Function Location (3'o clock = dust porch
Mission Operations (Assume EVA is part of mobile asset or other chamber)	IVA Support of EVA Crew - don't preclude	IVA crew member monitoring and communication with EVA crew	Does not need to be a dedicated station - could pull up from any appropriate computer interface	1F/12-2
	EVA Suit Donning/Doffing	Physical environment for donning or doffing EVA suits	Dedicated area not inside the actual airlock volume	1F/3
	EVA Ingress/Egress	Access path and environment for crew member ingress and egress to the exterior space or planetary environment	Could be internal or external airlock; aluminum or inflatable	1F/3
	Life Science Research (plant, animal, human, cellular, microbiology, etc.) - as required by HRP	Research related to life science disciplines including plant, animal, human, cellular, microbiology, and related domains	Study needed to determine appropriate number of workstations given crew size; approximately 7 ISPR-equivalent gives broad range of life science capability	1F/3
	Physical Science Research (physics, chemistry, metallurgy, geology, etc.) - don't preclude	Research related to physical science disciplines including physics, chemistry, metallurgy, geology, and other physical domains	Study needed to determine appropriate number of workstations given crew size; approximately 8 ISPR-equivalent gives broad range of life science capability	1F/11
	Earth/Planetary and Space Science Research (meterology, astronomy, etc.) - don't preclude	Research related to space, earth, an dplanetary science disicplines including meterology, astronomy, and other related domains	Study needed to determine appropriate number of workstations given crew size; approximately 1 ISPR-equivalent gives broad range of Earth/space/planetary science capability	OUTSIDE
	Technology Testing Research	Research related to testing of technologies including spacecraft subsystems, robotic systems, and other engineered devices or locally fabricated items	May be able to co-locate with maintenance and repair capability; might require some additional hardware/tools	1F/2
	Crew Training	Individual and group crew member training and evaluation activities	Does not need to be a dedicated station, but may require deployable panels (e.g. Orion mockup for crew training)	2F/6
Logistics	Frequent Access Stowage	Stowage of items designed to facilitate frequent crew member access	Consider logical stowage locations to store reasonable amount of supplies at point of use (e.g. 1-2 weeks of food in the galley)	ALL
	Infrequent Access Stowage	Long term stowage not intended for regular crew member access	Consider larger pantry stowage at strategic/architecturally sound locations (e.g. a food stowage wall in a corridor with 3 months food)	1F/TOP
	Cold Stowage	Stowage of food, science, or other items within specified temperature ranges	May need to store half or more of surface food supply in refrigerated or frozen form; may need to refrigerate or freeze fresh food; may need separate system to preserve life science and physical science (e.g. ISRU) samples	2F/C6
	Trash and Waste Accommodation	Stowage of trash or waste items	Include treatment for biologically active trash and waste	2F/C9
	Inventory Management	Manual and automated tracking of all portable items in the spacecraft	Include design of RFID readers, machine vision, or other technologies into the spacecraft architecture	2F/C12
Planetary Protection	Equipment / Sample Sterilization	Capability to sterilize equipment or local samples intended to be introduced into the ambient spaceraft environment	Incorporate into airlock or vehicle exterior	1F/3
	Equipment / Sample Isolation	Capability to isolate eqipment or local samples to prevent their introduction into the ambient spacecraft envrionment	Include transfer devices, bags, glove boxes, or other appropriate provisions	1F/10-11
Integrated Outfitting	Vehicle Lighting	Interior and exterior spacecraft ambient and task lighting	Maintain keep out zones for lighting; proper lighting intensity and mix of fixed general vs. task vs. portable lights. Exterior should also include navigation lights, searchlights, and beacons.	ALL
	Radiation Protection - don't preclude	Protection from radiation sources, including ambient solar, SPE, GCR, and radiation emitted by samples or spaceraft equipment	May include localized protection within workstations, spacecraft closeouts, and/or surface features/terrain	2F/ALL
	Odor Control	Isolation, containment, or removal of odors from the spacecraft cabin environment	Capability should exist throughout the spacecraft, not just in trash storage enclosures and hygiene crew station	PRE-INSTALLED
	Intervehicle ventilation	Circulation of breathable cabin atmosphere	Consider vent and ducting design as part of cabin layout	PRE-INSTALLED
	Acoustic control and adsorption	Maintenance of acoustic environment within tolerable levels	Look at separation of quiet and noisy activities, acoustic blankets, etc.	
Emergency Operations - ground based & some Mars scenarios	Fire Response - don't preclude	Fire detection and location, fire suppression, personal protective equipment, and post-fire recovery	Recovery may imply ability to isolate certain sections of the habitat from primary cabin air loop	PRE-INSTALLED
	Toxic Atmosphere Response - don't preclude	Toxin detection, removal, personal protective equipment, and post-incident recovery	Recovery may imply ability to isolate certain sections of the habitat from primary cabin air loop	PRE-INSTALLED
	Cabin Depressurization Response	Depressuization detection, leak location, leak repair, personal protective equipment, cabin repressurization, and post-incident recovery	Cabin design must include ability to treat leak at any location on the pressure vessel and docked assets; may include both temporary and permanent repairs.	IMMEDIATE DEATH
	Radiation Event Response	Radiation detection, shelter protection, personal protective equipment, and post-incident recovery	Determine if SPE shelter is needed or not as well as other radiation monitoring approaches	2F/ALL
	Crew Fatality Response	Personal protective equipment, deceased crew member containment and isolation	3 body bags (crew size minus 1) must be stowed somewhere in vehicle; identify where bags would be placed if used; consider associated PPE, labels, etc.	1F/TOP
	Spacecraft Evacuation	Evacuation visual and auditory cues, crew member location and tracking, spacecraft safing for uncrewed operation, and post-incident recovery	Consider steps and actions to abandon Mars surface outpost; include habitat safing needed to enable reentry by current or recovery crew	1F/3