Spacecraft Habitability (part 3)

- Case study: Minimum Functional Habitat Element
- Case studies: SSL habitat research
- Case studies: analogue habitats

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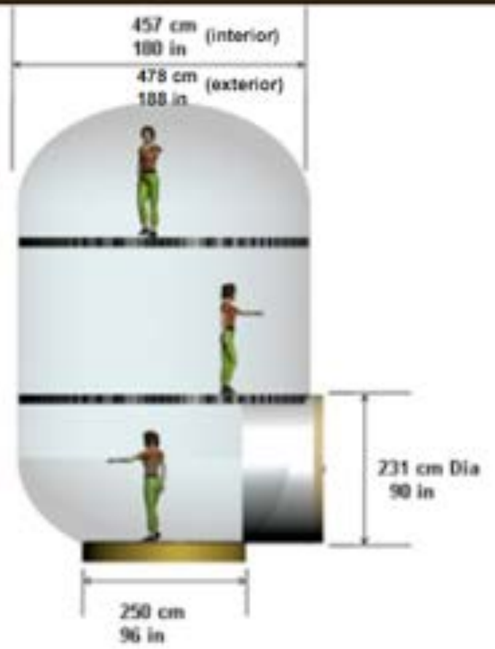
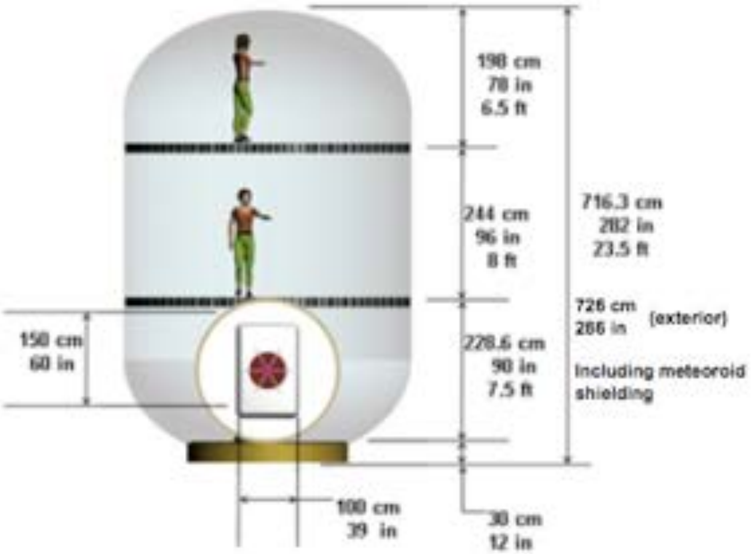
http://spacecraft.ssl.umd.edu

Minimum Habitat Functional Element Study

- NASA study 2009-2010 with three awards
  - Consortium led by Boeing
  - Consortium led by ILC-Dover
  - University of Maryland
- Focus on the design of a four-person lunar habitat module
  - 30 day duration
  - Capable of resupply and extended use
  - Part of Constellation architecture (i.e., power/comms available externally)

Boeing Integrated MFHE Concept
PILL - Pressurized Interim Lunar Lodge

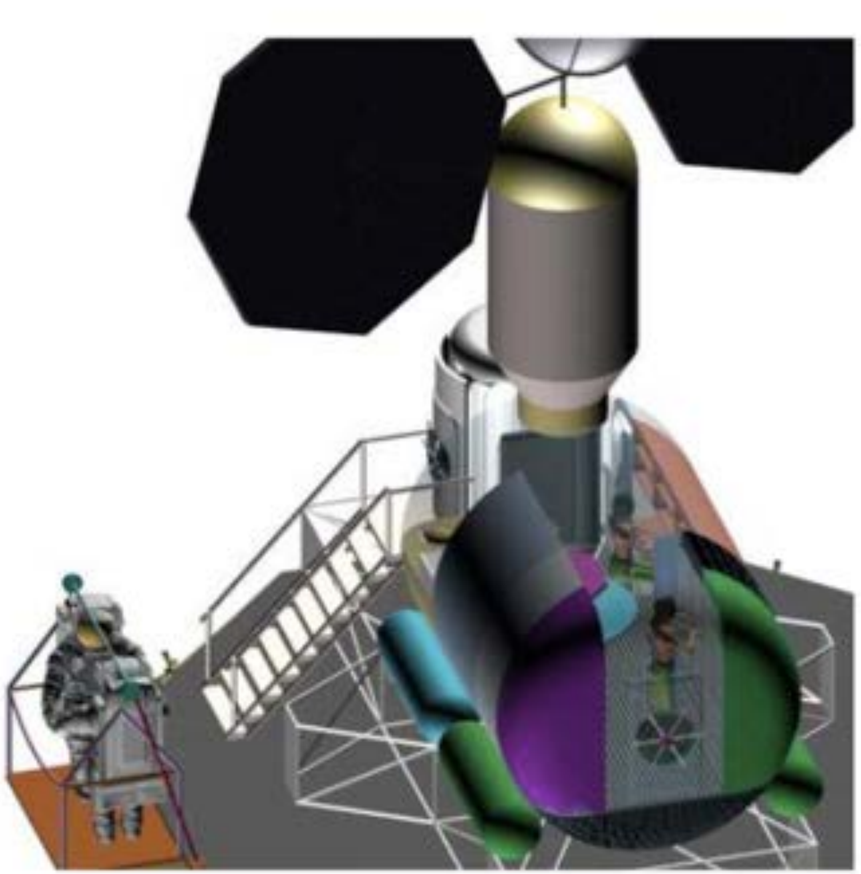


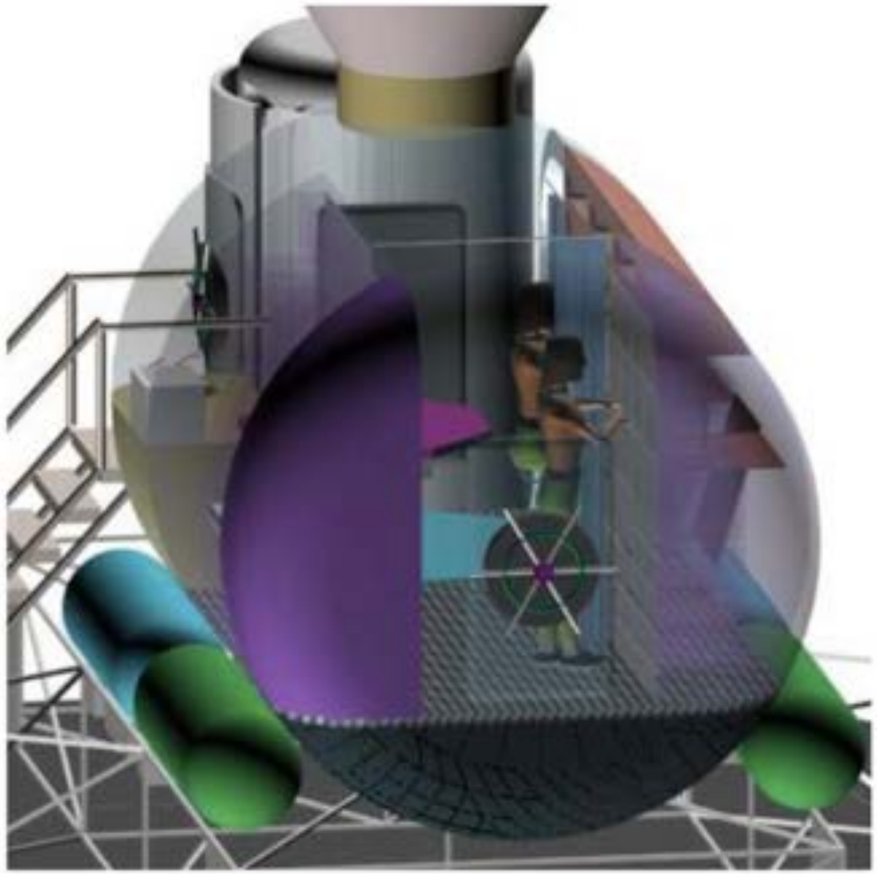


- One primary and two ancillary floors
- 78 m^3 habitable of 121 m^3 total pressurized volume
- 28 m^2 open of 35 m^2 total floor area
- 457 cm (15 ft) diameter with 228.5 cm (7.5 ft) ceiling
- Entry foyer on lowest floor; Sleeping on upper floor

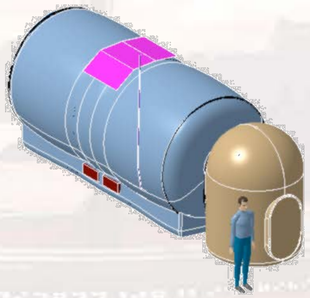
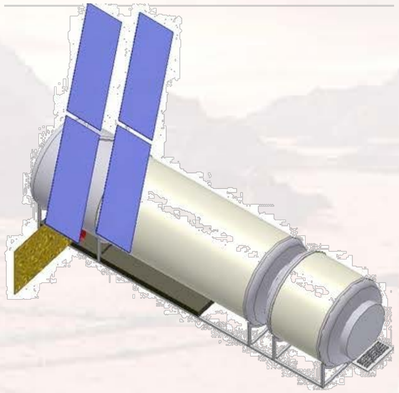
Baseline MFHE

3.0 m Diameter x 4.5 m Long MFHE

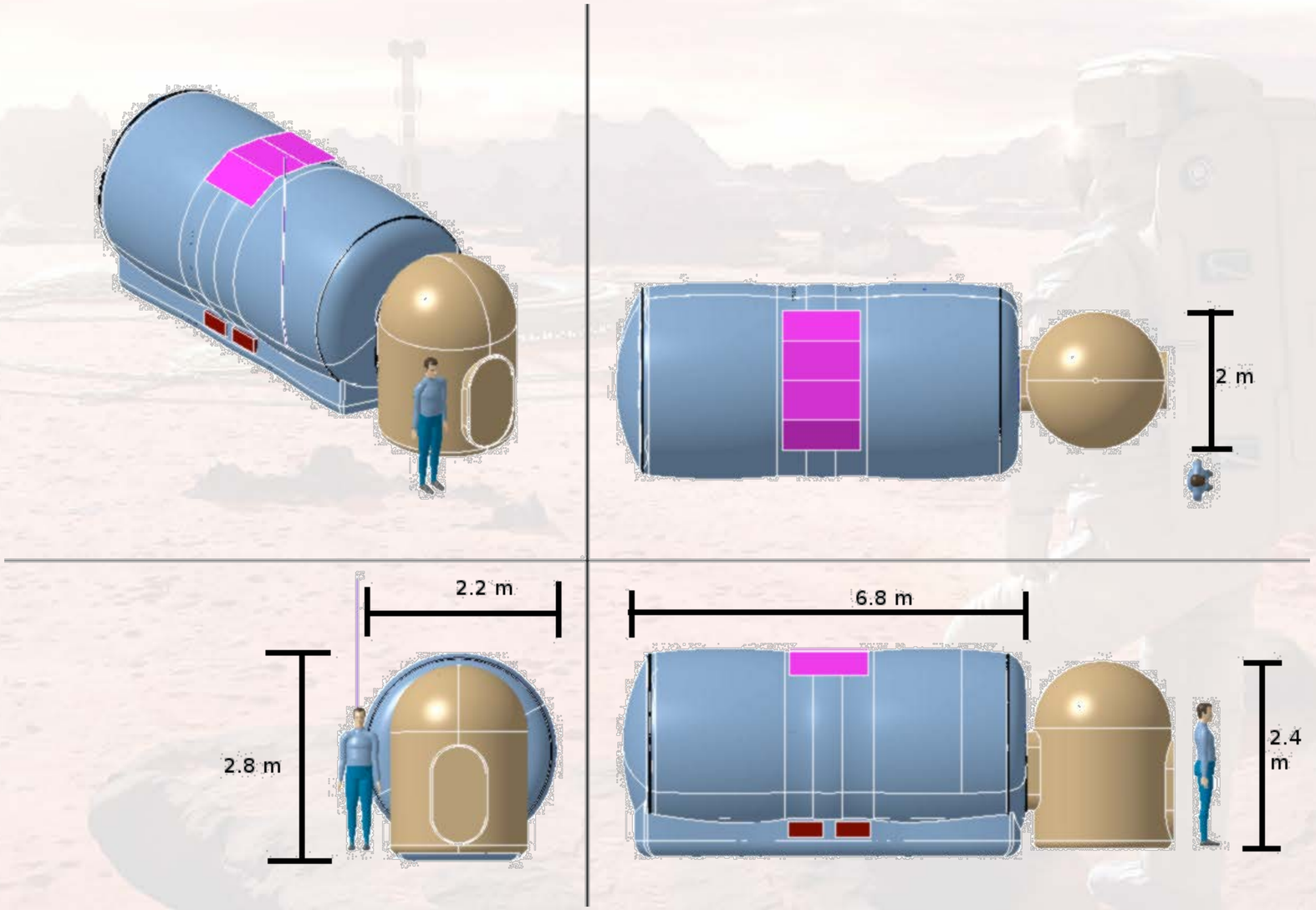




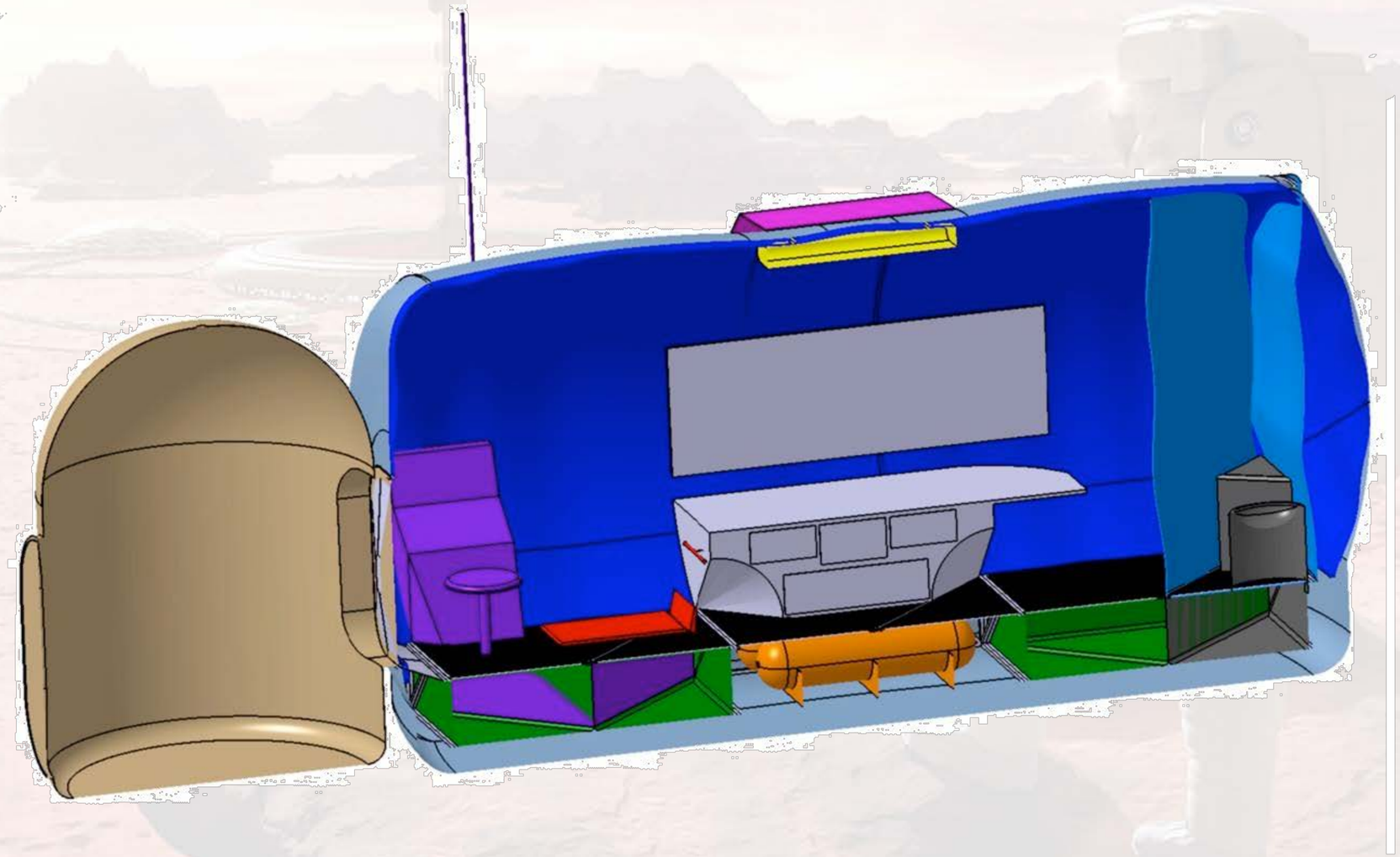
UMd Design Space Subdivision

	Lunar Puptent	Winnebago	Igloo
Concepts			
Available Systems	None	Altair Lander	Outpost
Purpose	Standalone Contingency	Initial Exploration Outpost Expansion	Extended Crew (+4) Outpost Dependent

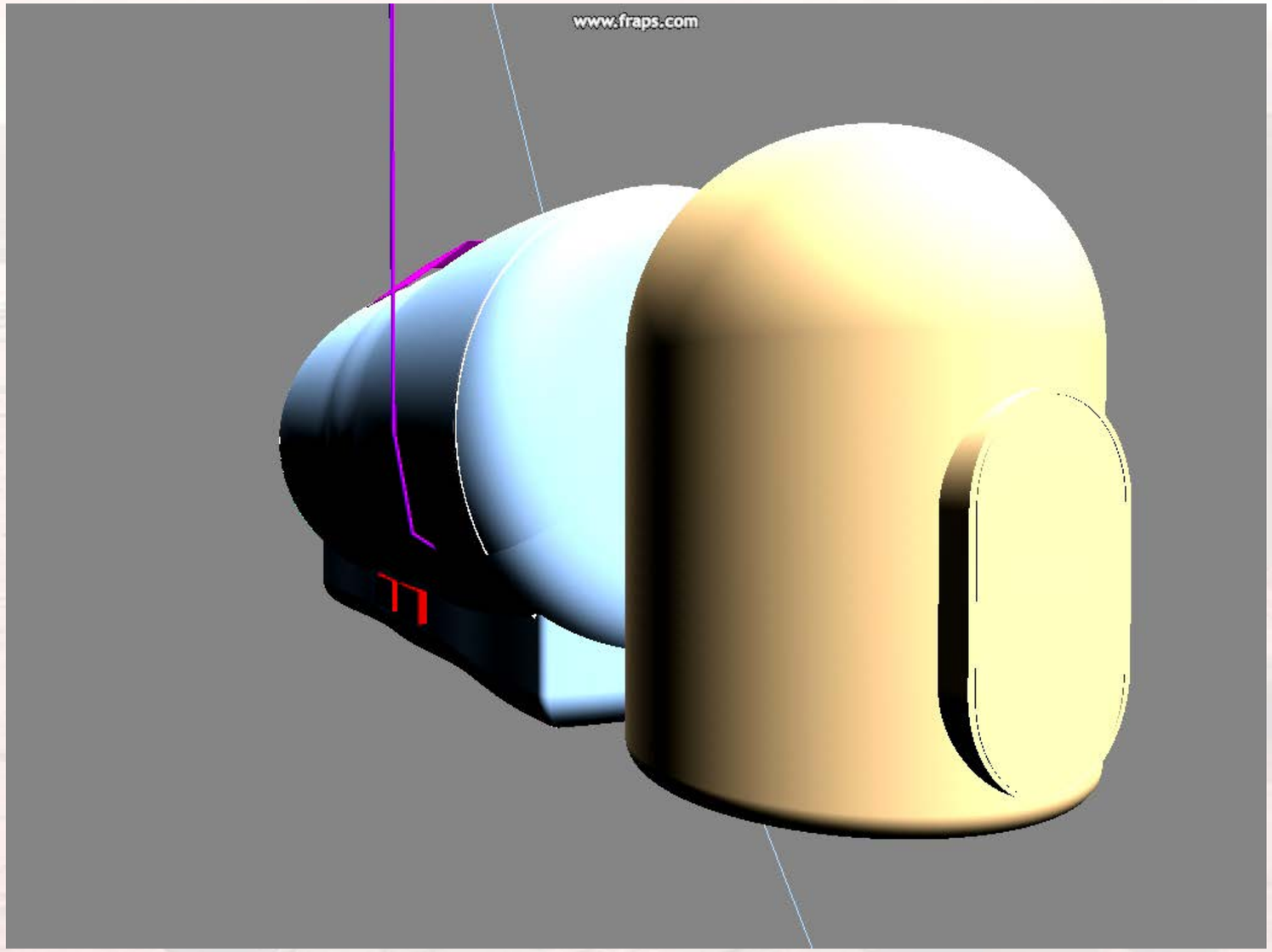
Exterior View



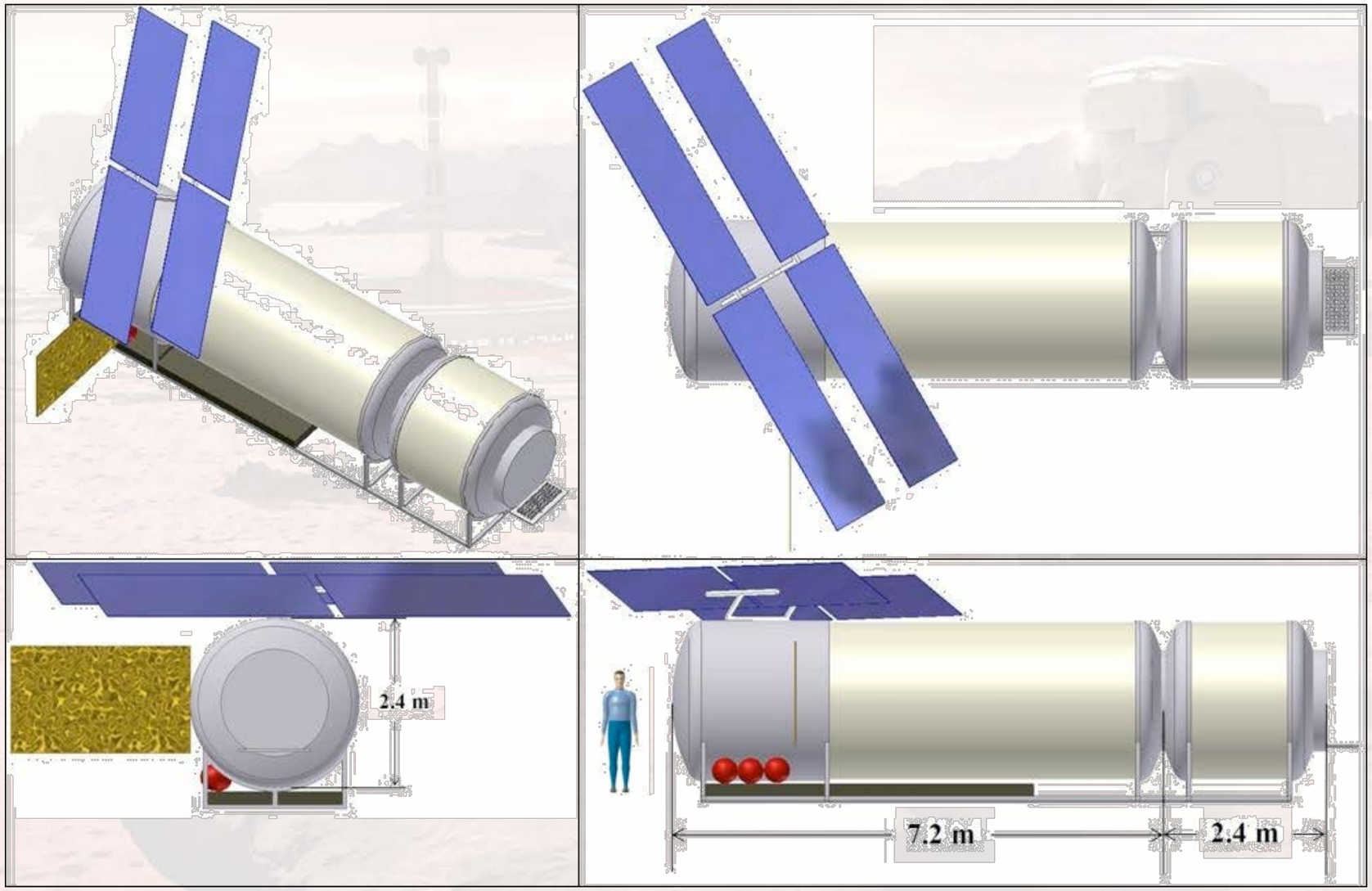
Interiors



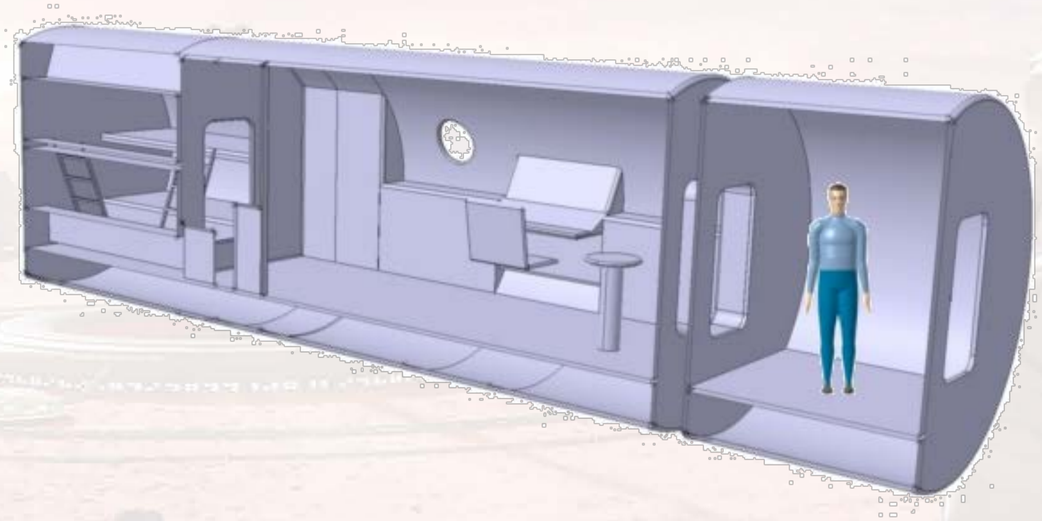
VR Walkthrough

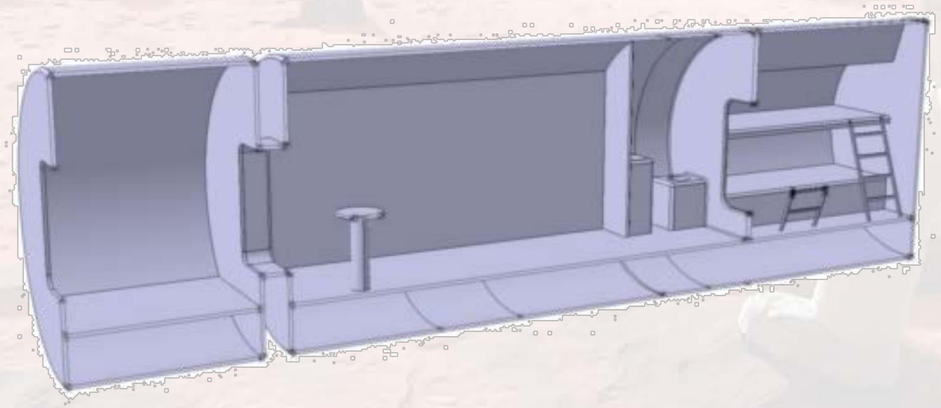


Exterior View

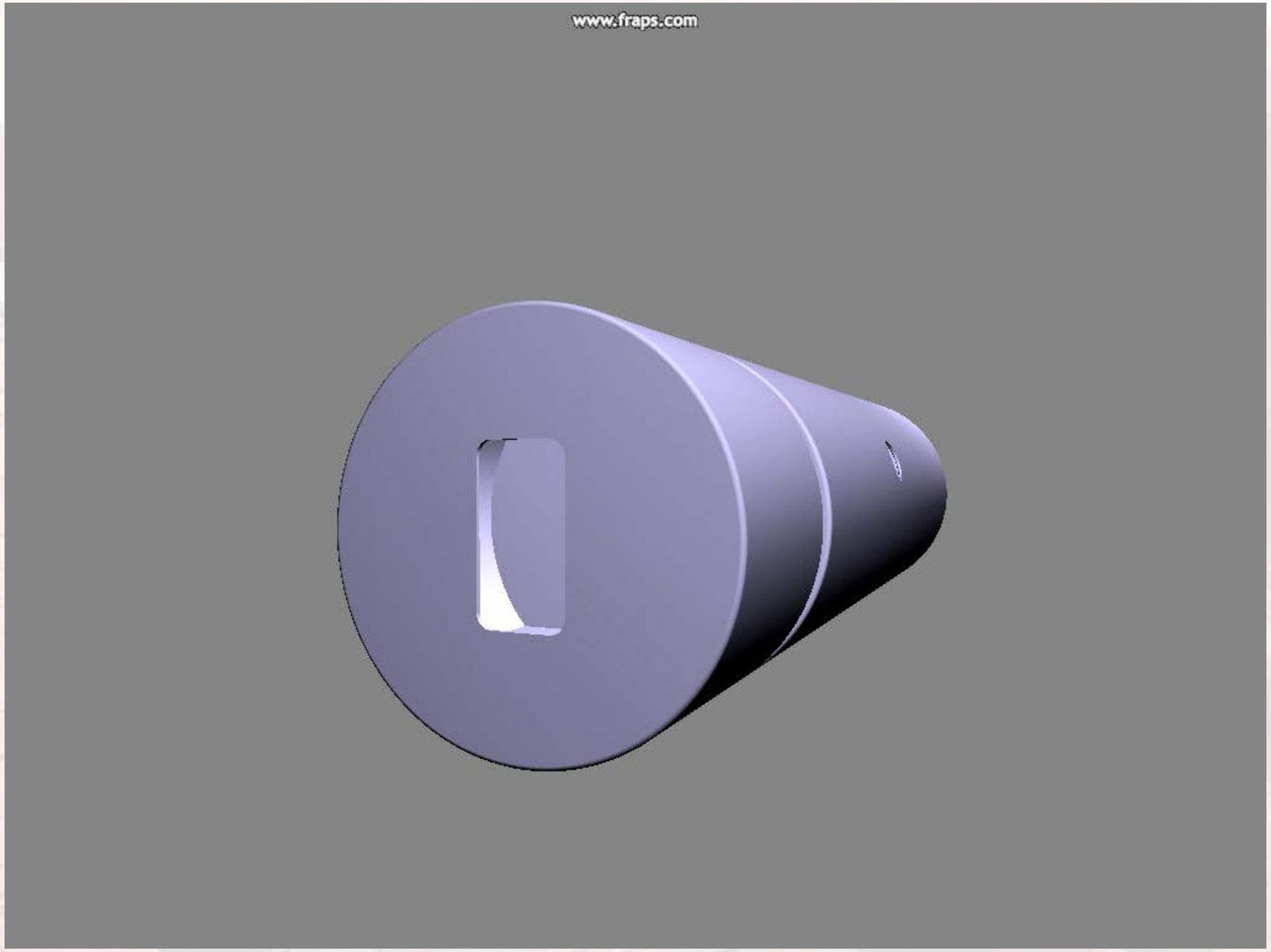


Interiors

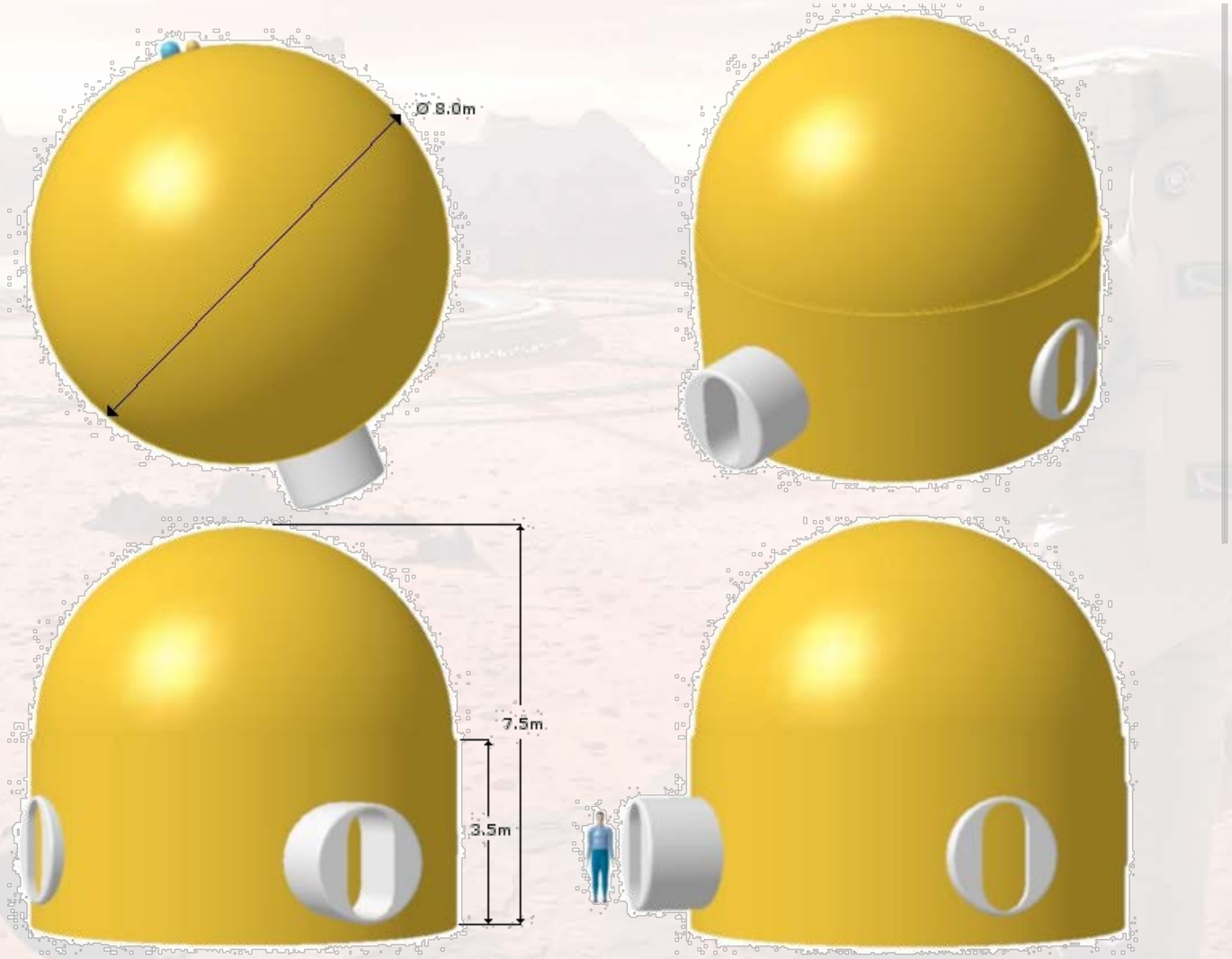




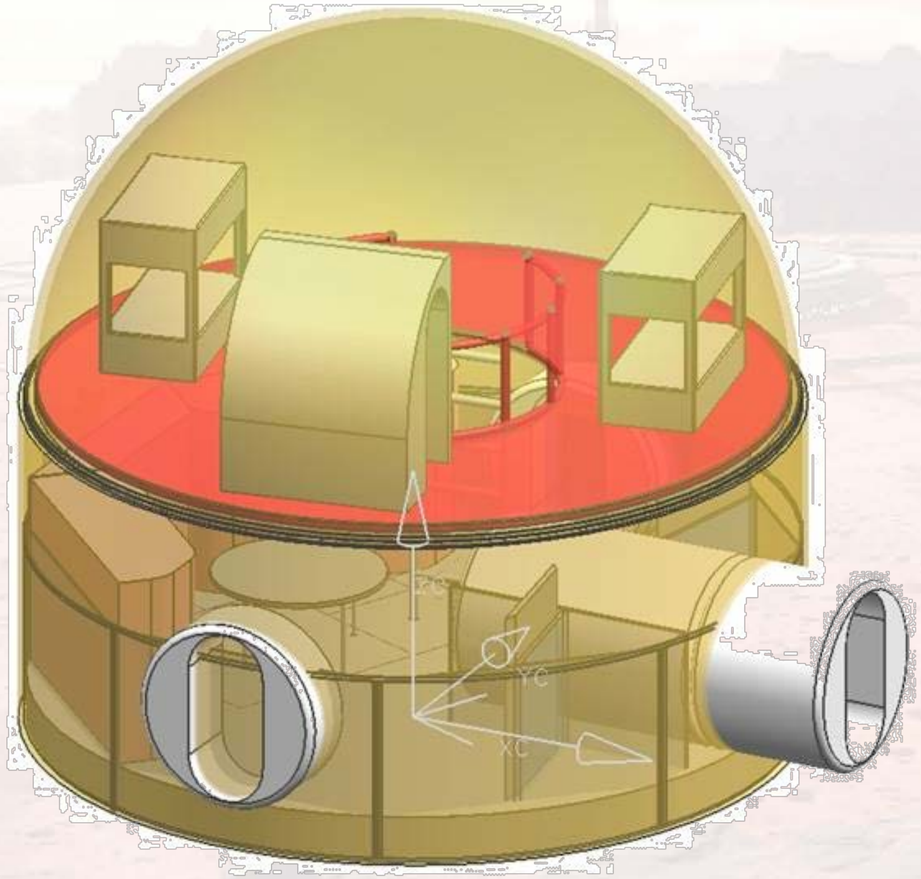
VR Walkthrough

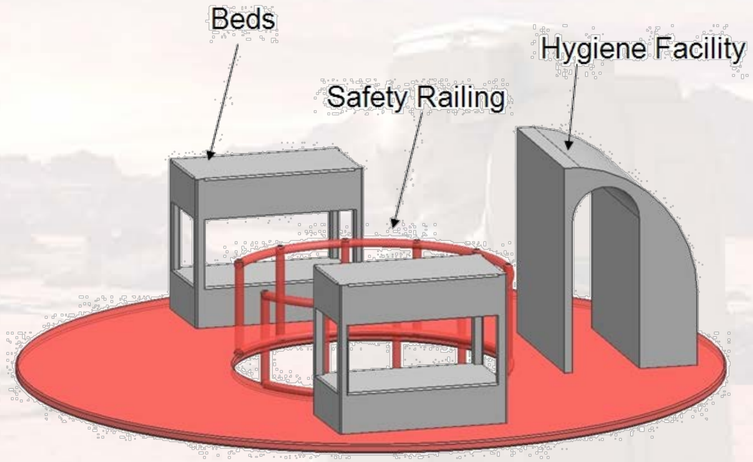


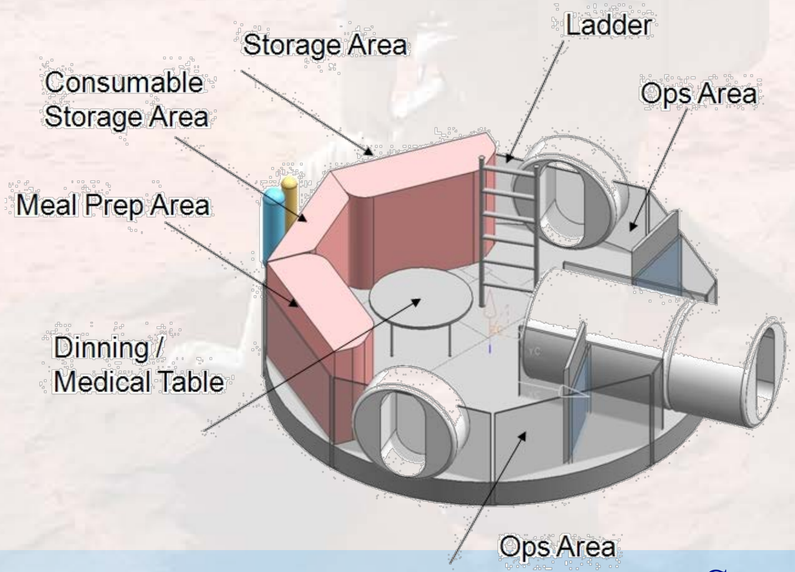
Exterior View



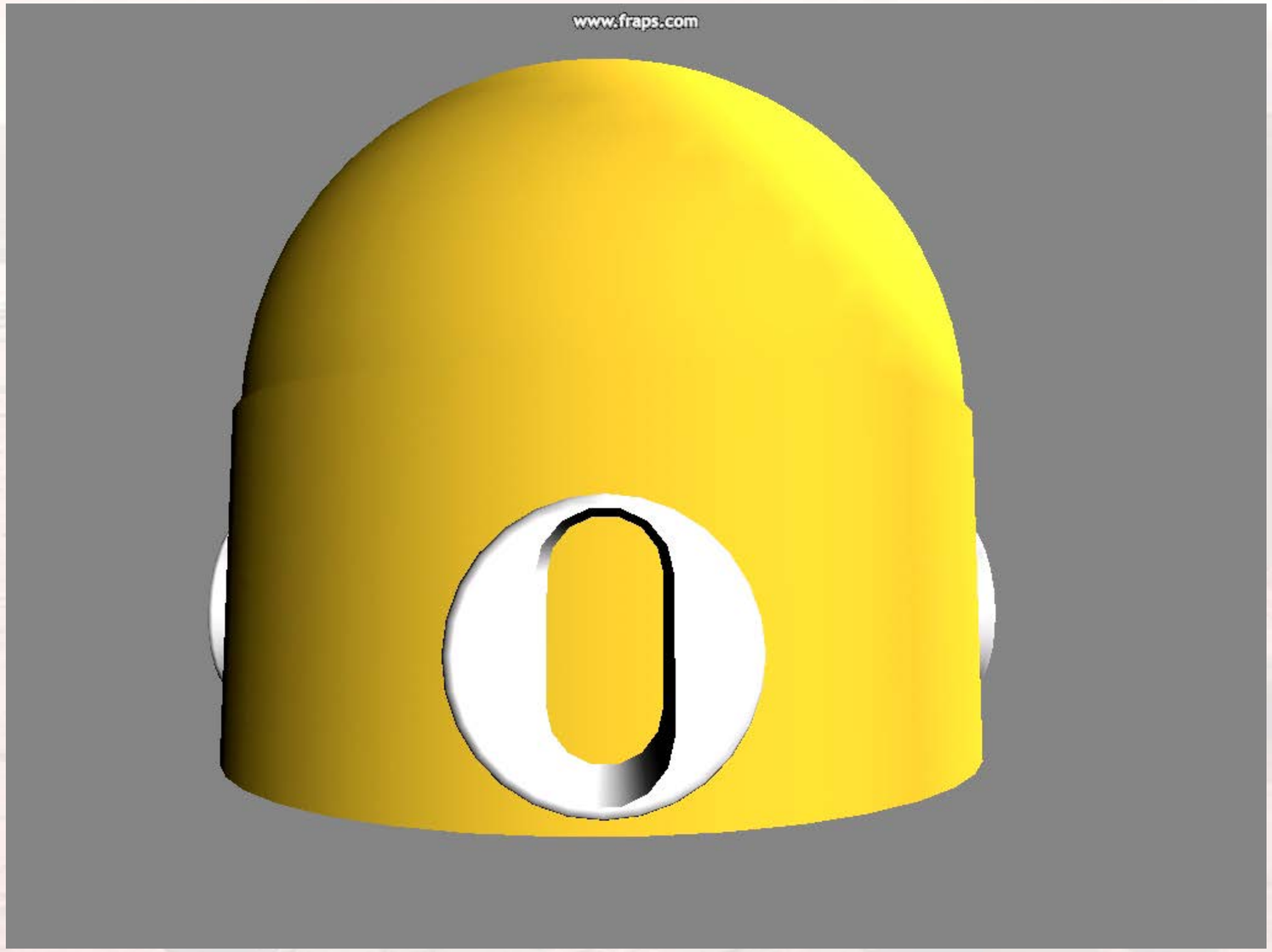
Interiors




Beds
Hygiene Facility
Safety Railing


Storage Area
Ladder
Consumable
Storage Area
Ops Area
Meal Prep Area
Dinning /
Medical Table
Ops Area

VR Walkthrough



Lessons Learned

- VR is a useful tool for rapid evaluation of concepts
- Accurate registration in the head tracking is fundamental
- Models must be very detailed in order to give a feel for the environment
- Simultaneous hand tracking is a very desirable feature
- Horizontal cylinders give a sense of tunnel vision
- Vertical cylinders allow for better floor space usage, but provide less wall area
- In vertical cylinders, vertical ladder should not be located in the center of the floor space

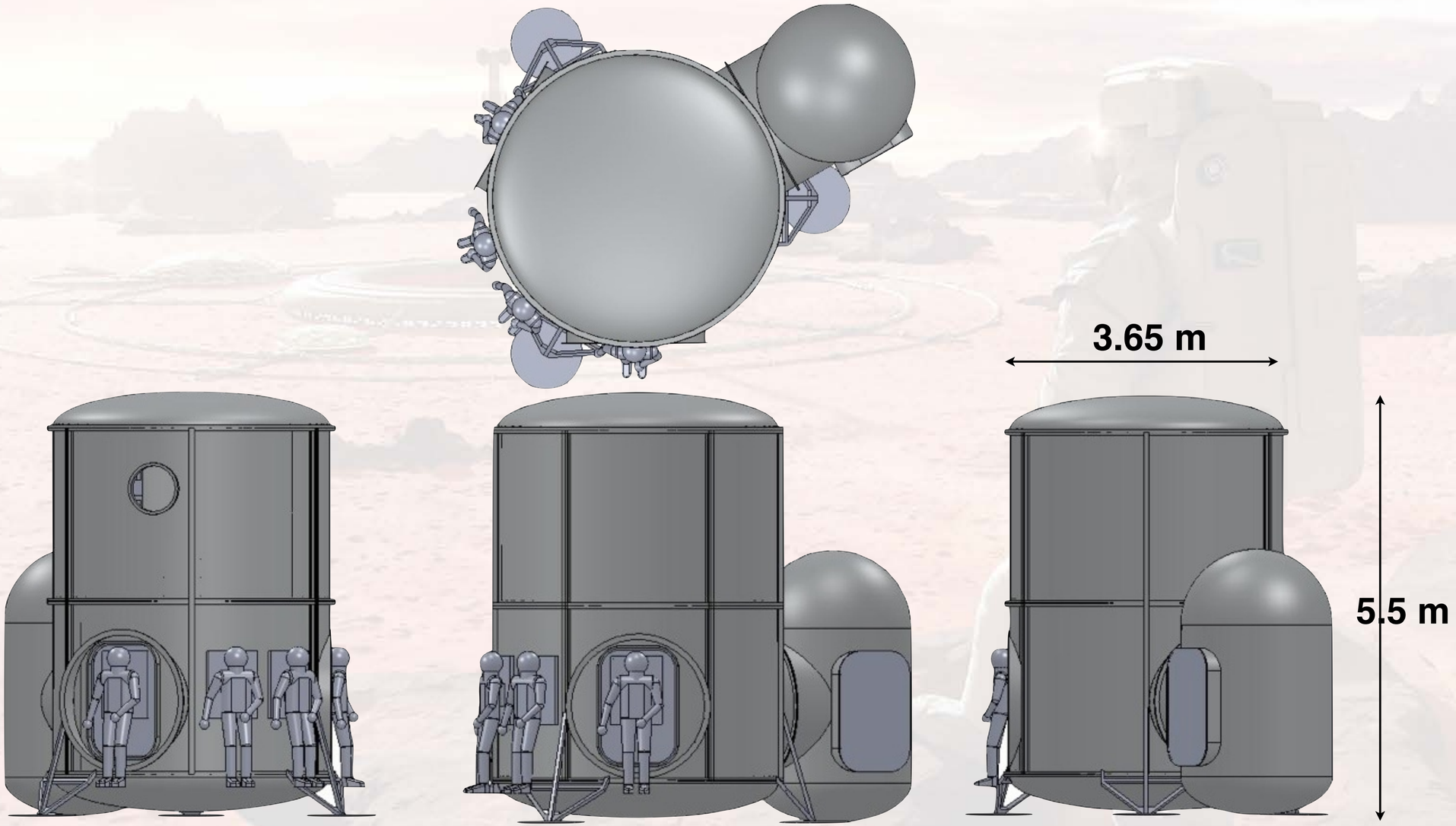
Conclusions From Trades and Designs

- Minimum functional habitat is feasible across the spectrum of possible designs
  - Inflatable
  - Horizontal cylinder
  - Vertical cylinder
- An MFH which meets the mass limitations of this study will be quite small
- Multilayer vertical configuration (clearly favored by parametric analysis) has much less design background (other than colonization concepts)
- Significant utility to a full-scale mockup for evaluation

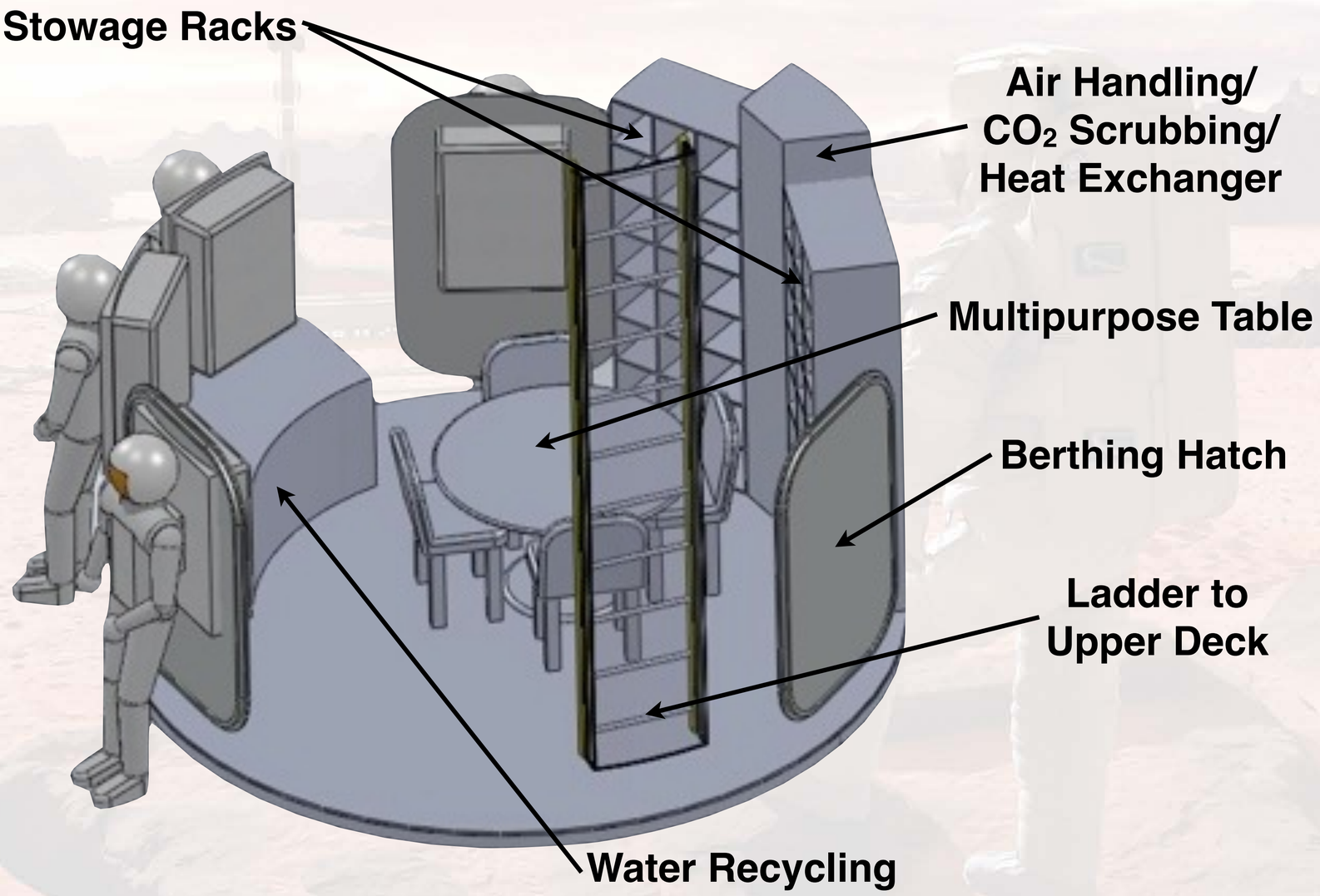
Development of Final Design

- Synthesis from preliminary designs, trade studies, virtual reality, and full-scale mockup tended to
  - 3.65 m diameter
  - Two full-diameter levels
  - Separation of operations and habitation functions
- Operational assumptions
  - Four suitports for nominal ops plus inflatable airlock
  - Premium on stowage, multipurpose space, functionality
- Design to MFH specifications for outpost; examine options in both growth (multihabitat) and isolated (self-sufficient habitat) directions

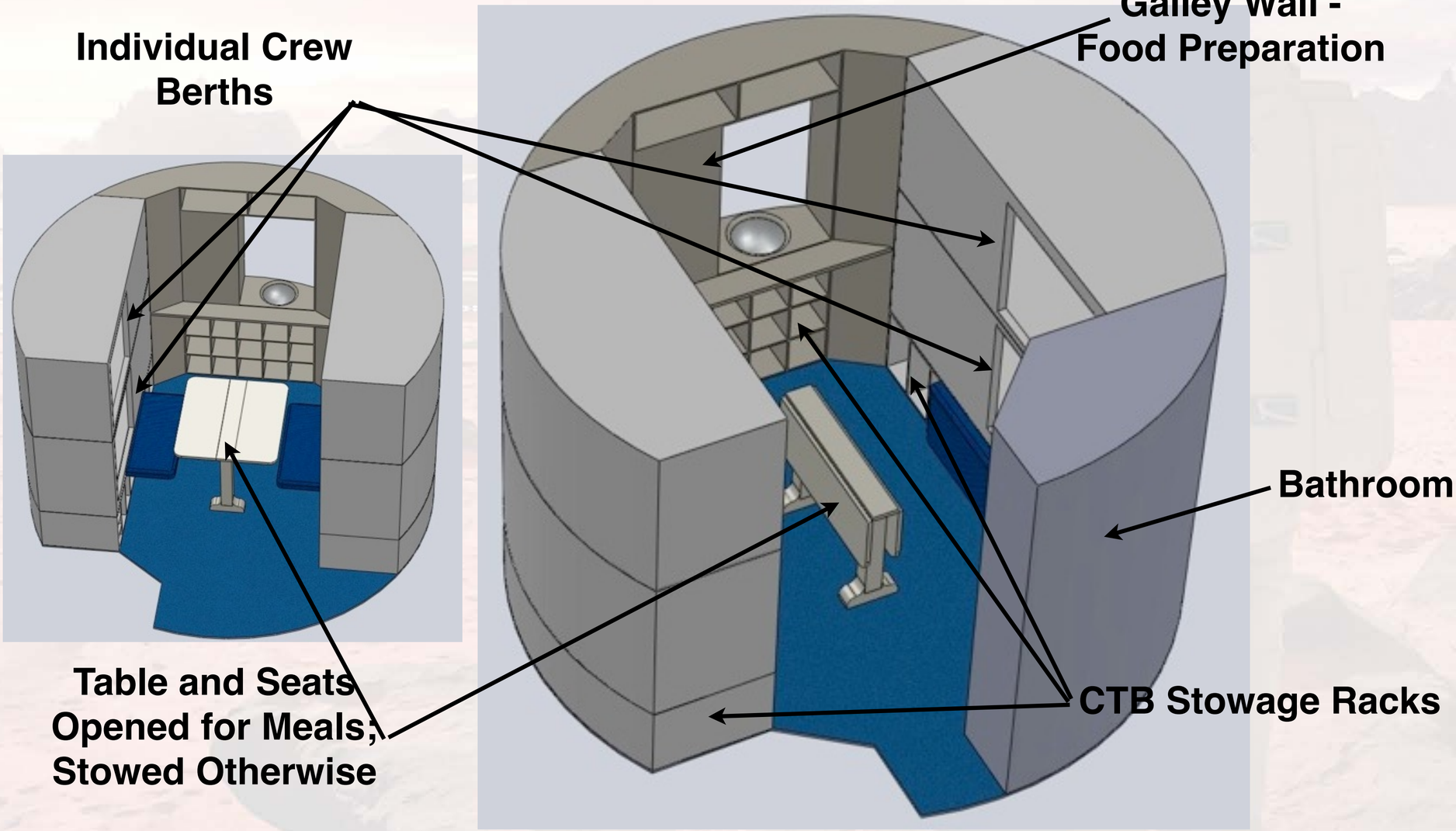
Habitat Orthogonal Views



Lower Deck Layout



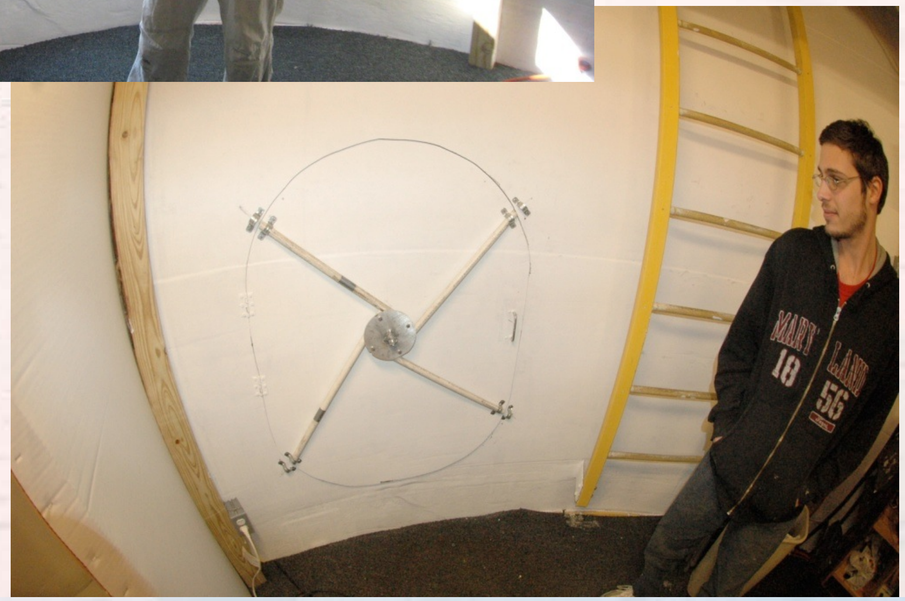
Upper Deck Layout



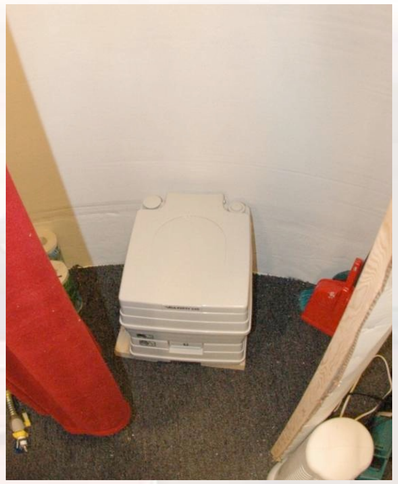
ECLIPSE Mockup – Main Structure

ECLIPSE Mockup – Main Structure

ECLIPSE Mockup - Interiors



ECLIPSE Mockup - Interiors



ECLIPSE Crew 1

UMd Final MFH Design

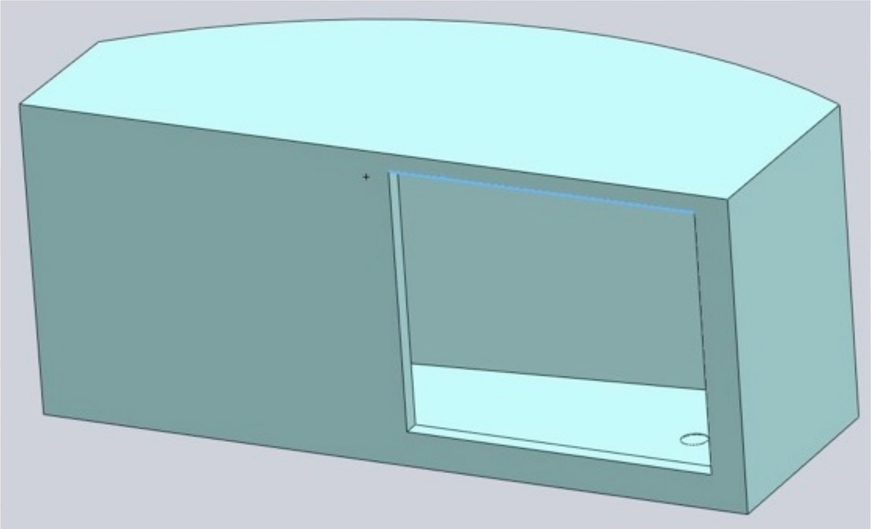
- 3.65 m diameter
- 5.5 m tall
- 4:1 ellipsoidal endcaps
- Three module berthing ports (Cx standard)
- Four suitports (two in berthing hatches)
- Inflatable airlock
- All 6063-T6 structure

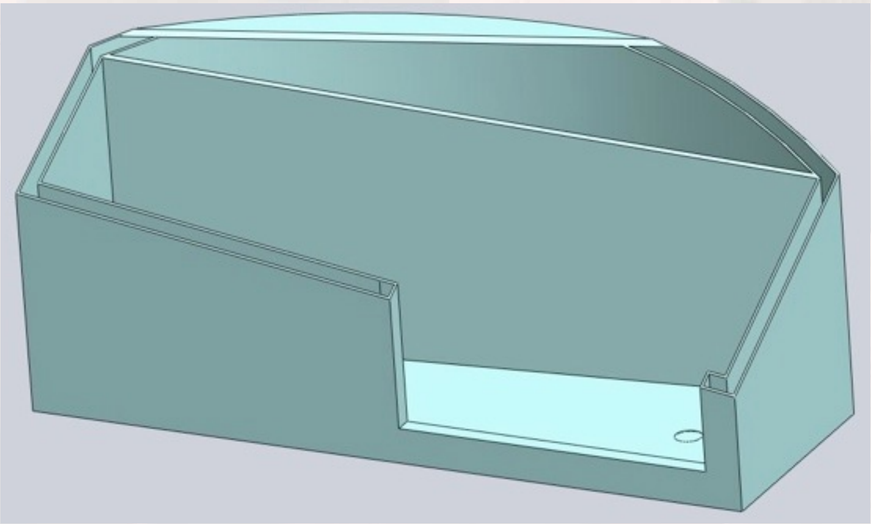
Lower Deck Layout

Upper Deck Layout

Crew Berths

- Personal sleeping berths
- Individual stowage for 6 CTBs and 0.24 m^3 of loose gear
- Water wall - 215 kg of water provides 5 gm/ cm^2 radiation shielding (polyethylene door not shown)
- Contingency waste management for 48 hours





Crew Berths

2011: X-Hab Inflatable Habitat

Interior Panoramas

1-G Testing: HAVEN Habitat

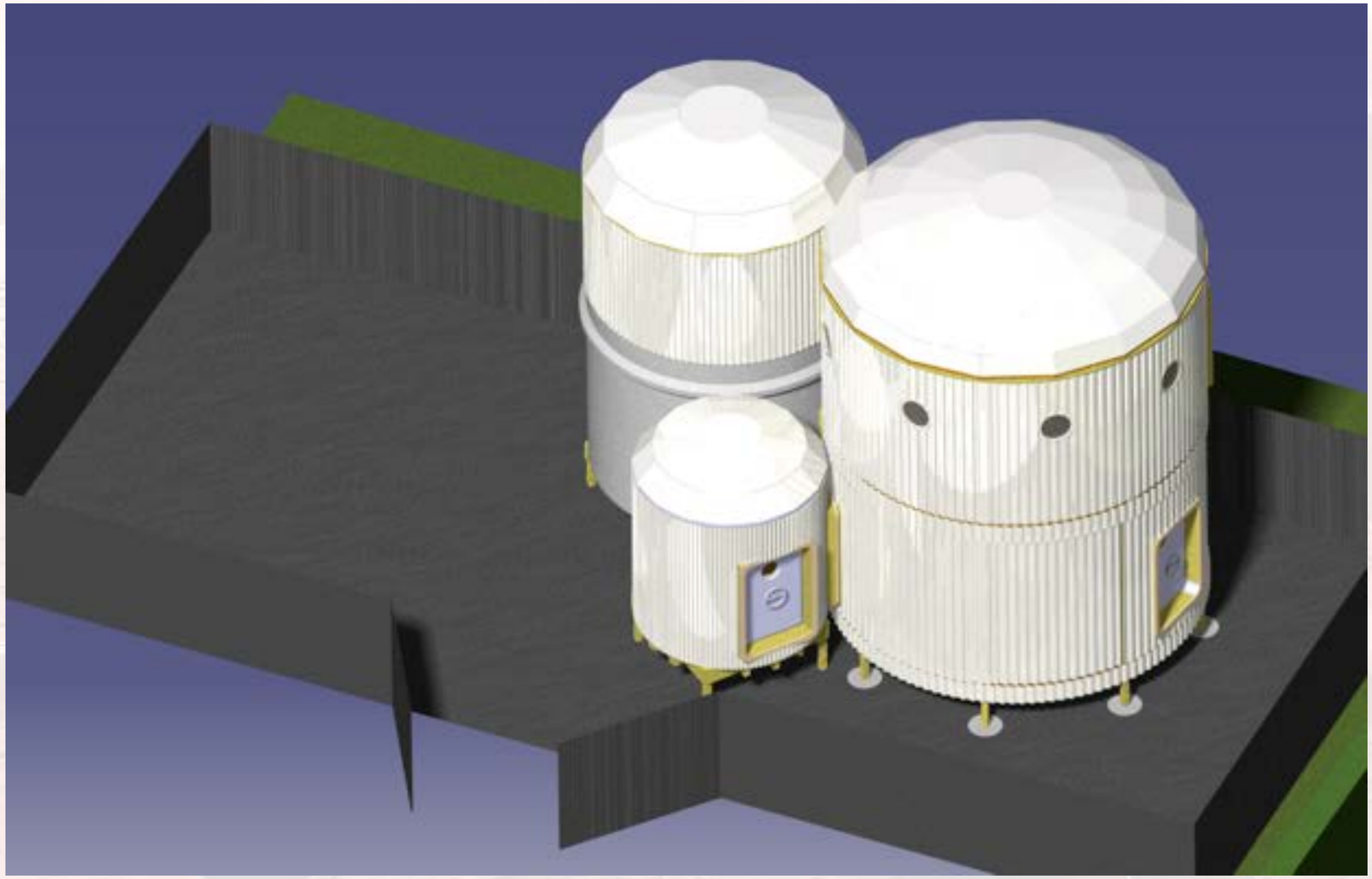
1-G Testing: HAVEN Module

- Two story habitat module (currently limited to one level)
- Modular removable wall sections (8x45° sectors)enable total reconfiguration of the habitat
- Multiple vertical hatch locations enables a wider variety of layouts to be implemented
- 5m outer diameter provides 20 m^2 floor area and 40 m^3 in current configuration; double if upper level is added

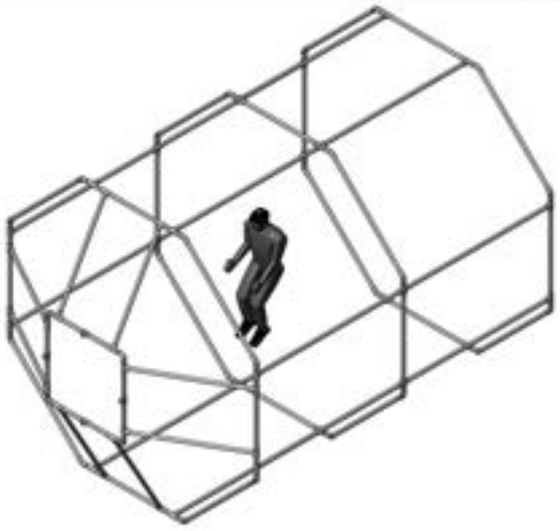
HAVEN Outfitting

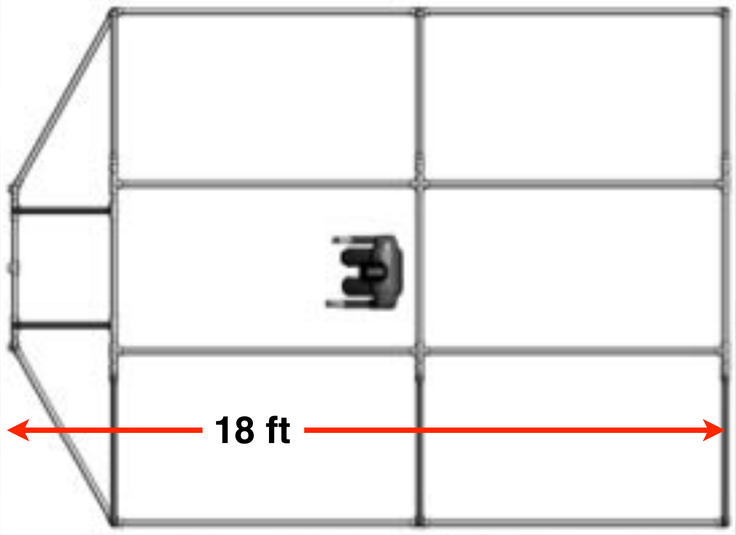
- HAVEN is designed to be highly modular and easily reconfigurable
  - Each interchangeable wall section is separately wired for power and lighting
  - Widespread use of pegboard panelling for quick additions of surface-mount items
- Designed with dual hatches to upper level (centerline and next to the wall) for comparison
- Potential access to storage volume between floor joists

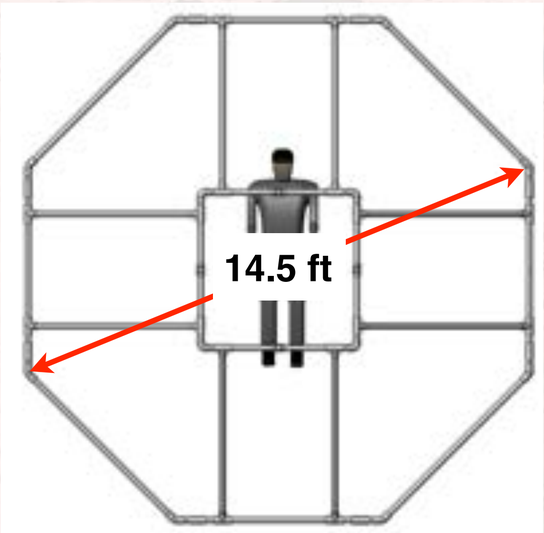
2012 X-Hab: CHELONIA Concept

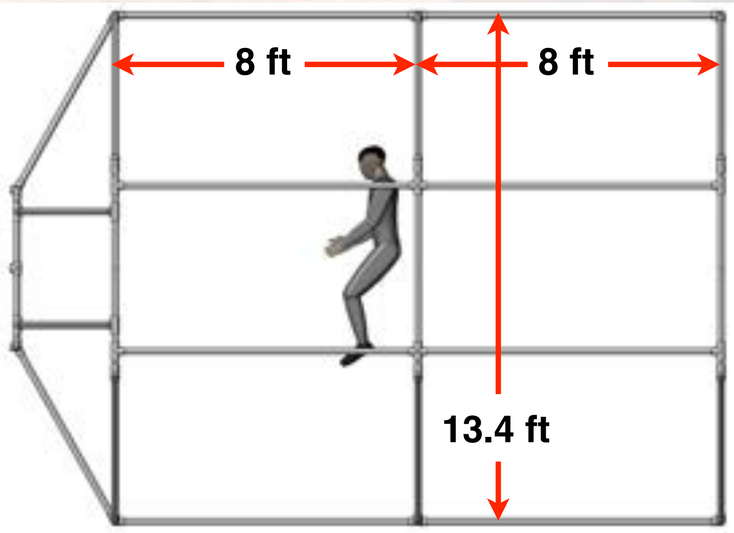


Underwater Habitat Three-View – 2014



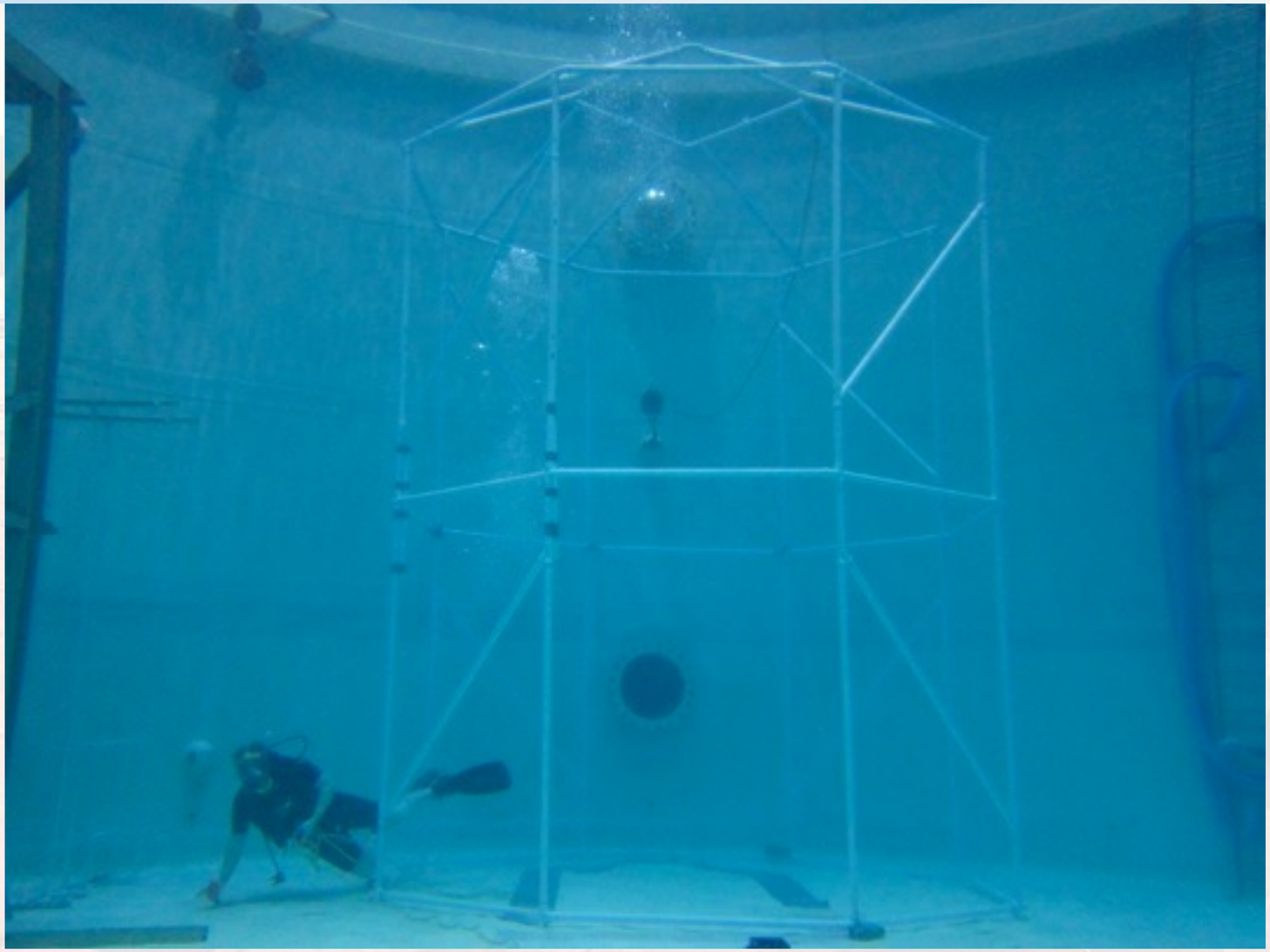




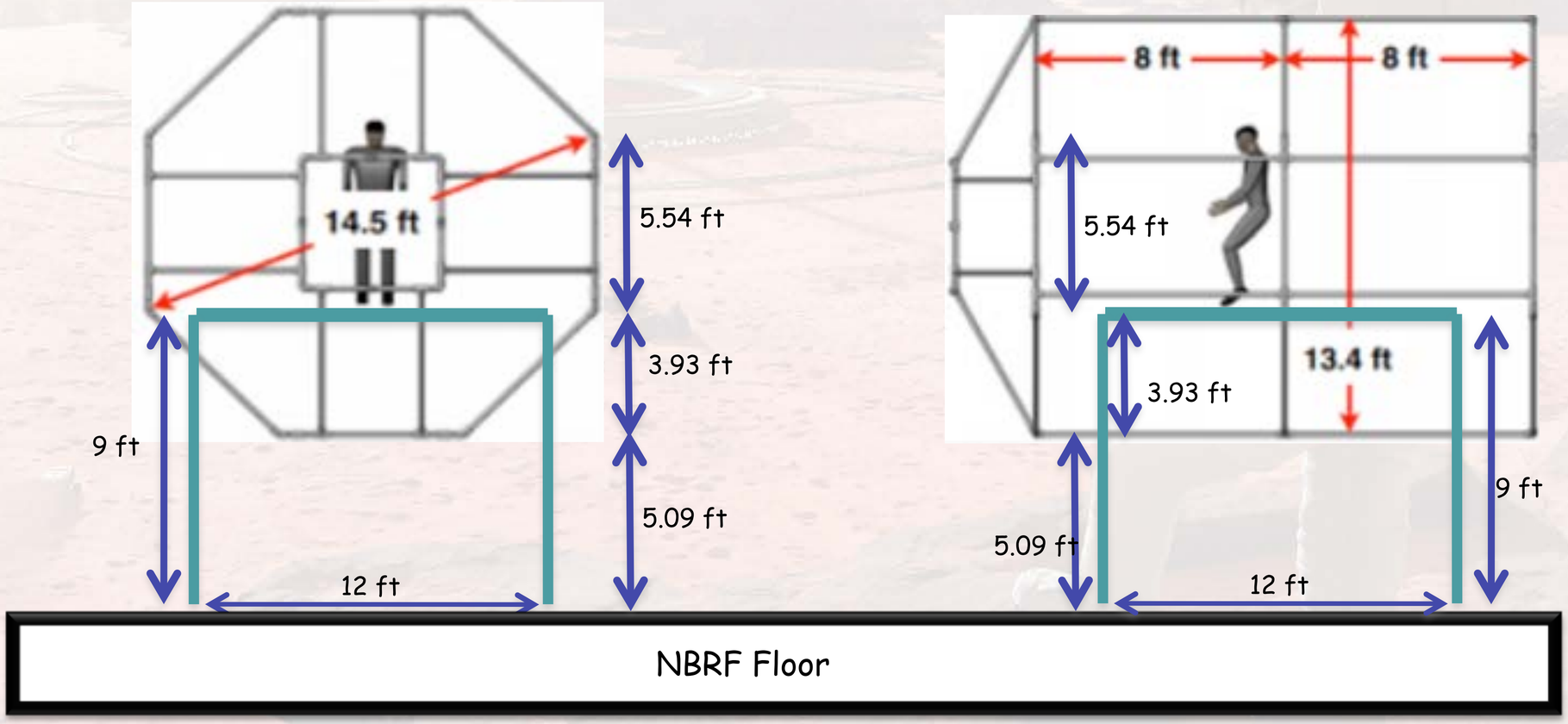


UW Hab Shell Construction

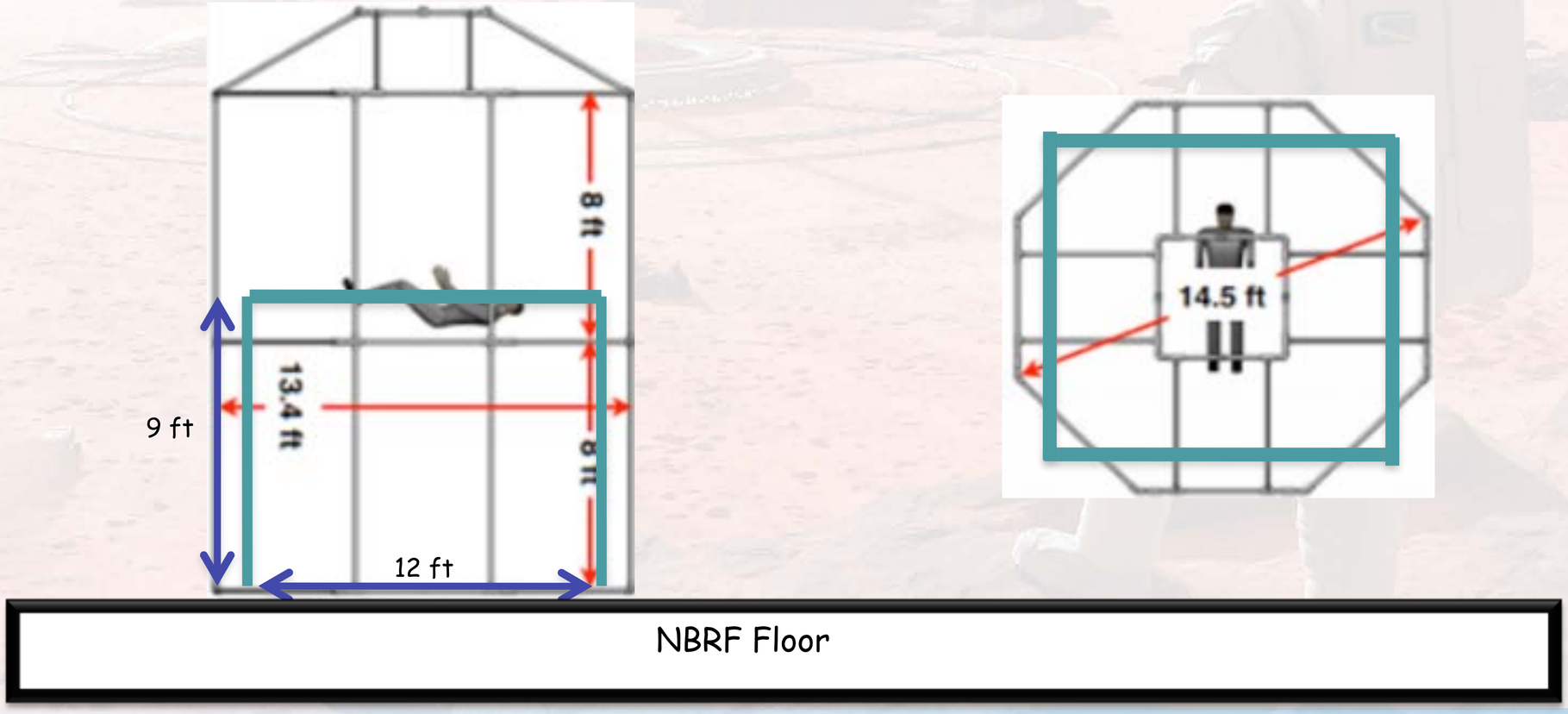
Habitat Envelope in Neutral Buoyancy Tank



Horizontal Configuration

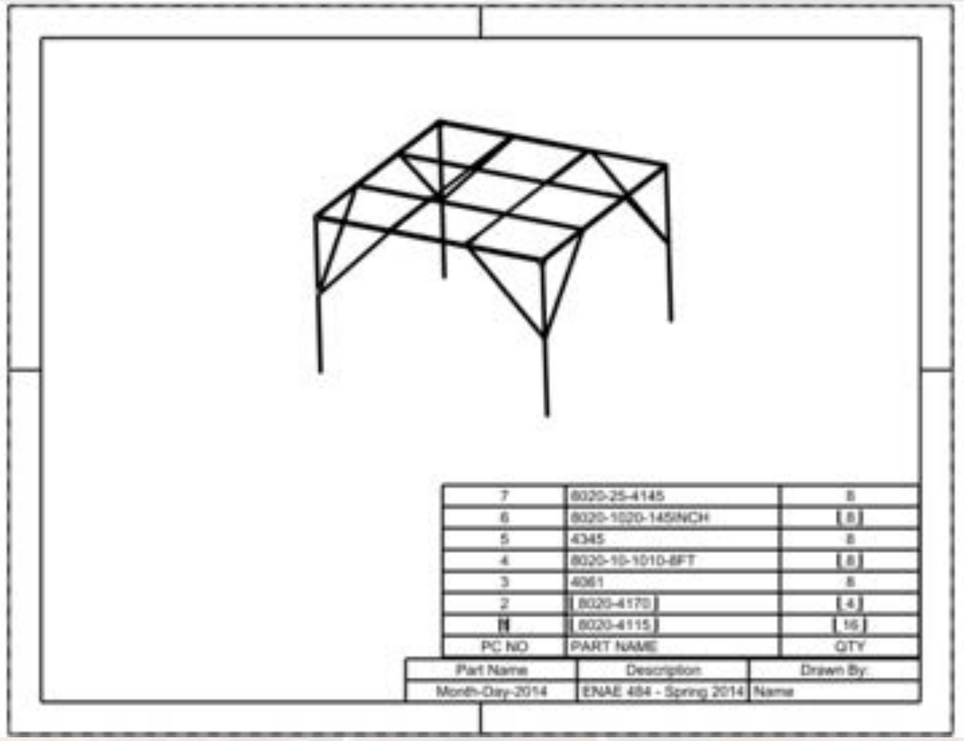


Vertical Configuration



Schematic of Hab Deck Structure

- Standard 4ft. x 4 ft. grid pattern
- Fiberglass extrusion floor panels
- Specialized panels (e.g., passagew
  repositionable upon need
- Works for horizontal and vertical l



Partial Gravity Sims of Habitability

Ballasting

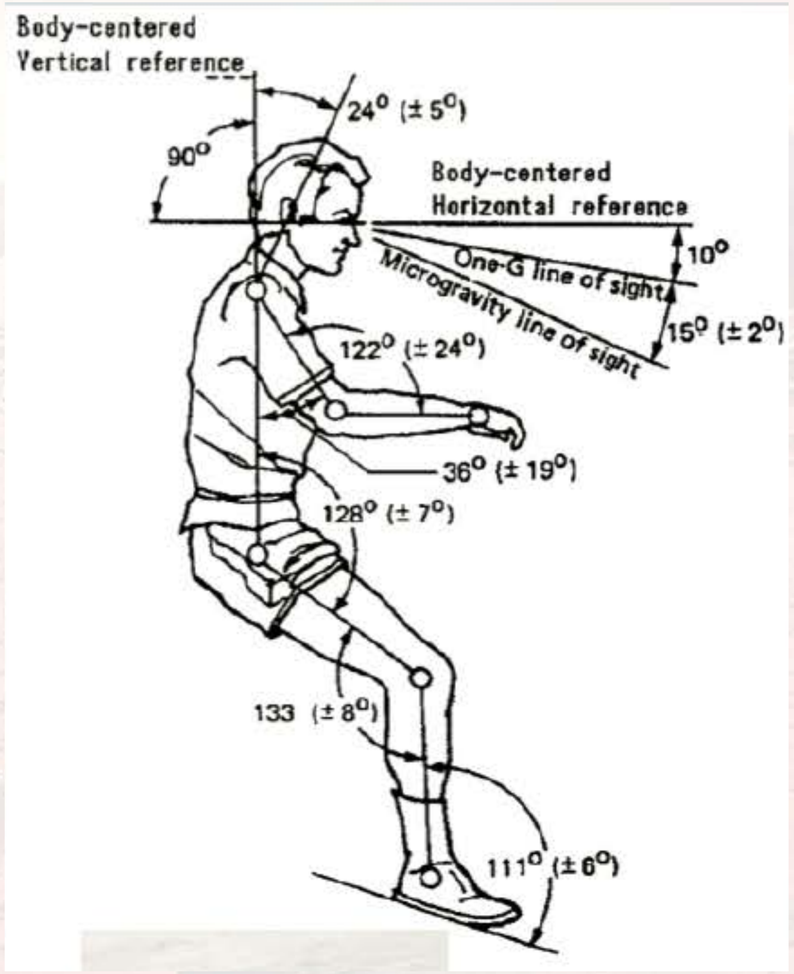
- An appropriate ballast distribution was calculated using body segment mass data for 50th percentile American males
  - 31% on the chest
  - 31% on the back
  - 13% on each thigh
  - 6% on each calf
- Arm masses only require ~1-2 kg and are not generally ballasted to preserve arm dexterity

Underwater Partial Gravity Simulation

Partial Gravity Anthropometrics

- Neutral body posture
- Jumping capability
- Access between levels
  - Stairs/ramps (35°, 67°, 78°)
  - Vertical ladder
  - Unencumbered and transporting 30-kg CTB at appropriate weight
- Body segment parametric ballasting
- Repeated at microgravity, 1/6 g (Moon), 3/8 g (Mars)

NBP: Microgravity

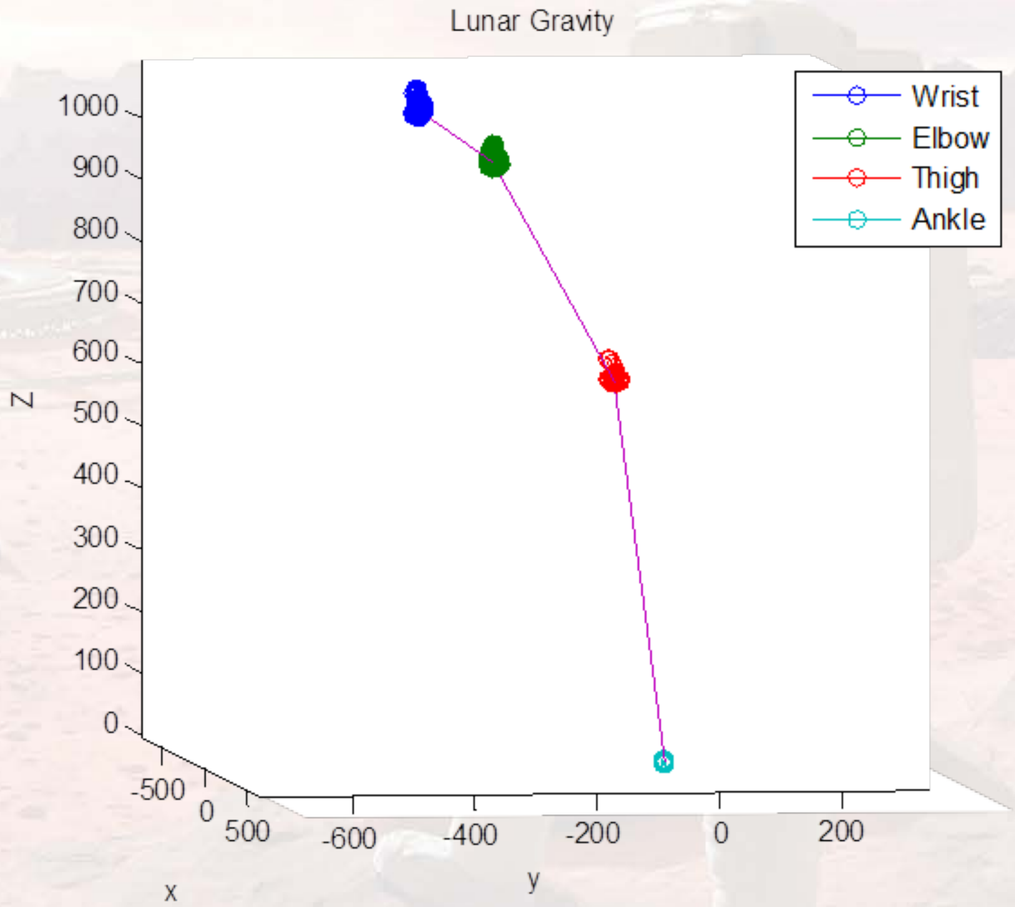


Keith H. Miller, ed., “Man-Systems Integration Standard" NASA-STD-3000, Rev. B July 1995.

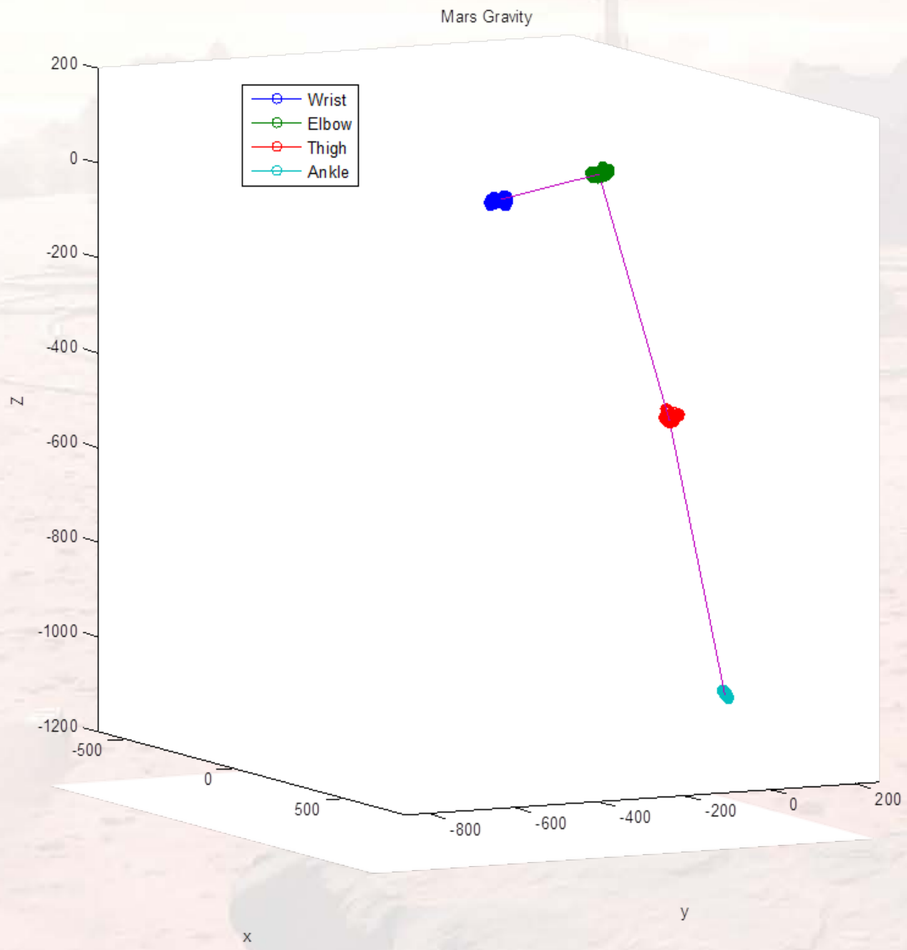
NBP: Microgravity Overlay

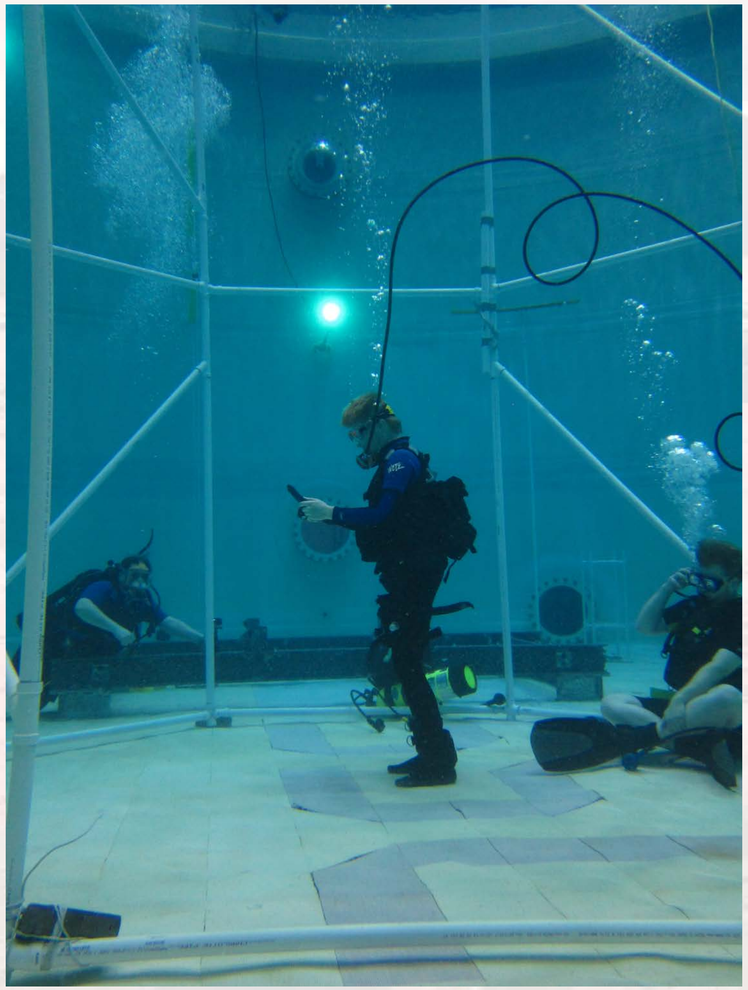
- Additional markers are needed
- Qualisys was able to successfully track markers
  - Angle between wrist and elbow markers and horizontal:
    - Underwater: 175 degrees
    - Microgravity: 180 degrees
  - Angles are about 20 degrees from theoretical, which are +/- 10

NBP: Lunar (1/6G)



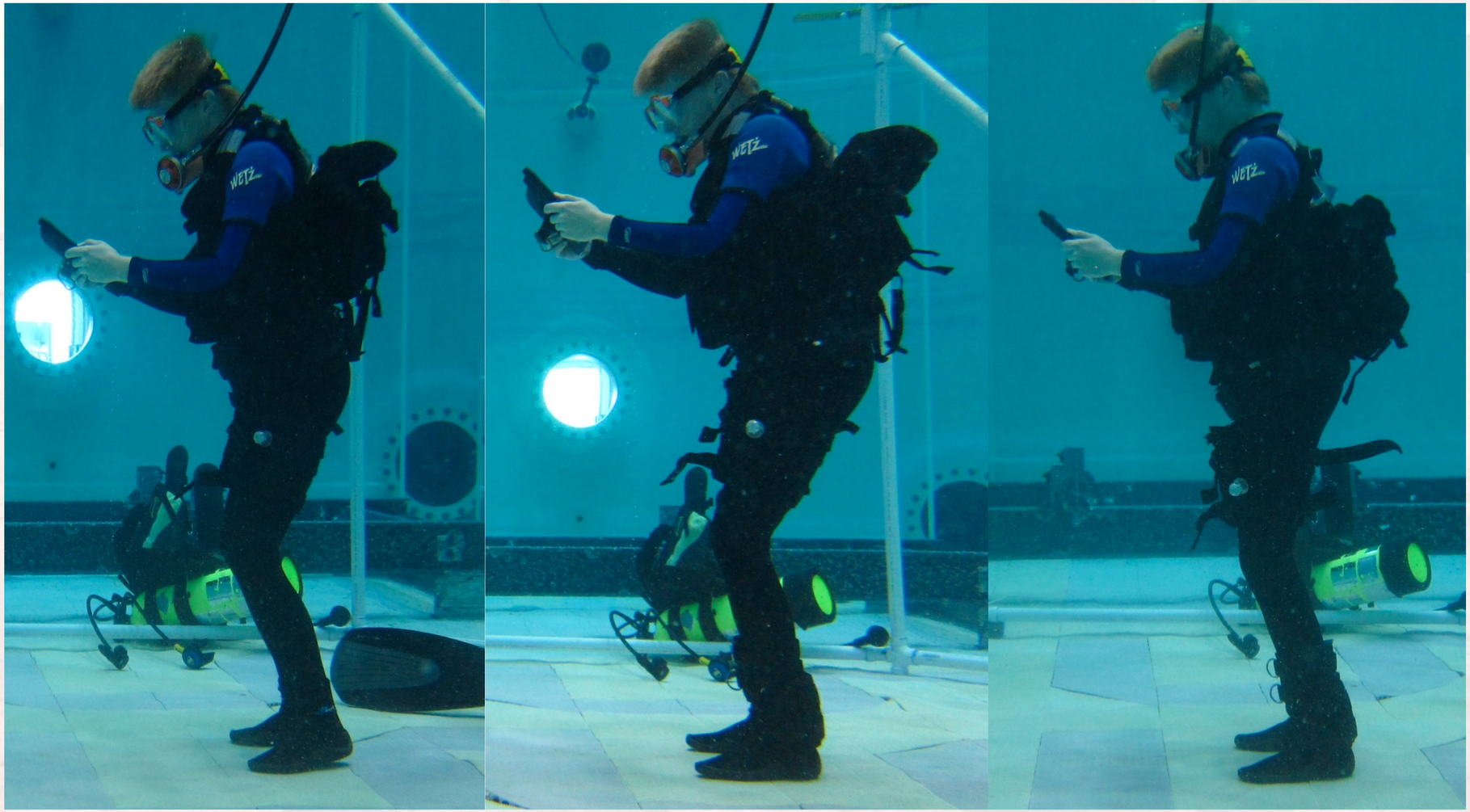
NBP: Mars (3/8G)


Mars Gravity
Wrist
Elbow
Thigh
Ankle
200
0
-200
-400
-600
-800
-1000
-1200
z
-500
0
500
x
-800
-600
-400
-200
0
200
y



NBP: Results

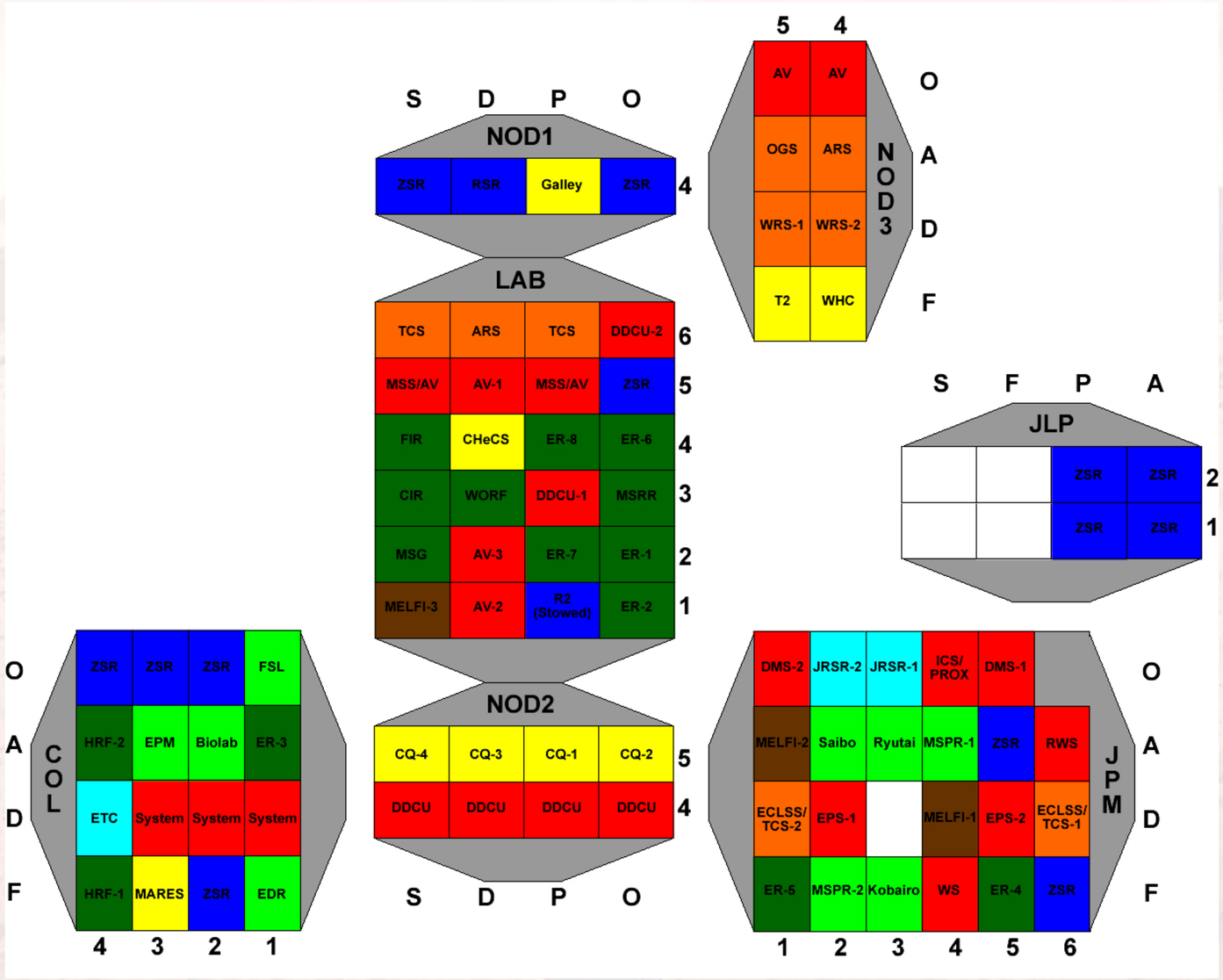
Microgravity | Lunar | Mars

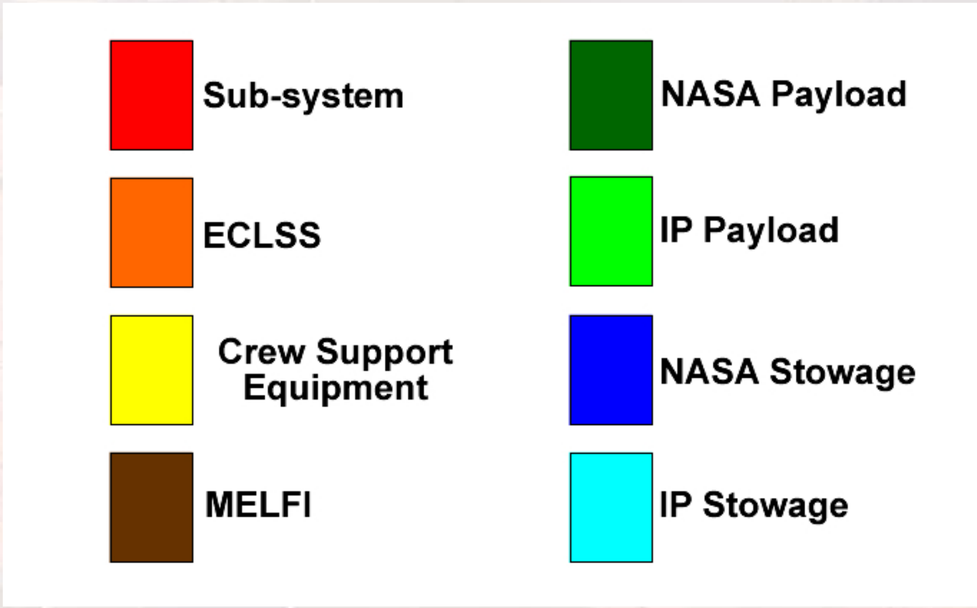


International Standard Payload Racks (ISPRs)

ISPR Interchange

ISS Rack Configuration (as of Oct. 2015)

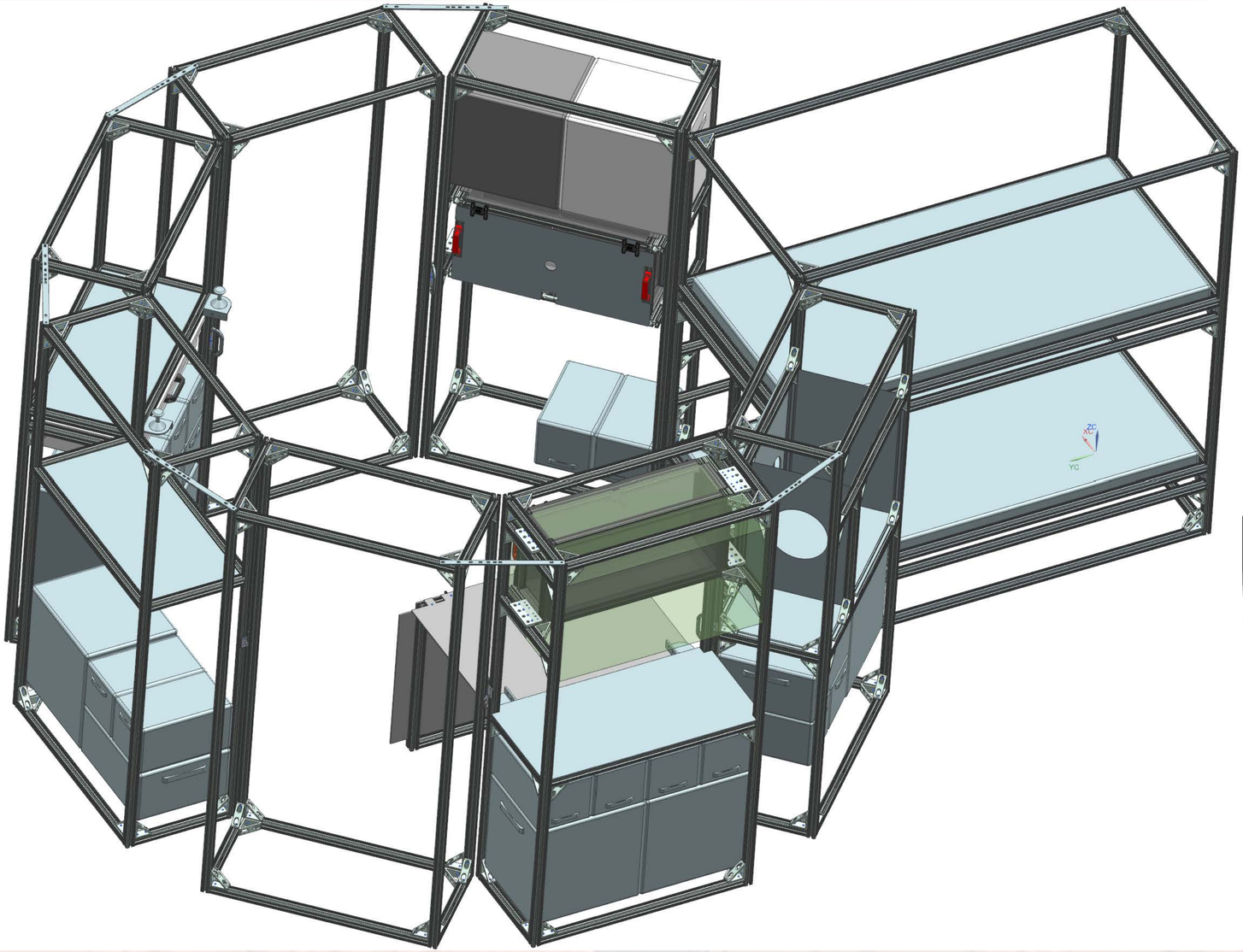


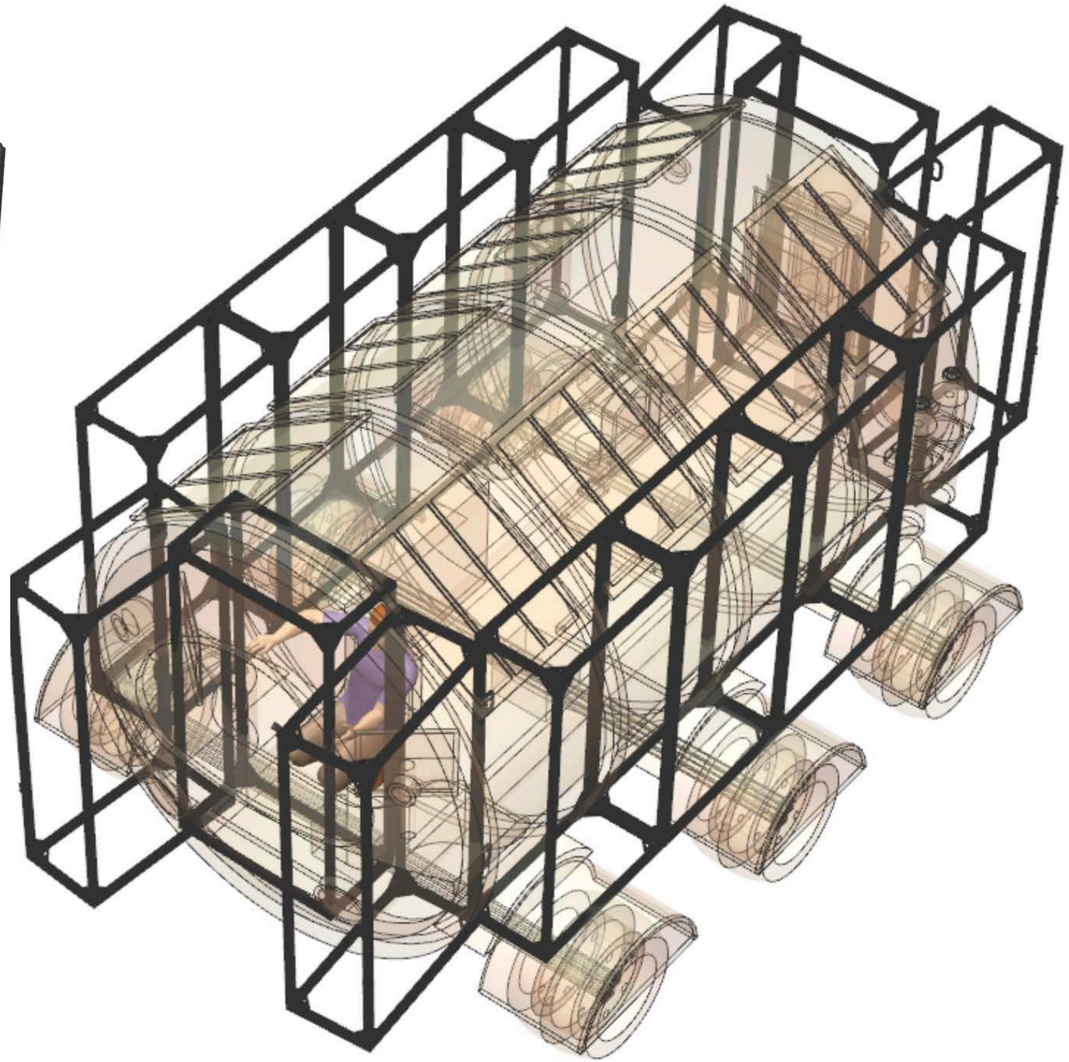


From NASASpaceflight.com

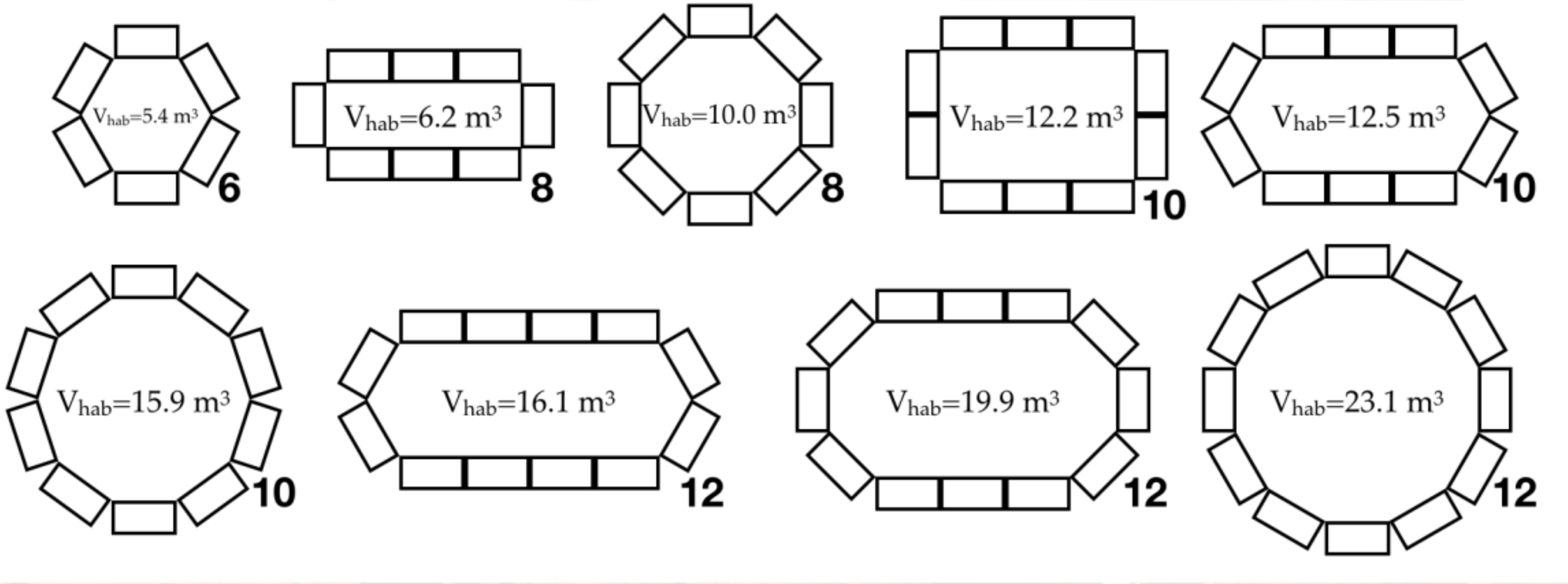
SSL Modular Rack System

Use of Modular Racks to Represent Habitats

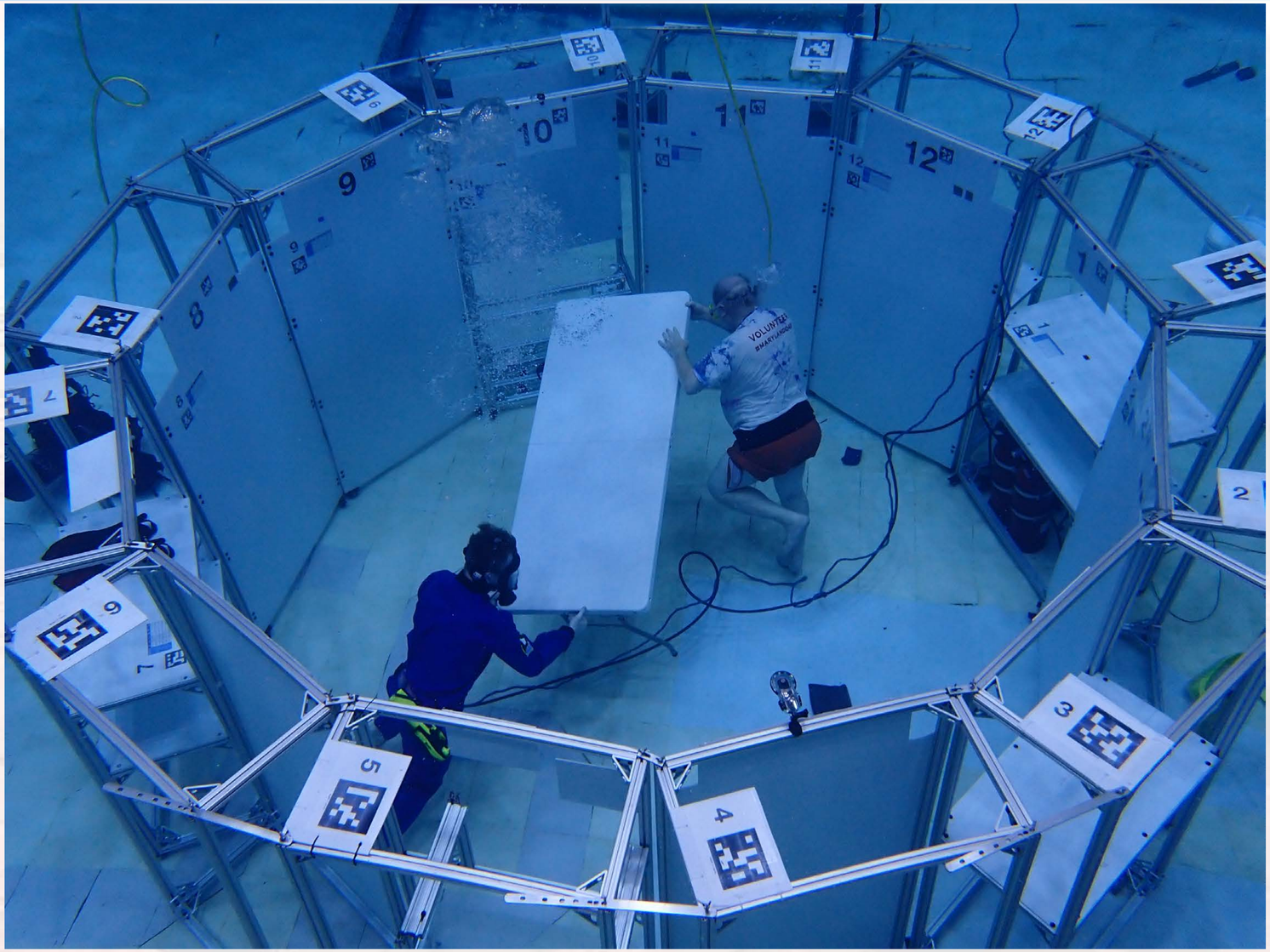




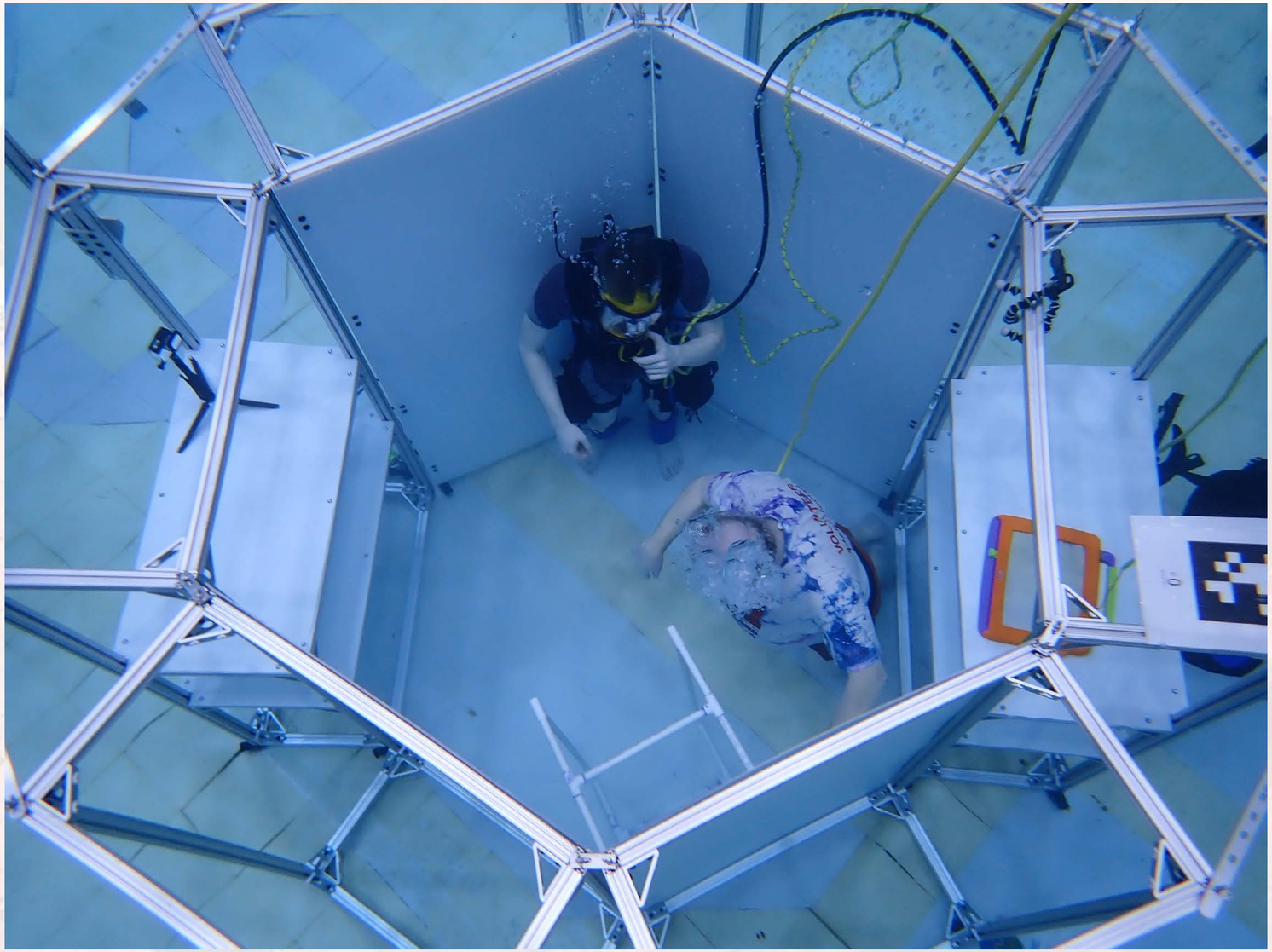
Modular Rack Habitat Configurations



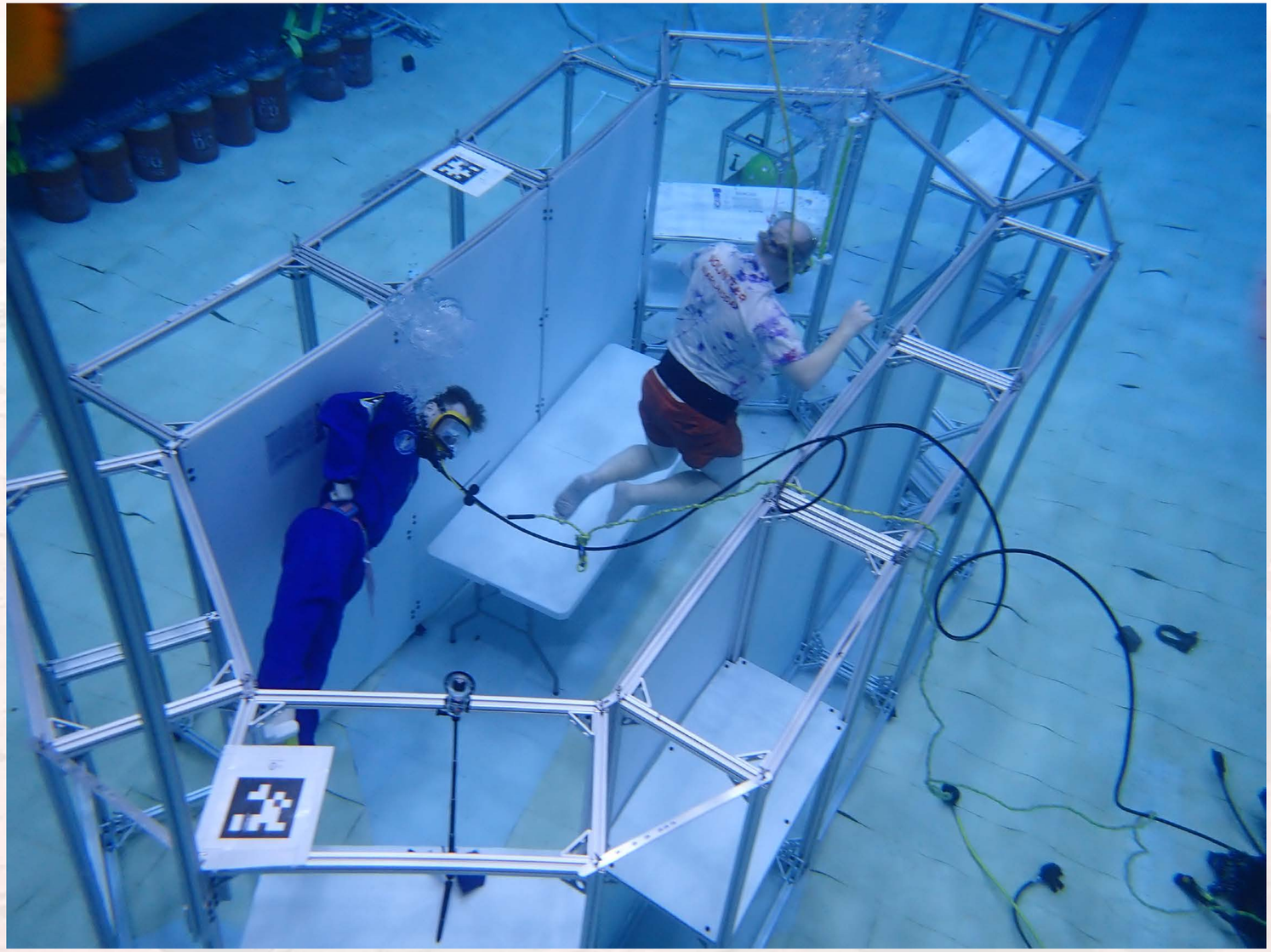
12-Rack Vertical Layout



6-Rack Vertical Layout



10-Rack Horizontal Layout



NASA Concept of Mobile Habitats

NASA Habitat Demonstration Unit

Interior of Habitat Demo Unit (HDU)

HDU Robotics Workstation

HDU Glovebox

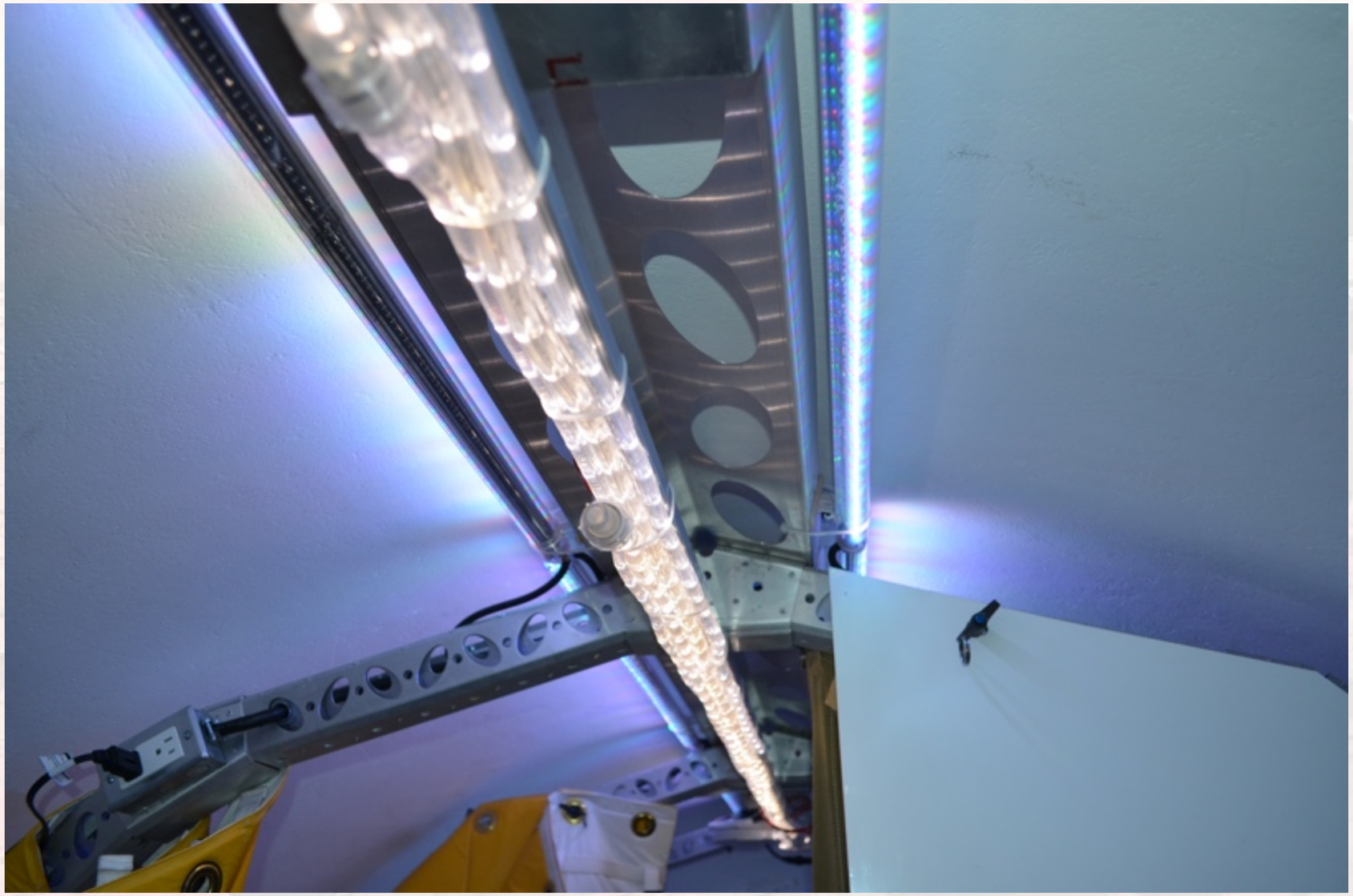
HDU Glovebox in Use

HDU General-Purpose Workstation

HDU Upper Deck (Habitation) Level

HDU Hygiene Module

Hygiene Module Overhead Lighting

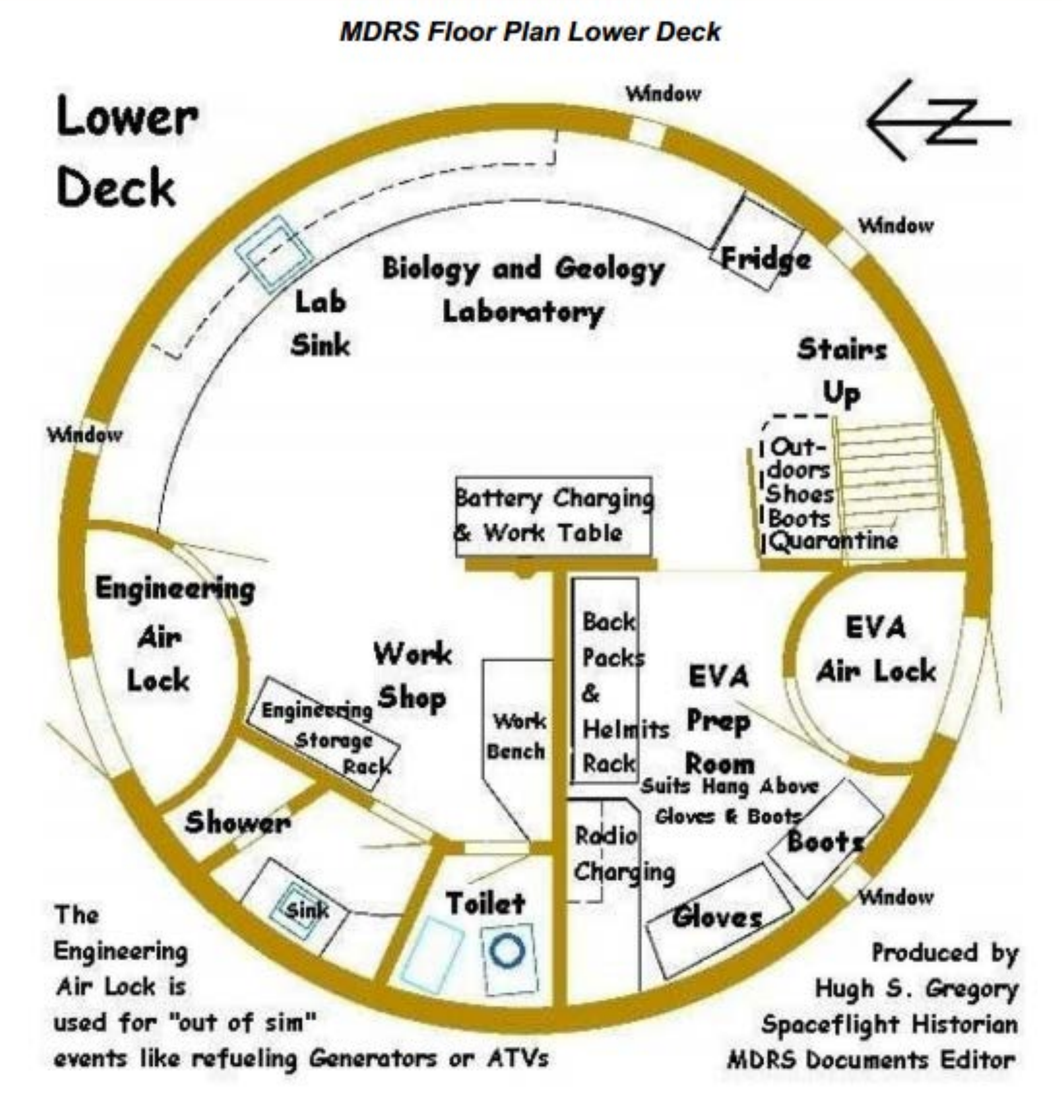


HDU Toilet Area

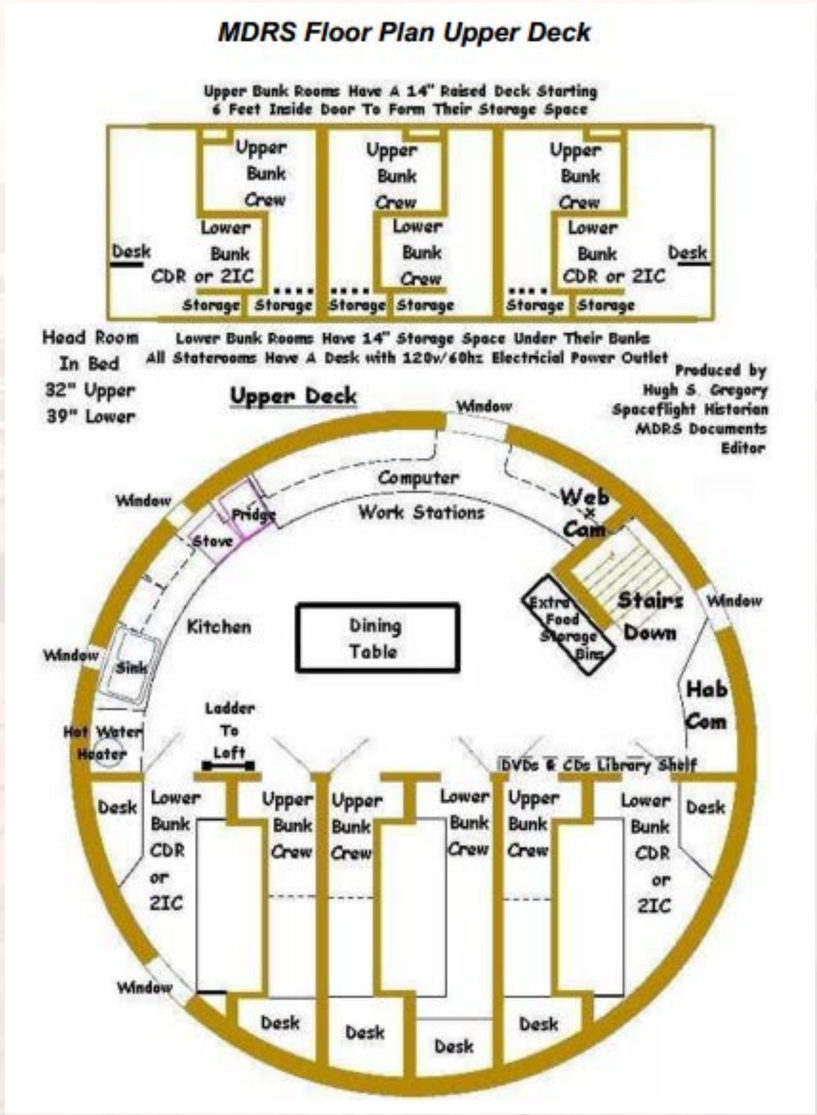
HDU Sink and Water Dispenser

Mars Desert Research Station

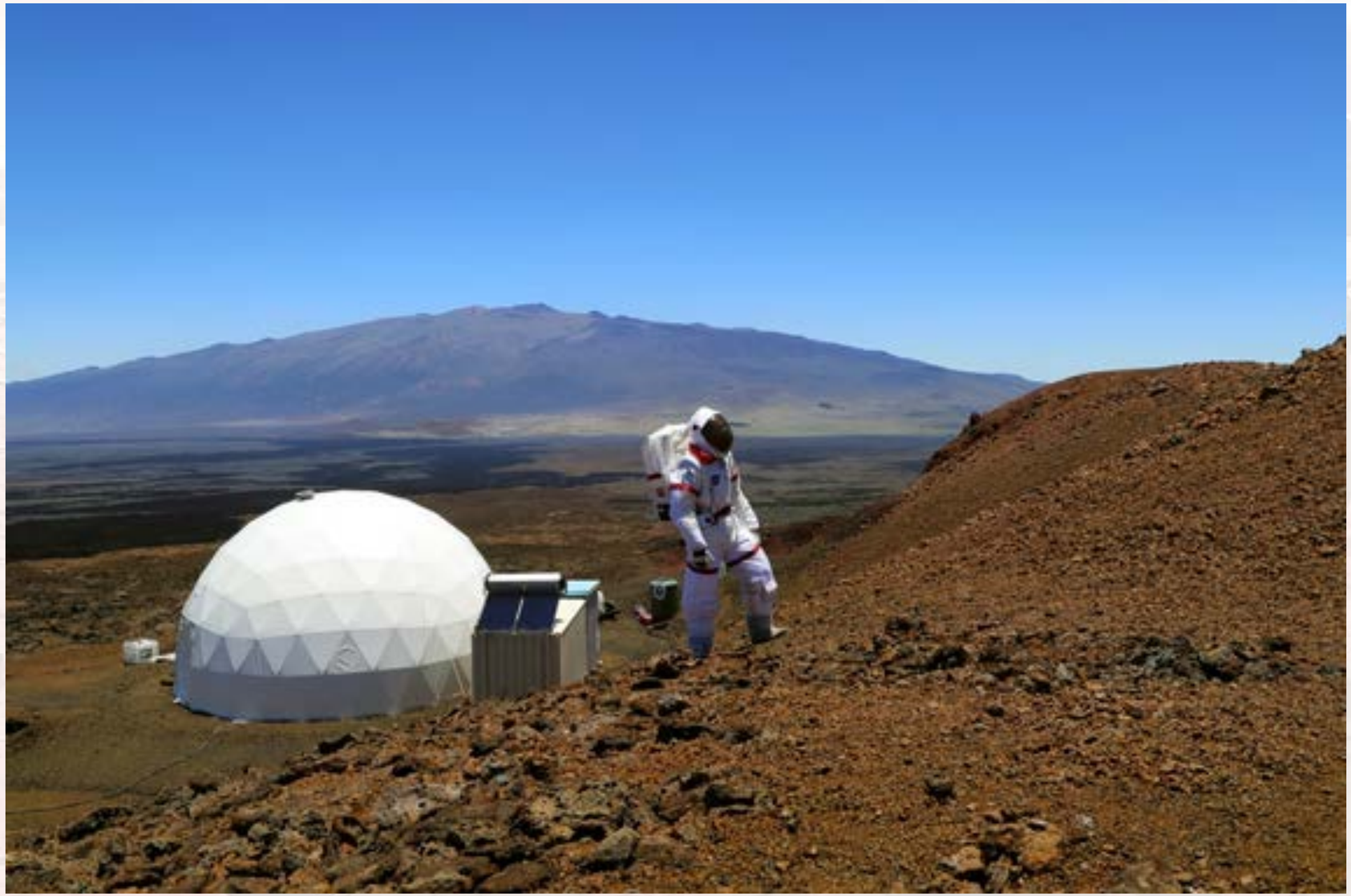
MDRS Lower Level Floor Plan



MDRS Upper Level Floor Plan



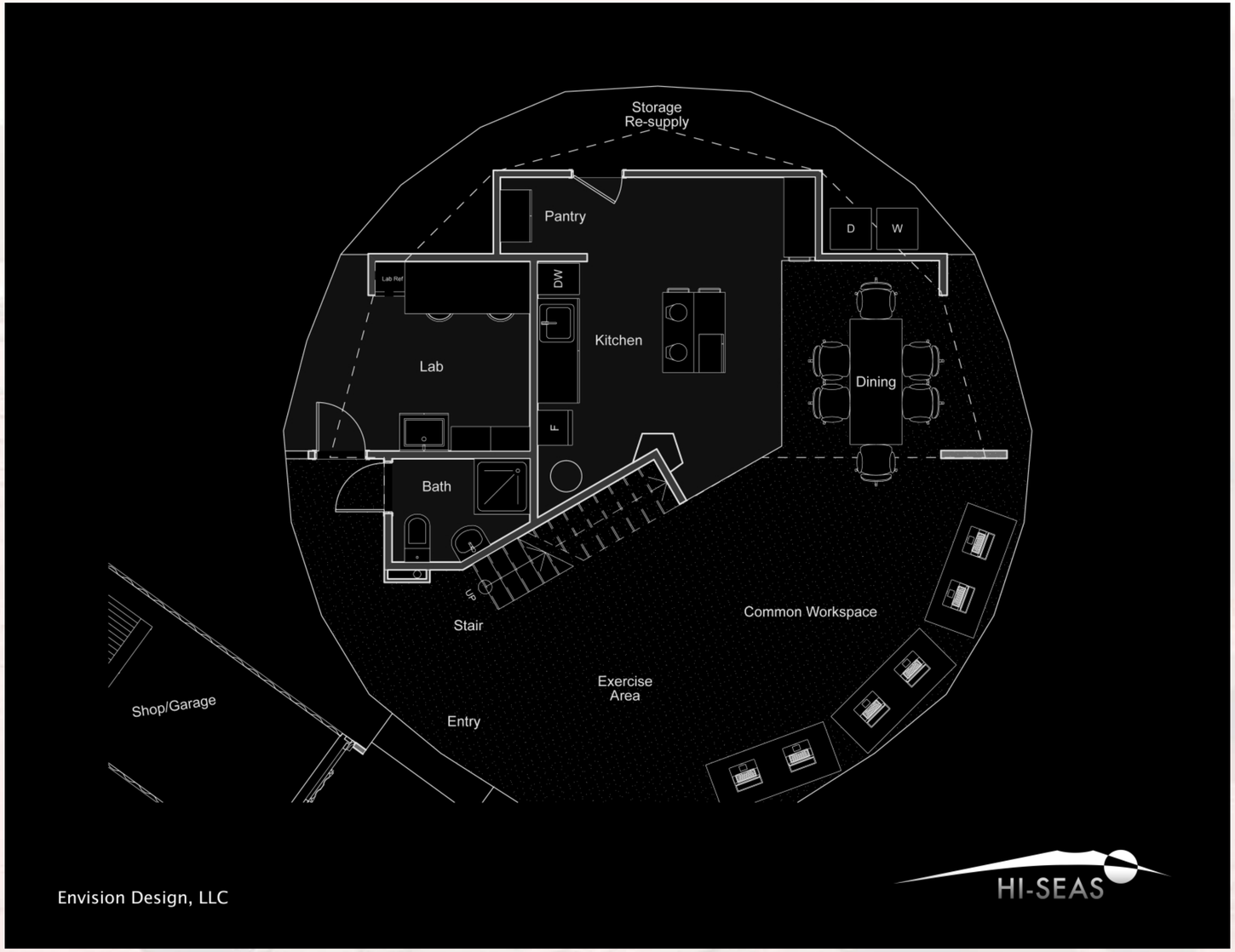
HI-SEAS Mars Simulation Site



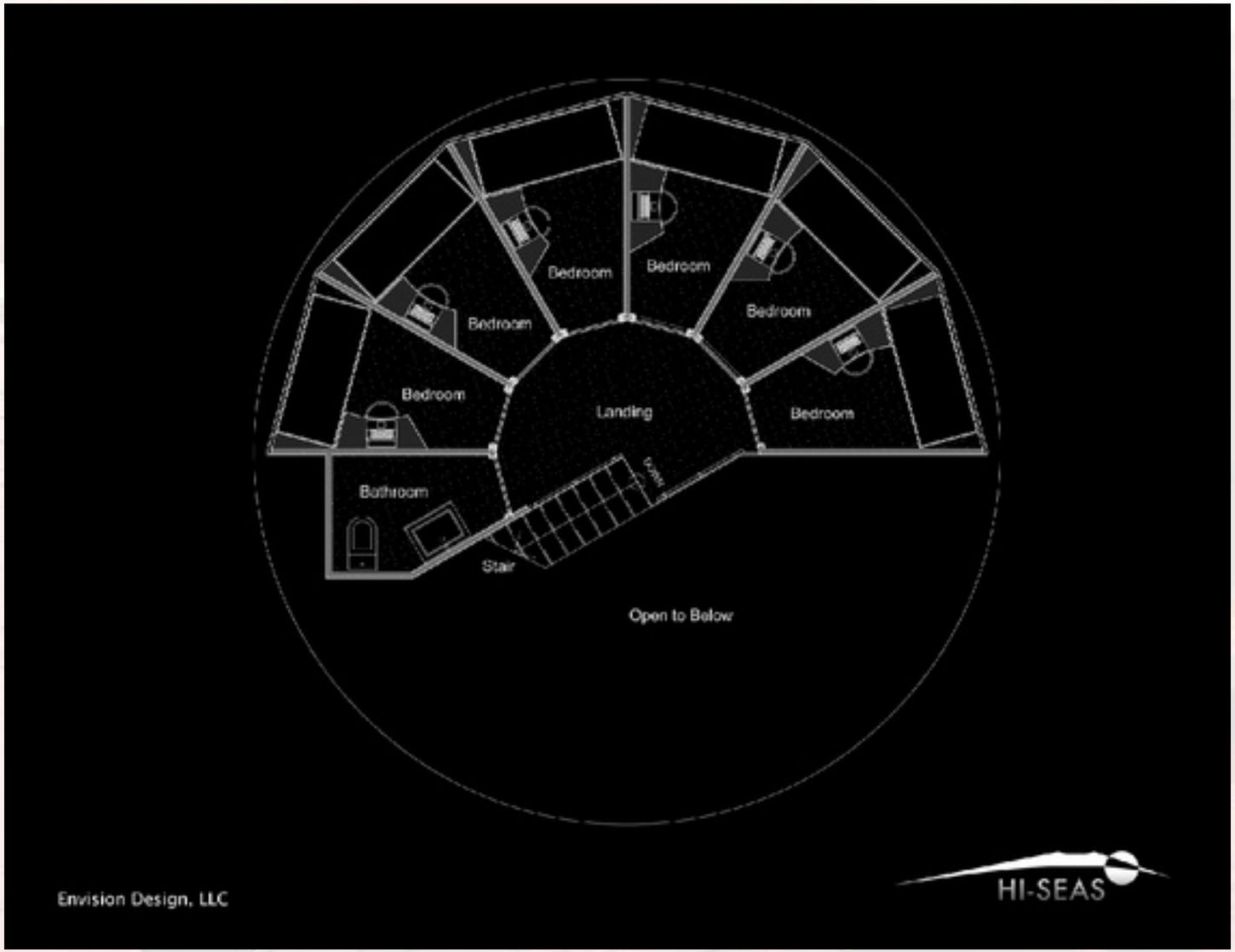
HI-SEAS Internal Visualization

HI-SEAS Lower Level Open Space

HI-SEAS Lower Level Floor Plan



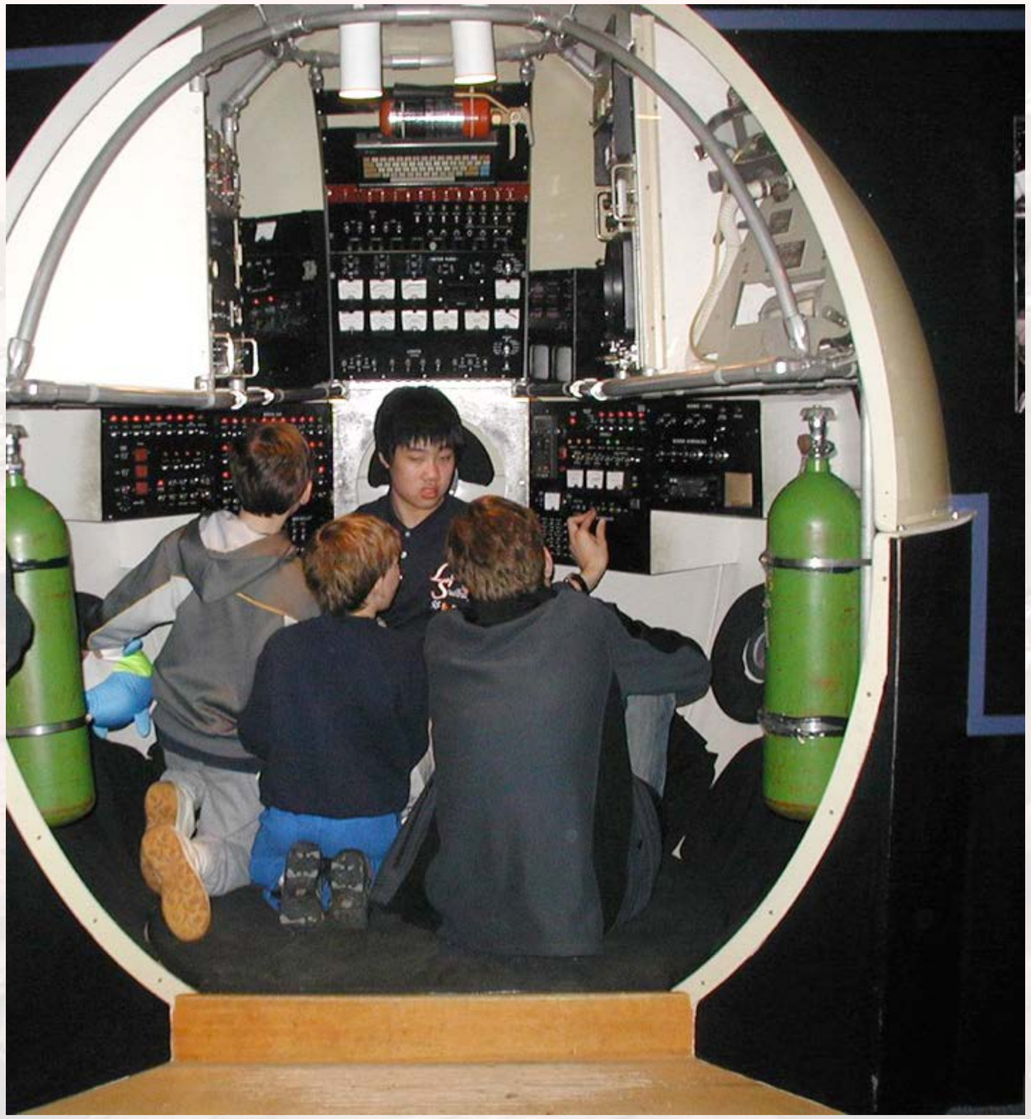
HI-SEAS Upper Floor Plan



HI-SEAS Food Preparation Area

Analogue Habitats - NR-1 Submarine

Interior Mockup of Alvin



Halley VI Station - Antarctica