

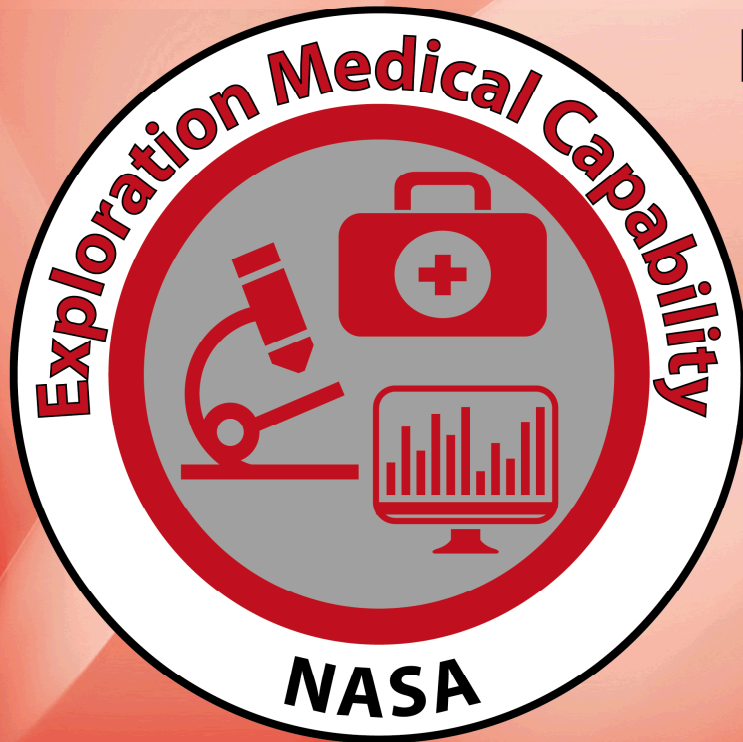
Space Habitat Preliminary Design

Samuel Park

University of California, San Diego

B.S. Candidate, Aerospace Engineering

Exploration Medical Capabilities (ExMC)



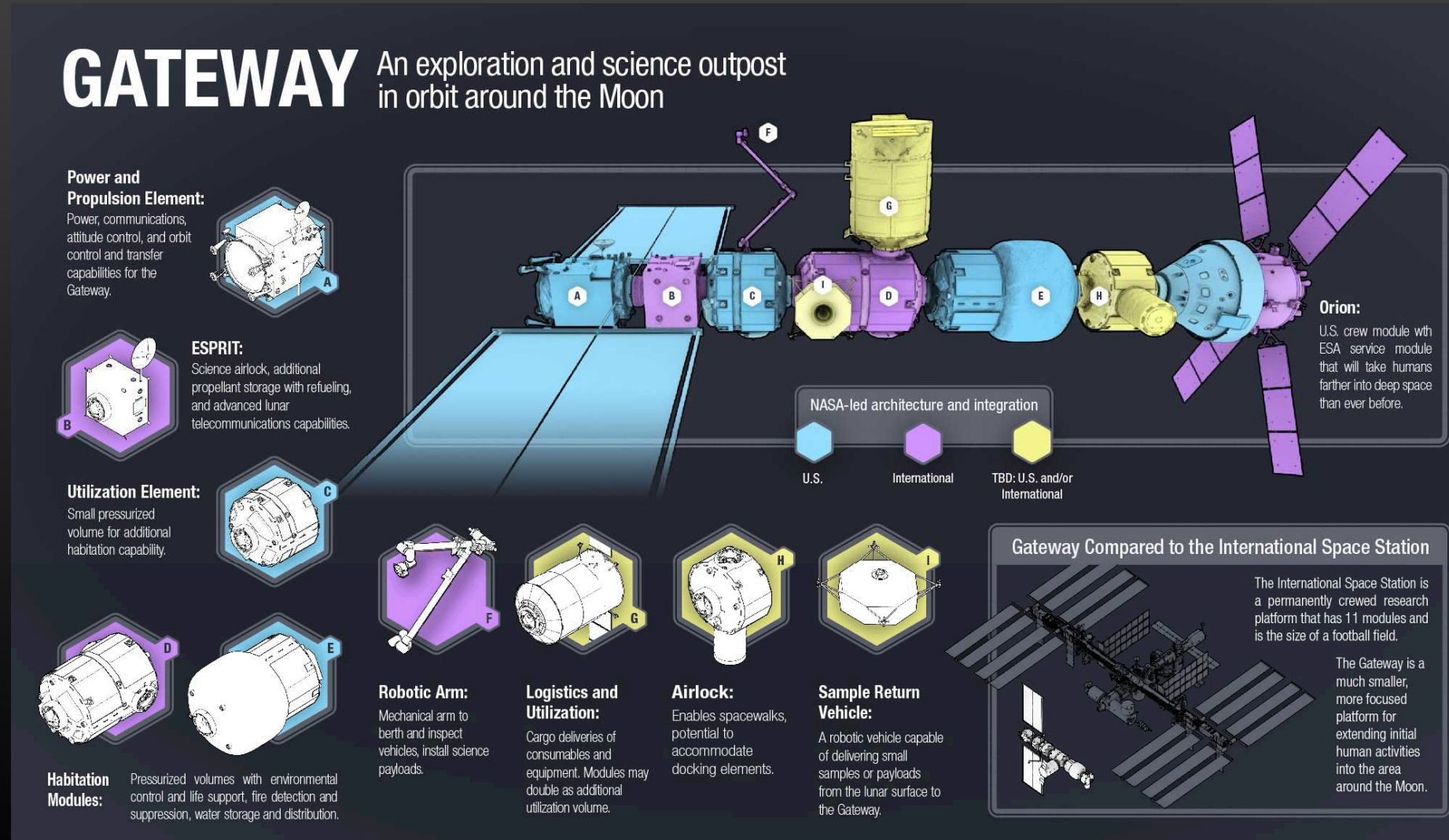
Element Overview

The mission of the Exploration Medical Capability (ExMC) Element is to advance medical system design and risk-informed decision making for exploration beyond low Earth orbit, to promote human health and performance in space.

The ExMC is one of FIVE research elements of the NASA Human Research Program

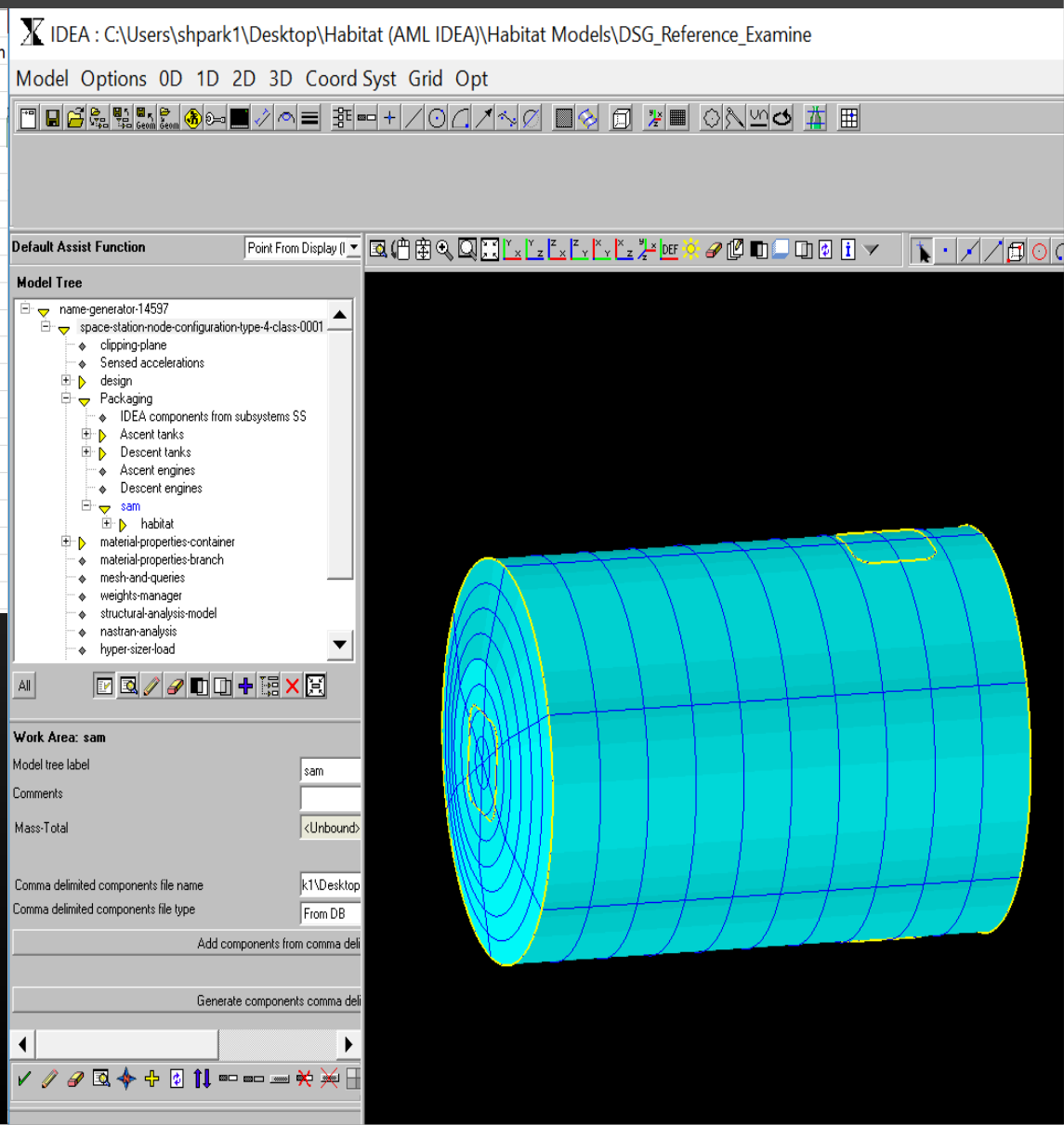
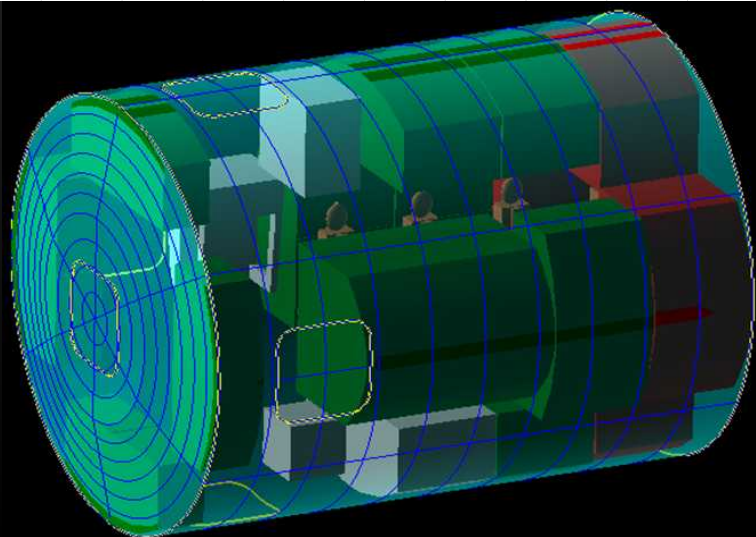
Project Overview

- Design for habitation module (sizing/packaging)
- Medical workstation/other applications

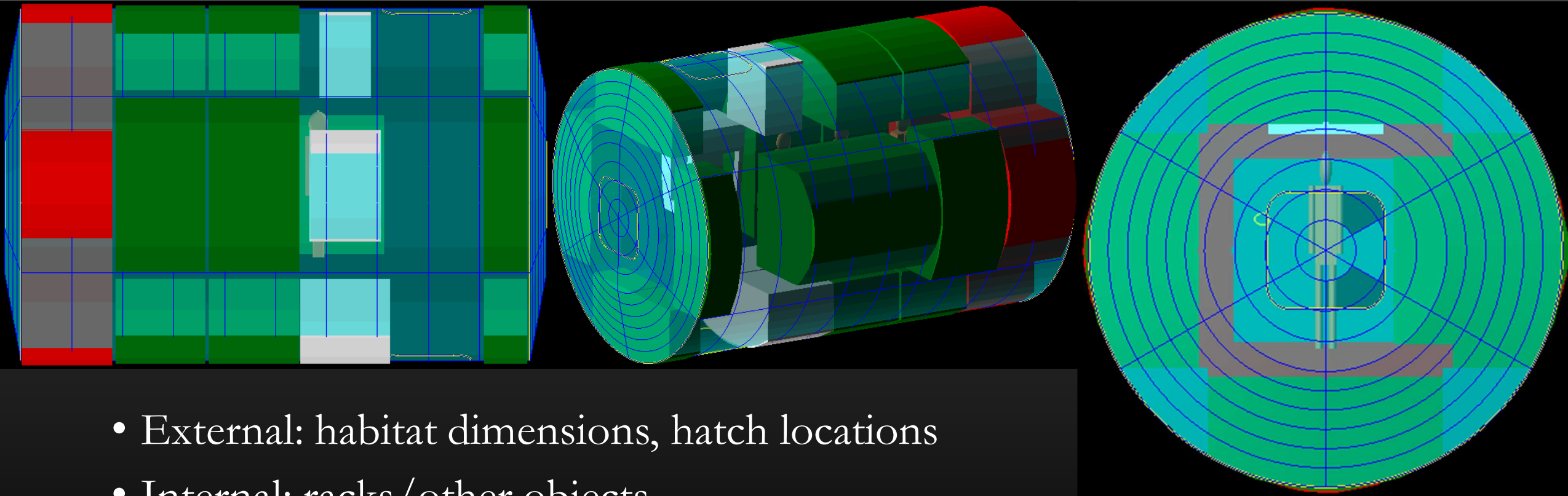


IDEA Software

\$ smpark														
\$ parent1	parent2	mass	conceptuanension ty	x-dim	y-dim	z-dim	density	type [rectaength - %avidth - %thwl - %radi	x-rotation	y-rotation	z-rotation			
habitat	Crew Quarters 1	x	"Q:\sam_ fixed	1.0541	1.30302	2.032		cylindrical 11 90 -72 0 0 0						
habitat	Crew Quarters 2	x	"Q:\sam_ fixed	1.0541	1.30302	2.032		cylindrical 11 180 -72 90 0 0						
habitat	Crew Quarters 3	x	"Q:\sam_ fixed	1.0541	1.30302	2.032		cylindrical 11 270 -72 180 0 0						
habitat	Crew Quarters 4	x	"Q:\sam_ fixed	1.0541	1.30302	2.032		cylindrical 11 0 -72 270 0 0						
habitat	Life Support - Water	x	"Q:\sam_ fixed	1.0541	0.988	2.032		cylindrical 28.5 90 -79 0 0 0						
habitat	Life Support - Air	x	"Q:\sam_ fixed	1.0541	0.988	2.032		cylindrical 28.5 180 -79 90 0 0						
habitat	Support - Environment Mod	x	"Q:\sam_ fixed	1.0541	0.988	2.032		cylindrical 28.5 270 -79 180 0 0						
habitat		Fire Safety	x	"Q:\sam_ fixed	1.0541	0.988	2.032		cylindrical 28.5 0 -79 270 0 0					
habitat	Power	x	"Q:\sam_ fixed	1.0541	0.988	2.032		cylindrical 46 90 -79 0 0 0						
habitat	Thermal	x	"Q:\sam_ fixed	1.0541	0.988	2.032		cylindrical 46 180 -79 90 0 0						
habitat	Avionics/Flight Software	x	"Q:\sam_ fixed	1.0541	0.988	2.032		cylindrical 46 270 -79 180 0 0						
habitat	Medical Workstation	x	"Q:\sam_ fixed	2.04	1.53	1.625		cylindrical 54 0 -67 270 0 0						
habitat	Equipment Stowage	x	"Q:\sam_ fixed	0.5	0.988	2.032		cylindrical 93 90 -79 0 0 0						
habitat	Food Stowage	x	"Q:\sam_ fixed	0.5	0.988	2.032		cylindrical 93 180 -79 90 0 0						
habitat	Hygiene	x	"Q:\sam_ fixed	0.5	0.988	2.032		cylindrical 93 270 -79 180 0 0						
habitat	Galley	x	"Q:\sam_ fixed	0.5	0.988	2.032		cylindrical 93 0 -79 270 0 0						
habitat	Astronaut 1	x	"Q:\clyde fixed	1.7	0.3	0.3		cylindrical 10 90 0 0 0 90						
habitat	Astronaut 2	x	"Q:\clyde fixed	1.7	0.3	0.3		cylindrical 27 90 0 0 0 90						
habitat	Astronaut 3	x	"Q:\clyde fixed	1.7	0.3	0.3		cylindrical 43 90 0 0 0 90						
habitat	Astronaut 4	x	"Q:\clyde fixed	1.7	0.3	0.3		cylindrical 58 90 0 0 0 90						



NASA Reference Model (I-Hab)



- External: habitat dimensions, hatch locations
- Internal: racks/other objects
- Driven by information on pre-existing ISS modules, habitat design publications, and current NASA architecture files (functional allocations, CAD models)

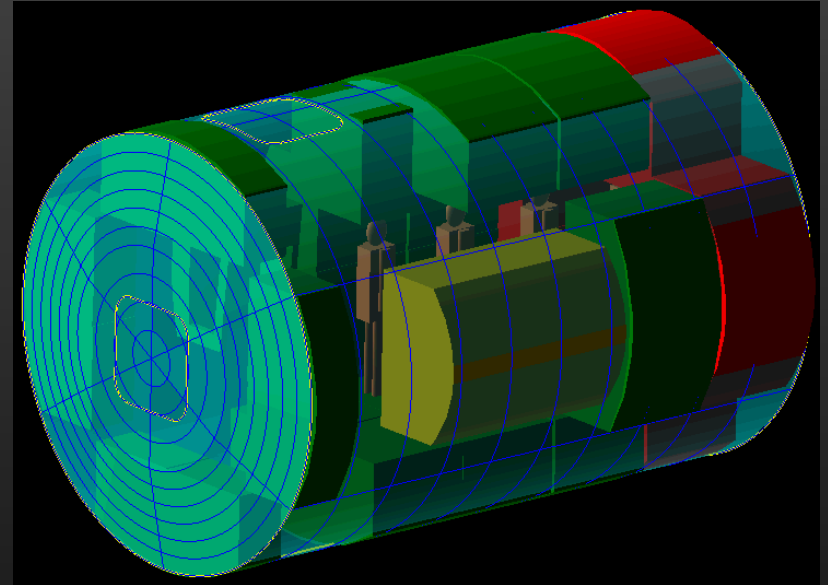
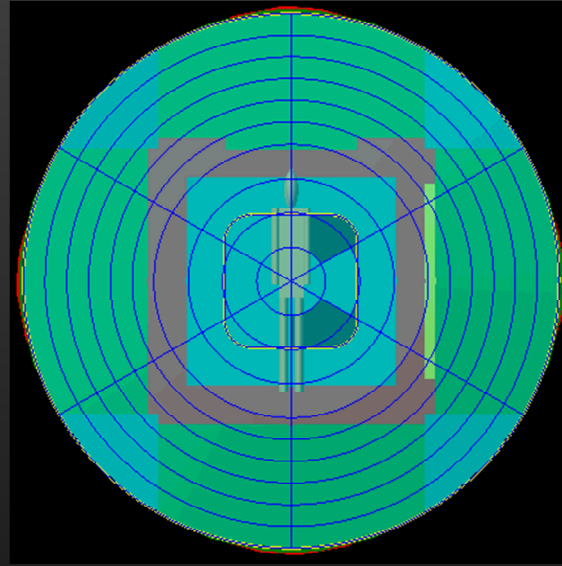
NASA Reference Model (I-Hab)

- Item Volume: 34.84 m³
- Vehicle Volume: 81.16 m³
- Usable Volume: 46.32 m³ (57%)

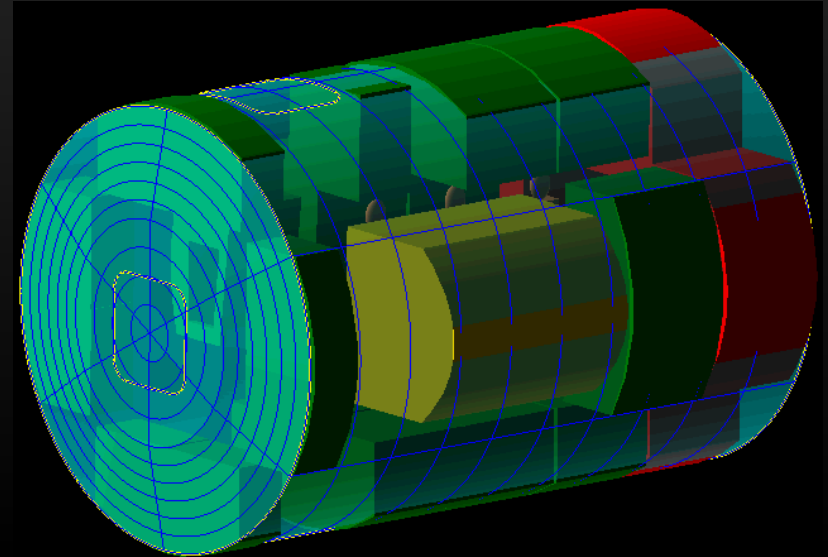
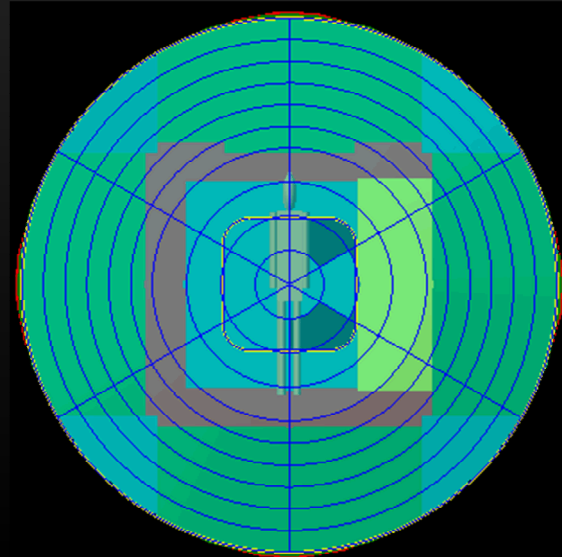
Space station node overall height	6.3
Space station node top diameter	2.1
Space station node body diameter	4.1
Space station node bottom diameter	2.1
Node cylinder length	5.1
Node eccentricity	0.95
Node taper angle	10.6
Node top cap height	0.9974999999999999
Node bottom cap height	0.9974999999999999
Space station node top angle	10.6
Space station node bottom angle	10.6
Space station node structural skin thickness	0.0127
Space station node TPS skin thickness	0.0254
Space station node IML volume	<Unbound>
Space station node HS grouping factor list	(list 0.0 0.10323136337039844 0.165170181392

Medical Workstation Modeling

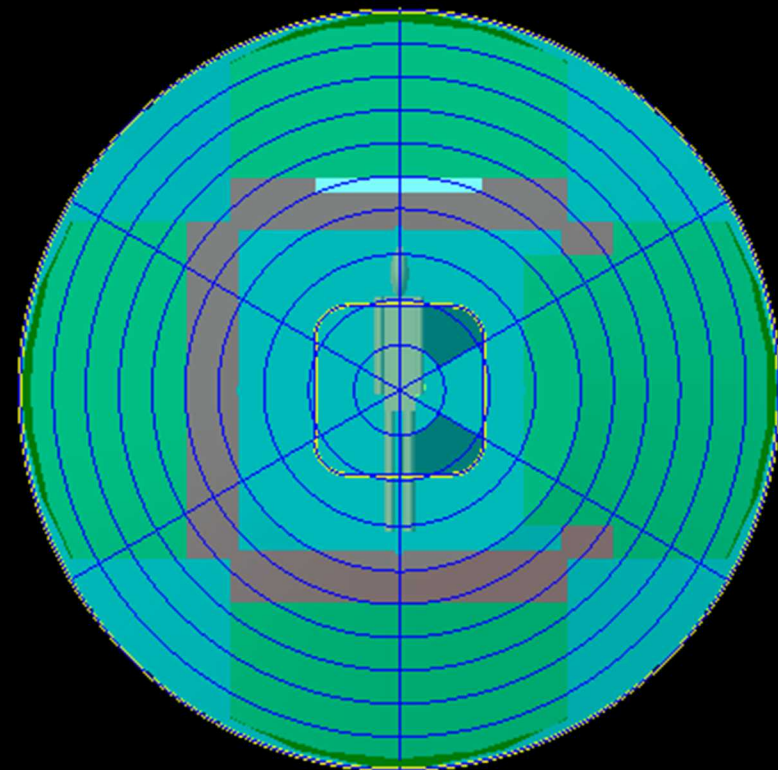
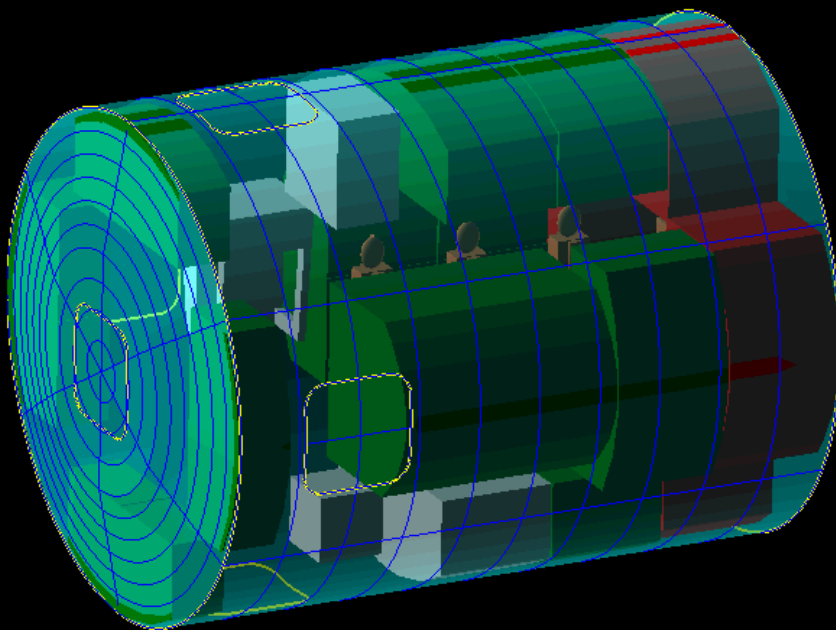
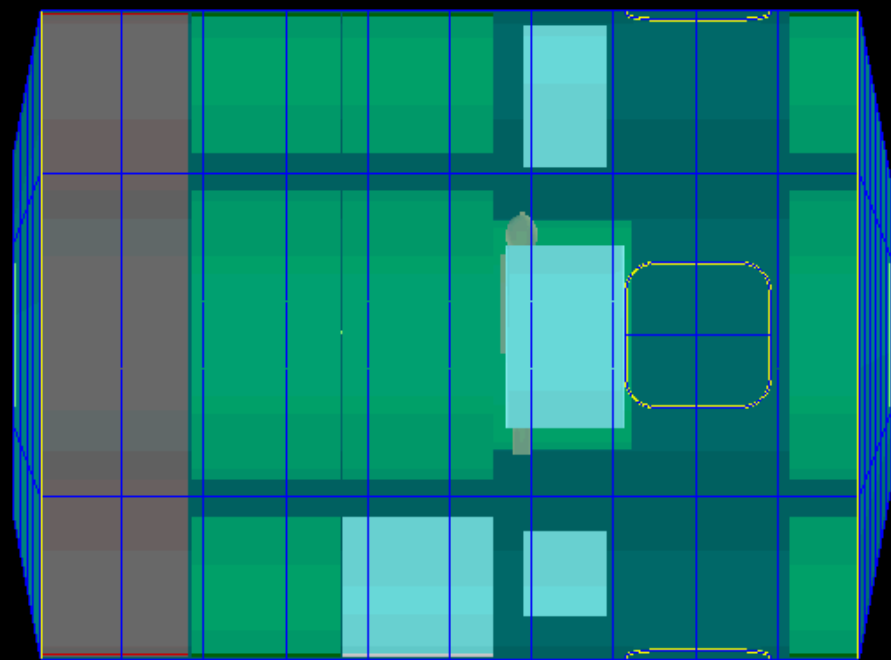
- Concept A: 2.81 m³



- Concept B: 4.57 m³



ISS Node 2 (Harmony)

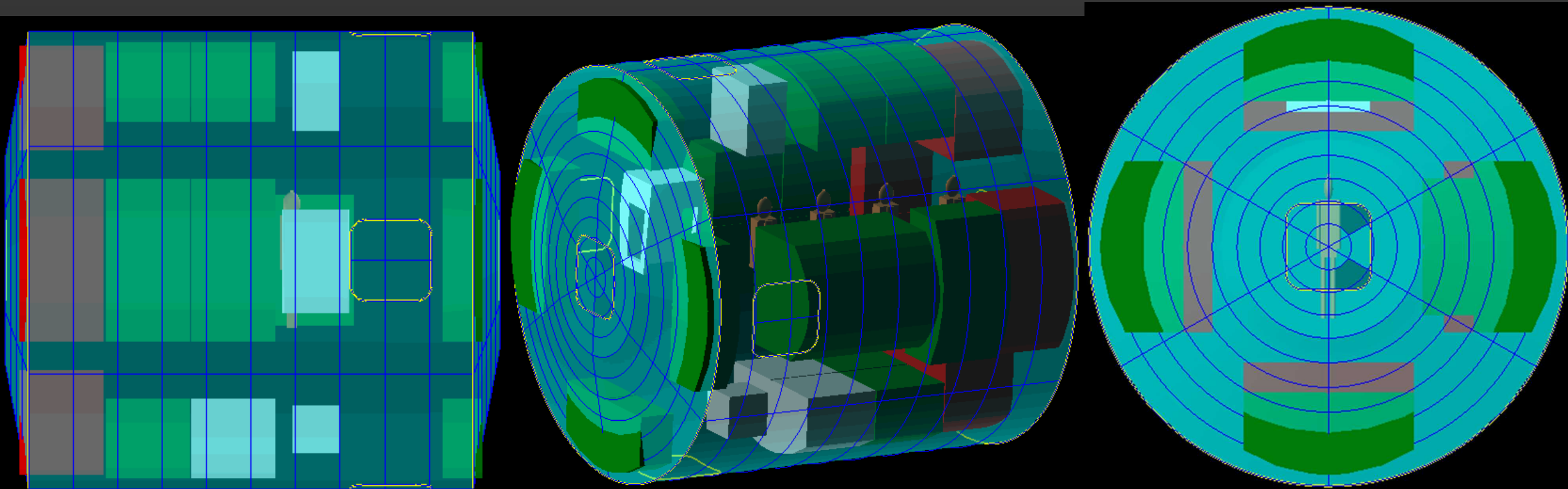


ISS Node 2 (Harmony)

- Item Volume: 33.14 m³
- Vehicle Volume: 98.81 m³
- Usable Volume: 65.67 m³ (66%)

Space station node overall height	6.19
Space station node top diameter	2.58
Space station node body diameter	4.57
Space station node bottom diameter	2.18
Node cylinder length	5.74
Node eccentricity	0.95
Node taper angle	10.6
Node top cap height	1.2255
Node bottom cap height	1.0355
Space station node top angle	10.6
Space station node bottom angle	10.6
Space station node structural skin thickness	0.0127
Space station node TPS skin thickness	0.0254
Space station node IML volume	<Unbound>
Space station node HS grouping factor list	(list 0.0 0.10323136337039844 0.1651701813926375

25% Larger Radius: ISS Node 2 (Harmony)

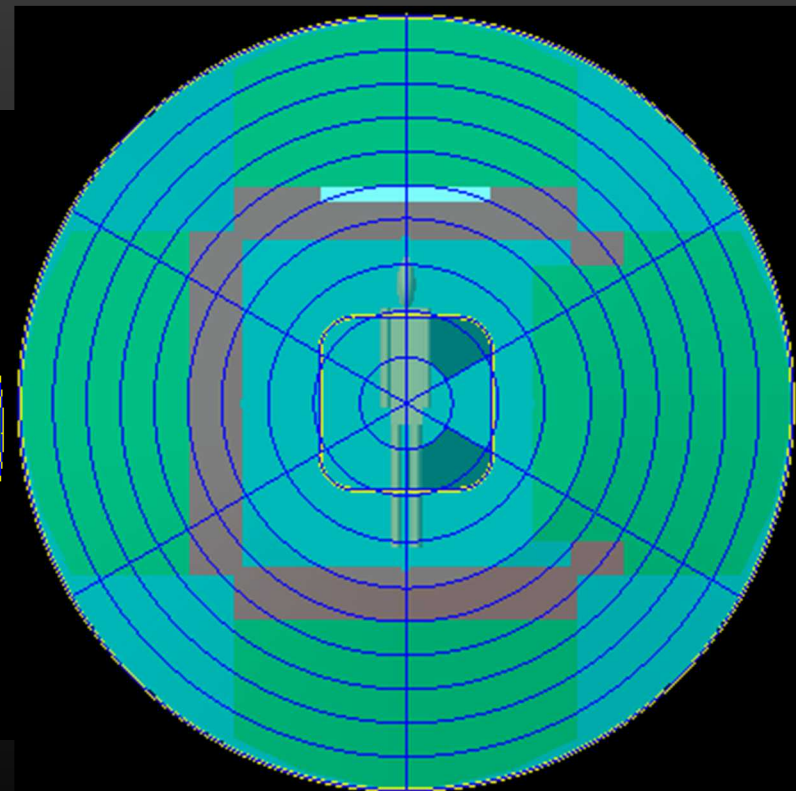
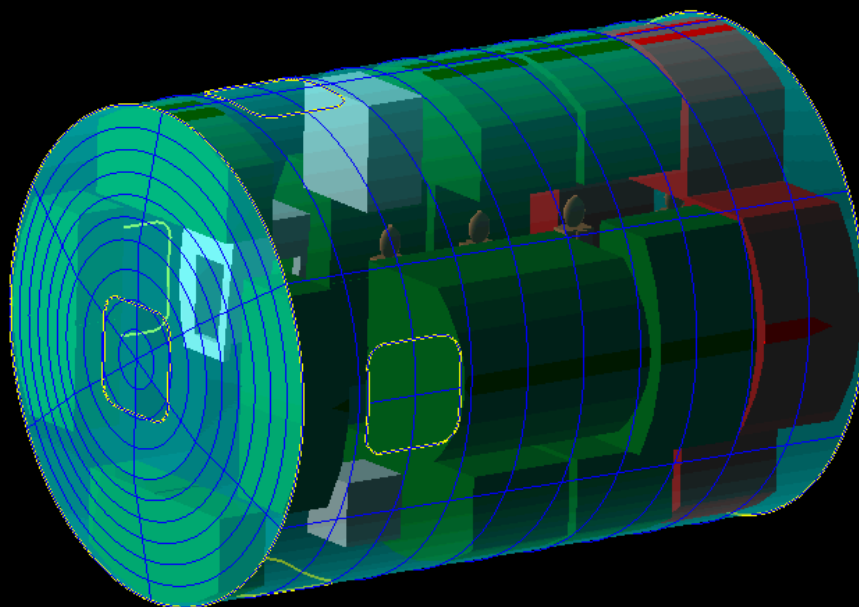
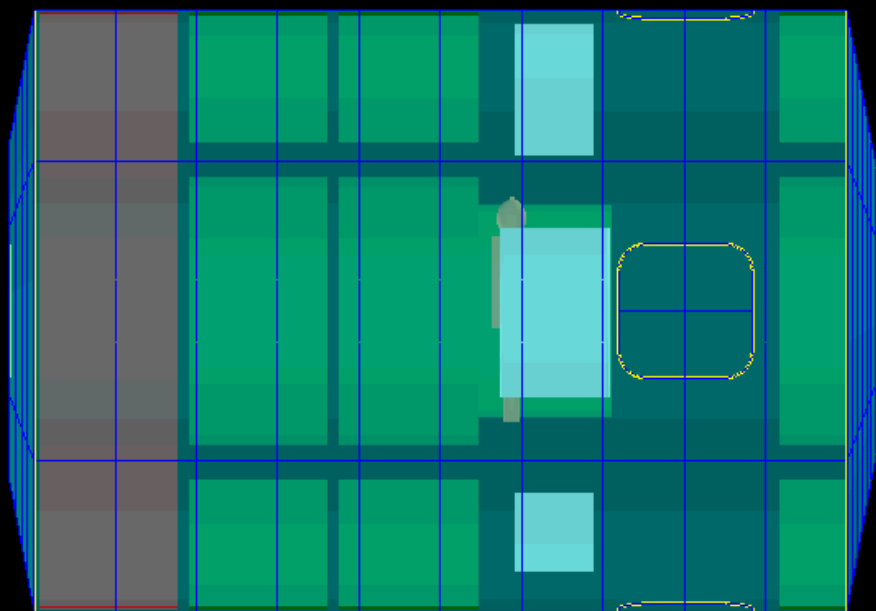


25% Larger Radius: ISS Node 2 (Harmony)

- Item Volume: 33.14 m³
- Vehicle Volume: 151.00 m³
- Usable Volume: 117.86 m³ (78%)

Space station node overall height	6.19
Space station node top diameter	2.58
Space station node body diameter	5.71
Space station node bottom diameter	2.18
Node cylinder length	5.74
Node eccentricity	0.95
Node taper angle	10.6
Node top cap height	1.2255
Node bottom cap height	1.0355
Space station node top angle	10.6
Space station node bottom angle	10.6
Space station node structural skin thickness	0.0127
Space station node TPS skin thickness	0.0254
Space station node IML volume	<Unbound>
Space station node HS grouping factor list	(list 0.0 0.10323136337039844 0.16517018139263753 0

Lockheed Martin Gateway Habitat (Donatello MPLM)



Lockheed Martin Gateway Habitat (Donatello MPLM)

- Item Volume: 33.14 m³
- Vehicle Volume: 105.54 m³
- Usable Volume: 72.4 m³ (69%)

Space station node overall height	6.6
Space station node top diameter	2.58
Space station node body diameter	4.57
Space station node bottom diameter	2.18
Node cylinder length	4.8
Node eccentricity	'nil
Node taper angle	10.6
Node top cap height	0.2
Node bottom cap height	0.2
Space station node top angle	10.6
Space station node bottom angle	10.6
Space station node structural skin thickness	0.0127
Space station node TPS skin thickness	0.0254
Space station node IML volume	<Unbound>
Space station node HS grouping factor list	(list 0.0 0.103231 36337039844 0.165170181392637

Parametric Modeling: EXAMINE

- EXAMINE= Exploration Architecture Model for IN-space and Earth-to-orbit

- Integration with IDEA



Graphic not to scale

Description

Mars Phobos Habitat provides crew habitation for long-duration stays at Phobos. It includes an internal Shuttle-class airlock for EVAs.

Design Constraints/Parameters

Pressurized Vol.	78.0 m ³
Habitable Vol.	38.5 m ³
Atmospheric Pressure	101.4 kPa
Crew Capacity	4
Crewed Mission Duration	102 d
EOL Power Required	14 kW
Total battery energy storage	28 kW-h
Number of Batteries	3
Depth of Discharge	80 %
Power load during battery oper	11.6 kW
ECLSS Closure - Water	Partially Closed
ECLSS Closure - Air	Partially Closed
Habitat Structure	Rigid Cylinder
Habitat Length	6.31 m
Habitat Diameter	4.10 m
Mass Growth Allocation	20%
Project Manager's Reserve	1%

Category	Vol., m ³
Systems Volume	6.9
Crew Equipment	10.4
Utilization	4.1
Airlock	0.0
Dry Goods Storage	12.6
Water Storage	0.3
VOIDS	5.1
Total Non-Habitable Volume	39.5
Habitable Volume	38.5
Total Pressurized Volume	78.0

Category	Mass, kg
Structure	2,490
Protection	142
Propulsion	0
Power	630
Control (ACS/RCS)	0
Avionics	368
ECLSS	2,054
Air Subsystem	966
Water Subsystem	677
Food Processing	36
Human Accommodations	80
Other	367
EVA systems	1,151
Thermal Control System	720
Crew Equipment	1,633
Utilization	630
Growth	1,765
Radiation Protection (waterwall)(Not include	732
DRY MASS SUBTOTAL	12,316
Logistics	5,755
Food (Including Trays & Wraps)	433
Waste Collection (Fecal Canisters, Urine Prefilt	195
Personal Hygiene Kit	4
Hygiene Consumables	21
Clothing	10
Recreation & Personal Stowage	50
Wipes/Paper/Tissue (Housekeeping)	51
Trash Bags	13
Operational Supplies	40
Survival Kit	0
Sleep Accommodations	18
Health Care Consumables	26
Emergency Breathing Apparatus	5
Spares	4,125
Maintenance Items	762
ECLSS Consumables (Nominal + Contingen	383
Reserve and Residual Prop.	0
INERT MASS SUBTOTAL	18,454
Propellant	0
TOTAL WET MASS	18,454

Parametric Modeling: EXAMINE

- Integration of EXAMINE + IDEA

Step 1: Inputs

Open “VersionB_Sam_Gateway_Baseline” Excel file (Current version of EXAMINE)

Manipulate inputs listed below

“Sam Params” Sheet

Pressurized volume per crew (G2)

Habitat Geometry (G7-G14)

Crew Number (D18)

Nominal Mission Days (D19)

“Element 1” Sheet

Mass Growth Allowance (Column AE)

“Crew Accommodations” Sheet

Type of vehicle (F189), (Details and customization at V210-AH210)

Specific mass (F190), (Details and customization at V256-AI256)

Mass per crew member (F196)

Step 2: Outputs

“Sam Params” Sheet

Click “Calculate” on bottom left of Excel

Observe changes to following outputs

CORE GEOMETRY MODEL OUTPUTS			
Habitat Core Length	m		6.31
Habitat Core Surface Area	m ²		96.69
Habitat Core IML Volume (Required)	m ³		78.00
Habitat Core IML Volume (Calculated)	m ³		78.00
Fwd Dome Diameter	m		4.10
Fwd Dome Eccentricity	---		0.96
Fwd Dome Length	m		0.60
Fwd Dome Surface Area	m ²		15.45
Fwd Dome Volume	m ³		5.29
Core Cylinder/Conic/BiConic Max Diameter	m		4.10
Total Barrel Length	m		5.11
Total Barrel Surface Area	m ²		65.78
Total Barrel Volume	m ³		67.43
Conical Barrel Length (Conic/BiConic only)	m		0.00
Conical Barrel Surface Area (Conic/BiConic only)	m ²		0.00
Conical Barrel Volume (Conic/BiConic only)	m ³		0.00
Cylindrical Barrel Length (Cylinder/BiConic only)	m		5.11
Cylindrical Barrel Surface Area (Cylinder/BiConic only)	m ²		65.78
Cylindrical Barrel Volume (Cylinder/BiConic only)	m ³		67.43
Aft Dome Diameter	m		4.10
Aft Dome Eccentricity	---		0.96
Aft Dome Length	m		0.60
Aft Dome Surface Area	m ²		15.45
Aft Dome Volume	m ³		5.29
Vol press/Sw	m		0.25
Volumetric Efficiency	---		0.19

Export to CSV for use with IDEA	Vol., m ³	Rack Len	Mass
Systems Volume	6.833971	3.774402	4,393
Crew Equipment	10.43292	5.762104	1,544
Utilization	4.14	2.286522	630
Airlock	0	0	0
Dry Goods Storage	9.142485	5.049394	1,725
Water Storage	0.30137	0.166446	611
Voids	4.582407	2.530863	737
Total Non-Habitable Volume	35.43316		
Habitable Volume	42.56684		
Total Pressurized Volume	78		

Category	Mass, kg
Structure	2,475
Protection	142
Propulsion	0
Power	615
Control (ACS/RCS)	0
Avionics	368
ECLSS	2,054
Air Subsystem	966
Water Subsystem	611
Food Processing	36
Human Accommodations	80
Other	360
EVA systems	1,151
Thermal Control System	674
Crew Equipment	1,544
Utilization	630
Growth	1,725
Radiation Protection (waterwall)(Not included i	737

Step 3: Excel

Open “SAM_CSV_Examine” excel file

Click “Copy from EXAMINE” macro button

Save current file as macro-enabled workbook

Save a copy as a CSV

Step 4: IDEA

Load “DSG_Reference_Examine” from Utilities > Load Model from File

Expand name-generator-14597 and select space-station-node-configuration-type-4-class-0001

Find the “Excel +” submenu

Click “Excel configuration file name” and select “VersionB_Sam_Gateway_Baseline”

Make sure “Input sheet name” and “Excel param file type” are both set to “Sam Params”

Save and the close “VersionB_Sam_Gateway_Baseline” (which was previously opened)

Click “Show/hide excel sheet”

Navigate to space-station-node-configuration-type-4-class-0001 > Packaging > sam

Load the CSV version of “SAM_CSV_Examine” in the “Comma delimited components file name” area

Click “Add components from comma delimited file” to update IDEA

Right click “sam” branch and click “draw”

Right click “space-station-node-configuration-type-4-class-0001” and click draw

Adjust transparency of habitat to show internal items

Step 4: Parametric Sizing

Adjust inputs in “Sam Params” sheet in EXAMINE

Click Calculate

Transfer values to “SAM_CSV_Examine” macro-enabled workbook file with macro button

Save current file as macro-enabled workbook

Save a copy as a CSV

Click “Add components from comma delimited file” to update IDEA

Draw habitat and internal objects

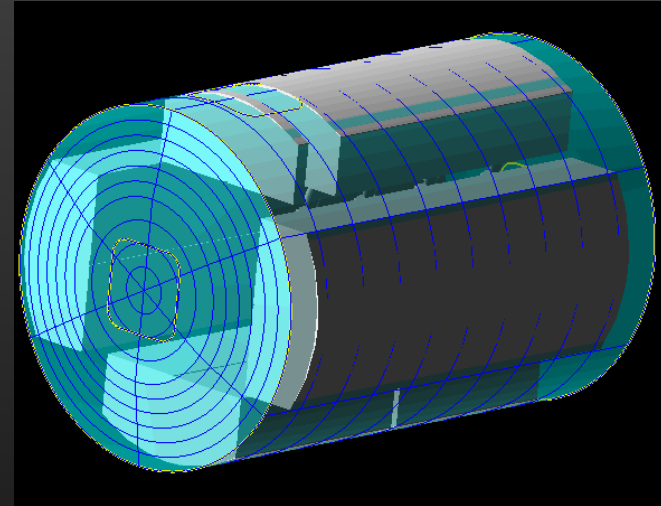
Results in IDEA

- 4 Crew, 30 Days

Item Volume: 35.67 m³

Vehicle Volume: 81.16 m³

Usable Volume: 45.49 m³ (56%)

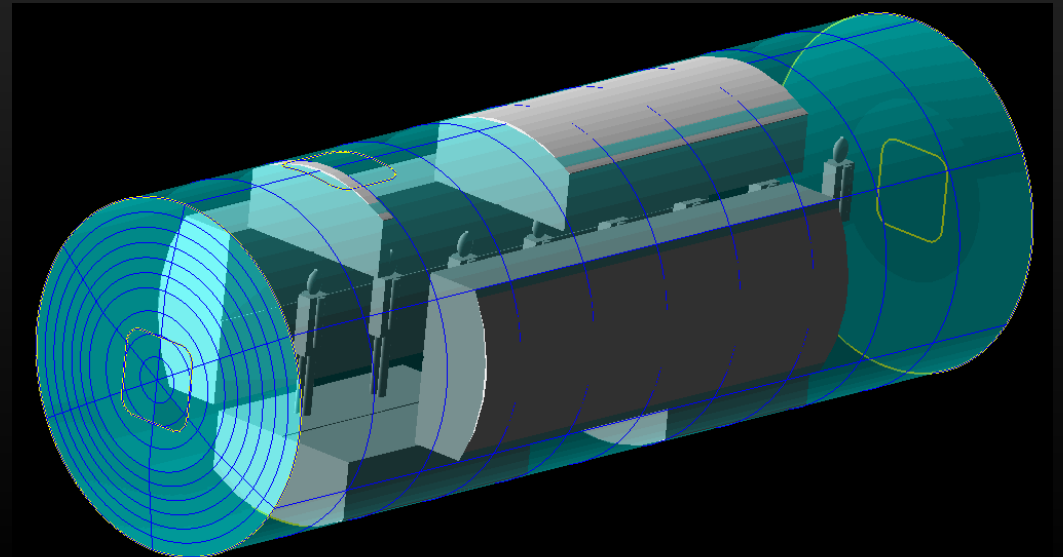


- 8 Crew, 60 Days

Item Volume: 42.18 m³

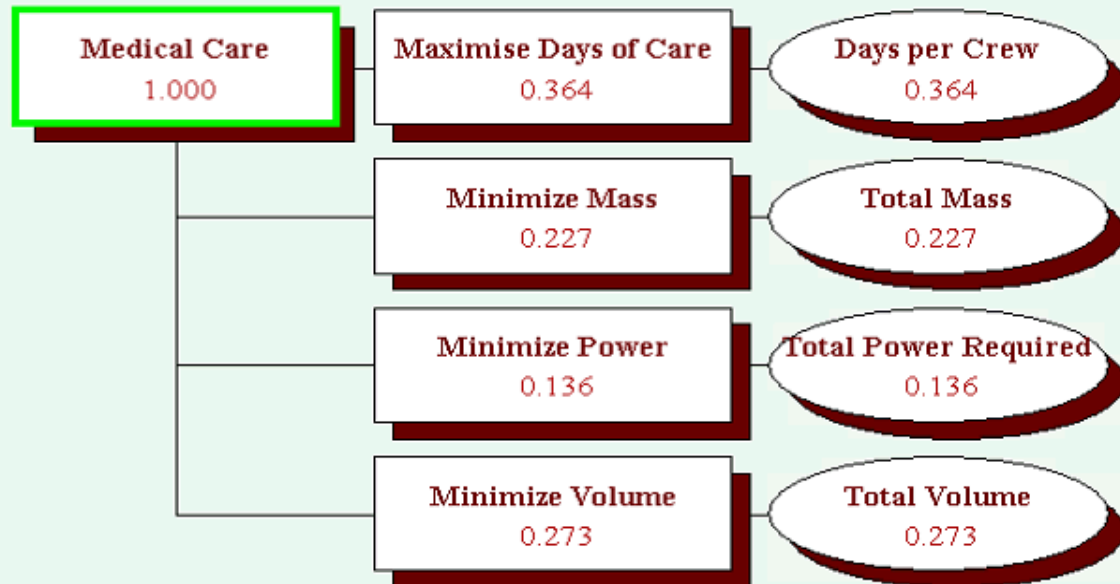
Vehicle Volume: 159.32 m³

Usable Volume: 117.14 m³ (74%)



Future Work

- Logical Decisions (Trade Study Software)



Ranking for Medical Care Goal

Alternative Utility



■ Maximise Days of Care
 ■ Minimize Volume
 ■ Minimize Mass
 ■ Minimize Power

Preference Set = NEW PREF. SET

Utility uncertainty summary for Medical Care Goal

Alternative	Mean	Std. Dev.	Median	Min.	5%P	95%P	Max.
Level 1	0.488	0.193	0.473	-0.001	0.203	0.868	0.989
Level 2	0.457	0.193	0.442	-0.032	0.172	0.837	0.958
Level 3	0.430	0.193	0.415	-0.058	0.145	0.810	0.931

Preference Set = NEW PREF. SET

International Astronautical Conference (2019)

Utilizing In-Space Assembly to Add Artificial Gravity Capabilities to the Deep Space Transport for Use on Mars Exploration Missions

Nicholas M. Houghton¹, Joseph Fulton², Alexander Mazarr³, Samuel Park⁴, Dr. Phillip Williams⁵

NASA Langley Research Center, Hampton, Virginia, 23681-2199

For decades, mitigation tactics have been explored to minimize the negative effects of microgravity on the human musculoskeletal and cardio-pulmonary system. Although significant progress has been made, there are still substantial medical hazards that must be addressed before deep space exploration missions can be safely performed. Skeletal muscle atrophy, orthostatic hypertension, and a loss of bone mineral density each contribute to harsh gravity field re-adaptation issues that are experienced when returning from a long duration stay in a microgravity environment. Artificial gravity vehicle concepts have long been considered as a solution to the problems posed by microgravity, and various experiments conducted in low earth orbit (LEO) have proven that artificial gravity created by centripetal acceleration can alleviate the detriments of microgravity. The most salient application of an artificial gravity vehicle (AGV) is for long duration exploration missions during which astronauts are exposed to microgravity for a period of 6 months or greater. However, an AGV fit to house humans for such missions would require a centrifuge exceeding 50 meters to produce the necessary gravity field without incurring a dangerously high rate of spin. The current assemble-then-launch process cannot support the launch of objects of such great length or mass. Opportunely, in-space assembly (ISA) provides the capability to assemble large, complex structures in space that do not have to adhere to the constraints of a launch vehicle. This study evaluates the technological gaps that can be overcome using in-space assembly to make artificial gravity vehicles a realistic and advantageous option for future human Mars exploration missions. NASA's Deep Space Transport (DST), the current Mars vehicle design concept, is introduced for use in comparison to an in-space assembled DST with artificial gravity capabilities. Conclusions about artificial gravity vehicles are drawn from the mass, cost, and architecture differences between the two vehicle designs.

Thank you

Mentor: Jeffrey Cerro

Organization: Vehicle Analysis Branch

Program Coordinators: Christine Dillard, Valerie Ellis, Christine Linsinbigler