Surface Habitats

Thales Alenia Space, Mr. S. Pelle

ESA-ESRIN, 16 January 2009

Pressurized rover

Functionalities

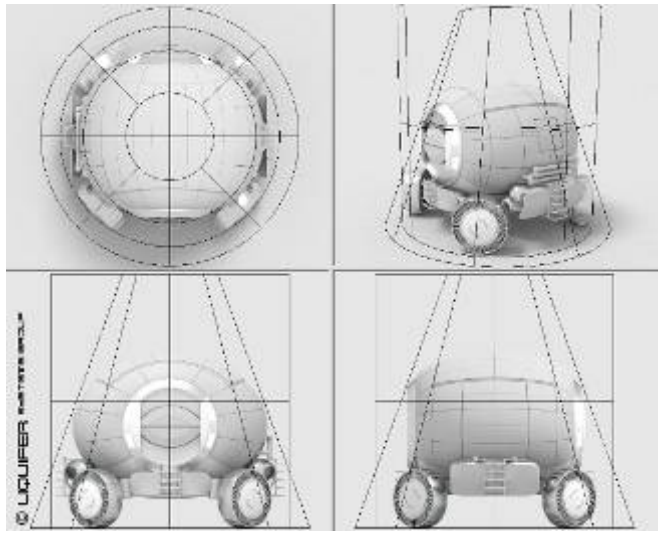
- Provide surface mobility capabilities
  - Range up to 1000 km
- Provide crew support and housing
  - 2 crew
  - 40 m^3
- Provide Lunar surface rescue capabilities
- Enable Science on Lunar Surface
- Support maintenance operations
- Protect the crew against Lunar environment
- Synergies with Mars exploration

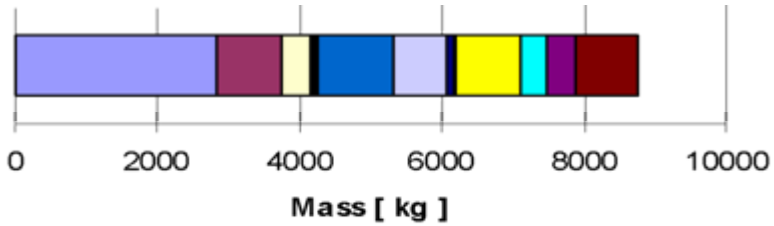
Pressurized rover

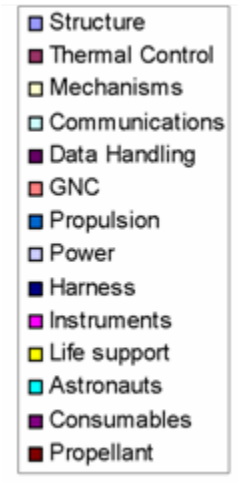
Detailed Design

Main characteristics:

- Mass at Launch: 6200 Kg
- Total wet mass: 9600 kg
- Launch envelope: h 4.4 m; Ø 6 m
- Habitable volume: 49 m³
- max heat load rejected: 10kW
- Lifetime:10 years



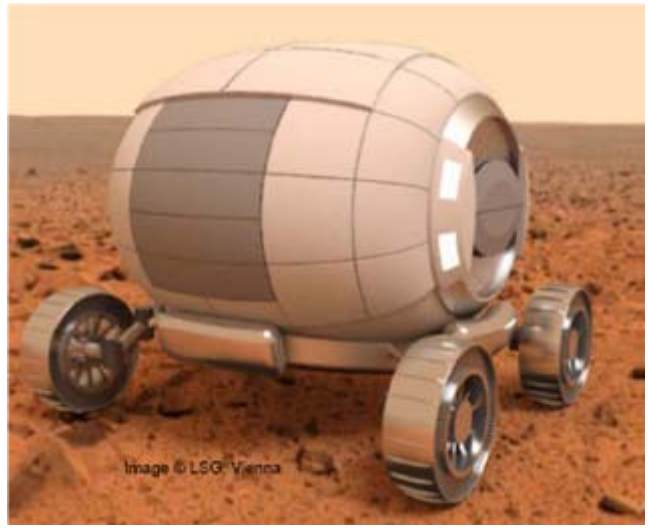


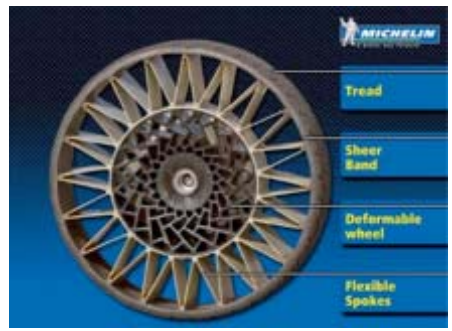


Pressurized rover

Subsystem description

- Avionics:
  - Autonomous navigation
  - Obstacle avoidance
  - Drive-by-wire
- Energy
  - Fuel Cell
  - Long-term cryogenic storage
- EVA Systems
  - Adv. Rear Entry Space Suit
  - Suitport
- ECLSS
  - CO_2 removal no water or air regeneration
  - Advanced Radiation Shielding
  - Dust Mitigation Systems
- Mechanics On-board drilling systems
- Mobility
  - Electromagnetic Suspension
  - Non-pneumatic Tires





Pressurized rover

Capability Assessment

- Integrated storm shelter for SPE
- Lunar Surface Access
  - 2 Suitports
  - 1 docking hatch
  - 1 sample airlock
- Design features
  - High TRL subsystems
  - Strong synergies with Mars Pressurised Rover
- Operations in (42 days sortie mission):
  - 20 days driving
  - 22 days of local exploration
  - 6 h EVA time

Pressurized rover

Development Plan

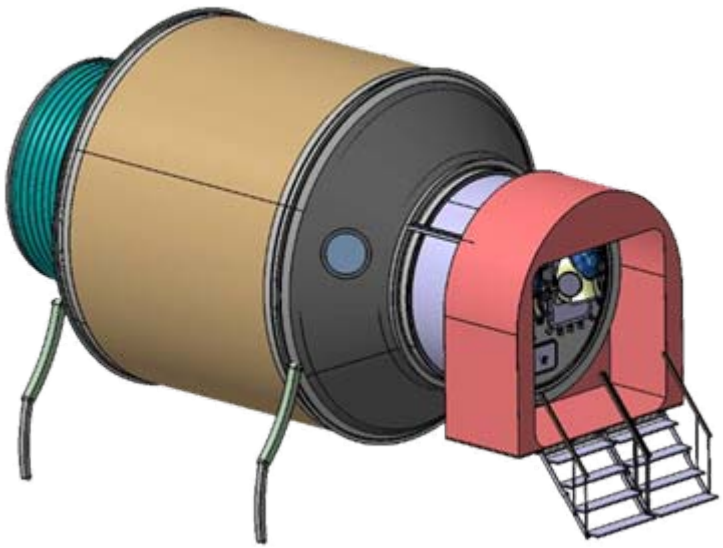
- The development of the pressurised lunar rover shall be scheduled with the objective of a launch in the beginnings of 2020's in order to be available for Phase 2 operations

Pressurised Lunar Rover Development Schedule								
	2013	2014	2015	2016	2017	2018	2019	2020
Phase A								
Phase B								
Phase C/D								
Contingency								
Launch Campaign								
Launch								

Mini-Hab

Functionalities

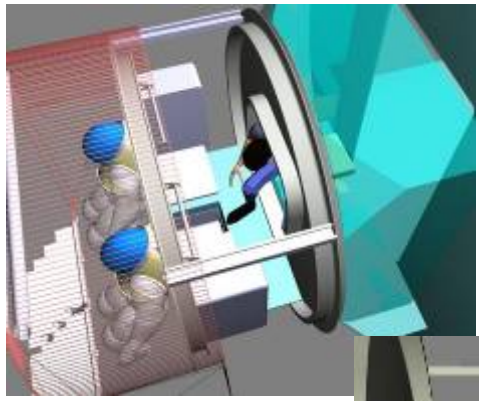
- Provide crew support and housing
  - 2 crew
  - Up to 42 days
  - provide the crew with a safe operating and living environment which supports eating, sleeping, relaxation, health care, personal hygiene
- Enable EVA for 2 astronaut
- Enable Science on Lunar Surface
- Can be relocated on different sites
- Possibility of re-using the same habitat for several sortie missions

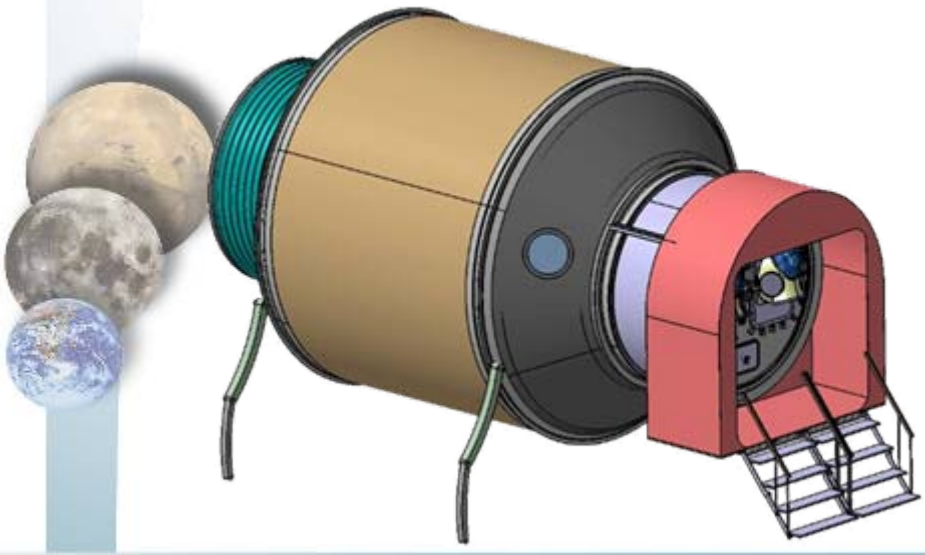


Mini-Hab

Detailed Design

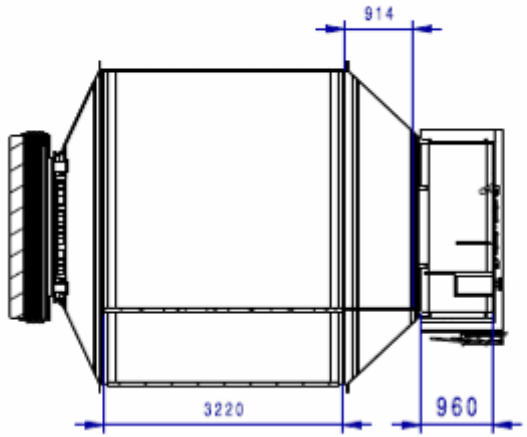
- Main characteristics:
  - Mass at Launch: 7000 Kg
  - Overall length: 6.8 m
  - External diameter: 4.2 m
  - Habitable volume: 40 m³
  - Lifetime:10 years





Mini-Hab

Subsystems description



- Structures
  - Cylinder with two radial cones
  - Made of Aluminum alloy
- EVA Systems
  - Adv. Rear Entry Space Suit
  - Suitport
- Energy
  - External sources
  - Secondary Power: Lithium-Ion batteries (24 h independency)
- ECLSS
  - Open Loop. Resources provided by logistic lander
    - 1 logistic lander for 14 days mission
    - 2 lander landers for 42 days mission
- Thermal Control
  - Deployable radiators

Mini-Hab

Capability Assessment

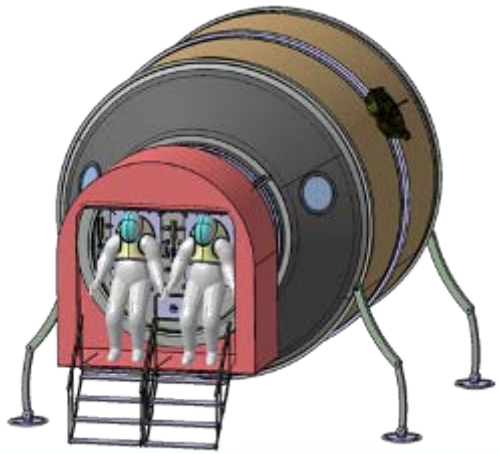
- Design features
  - High TRL subsystems
  - Strong synergies with ISS modules
- Access to lunar Surface
  - 2 suitlock
  - 1 scientific airlock
  - Pressurised mating system (tunnel) to berth with Lunar rover, PLM or other lunar base elements
- Survive lunar night
  - Needs of external power source (NPP)
- Operations:
  - Can support 14 or 42 days missions
  - EVA can be performed every day by 2 astronauts

Mini-Hab

Development Plan

- The first possible utilisation of Mini-Hab is beginning of Phase 2. It means that for early 2020's Mini-Hab must be available

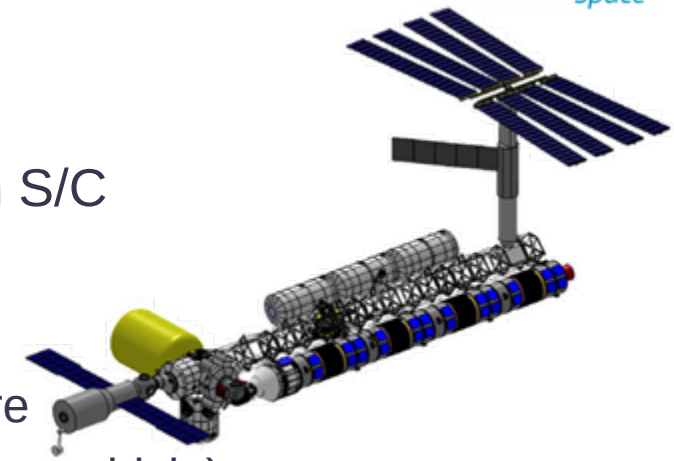
Mini Hab Development plan						
	2015	2016	2017	2018	2019	2020
Phase A						
Phase B						
Phase C/D						
Contingency						
Launch Campaign						
Launch						



In-Space Habitats

Thales Alenia Space, Ms. I.Zoccali

ESA-ESRIN, 16 January 2009



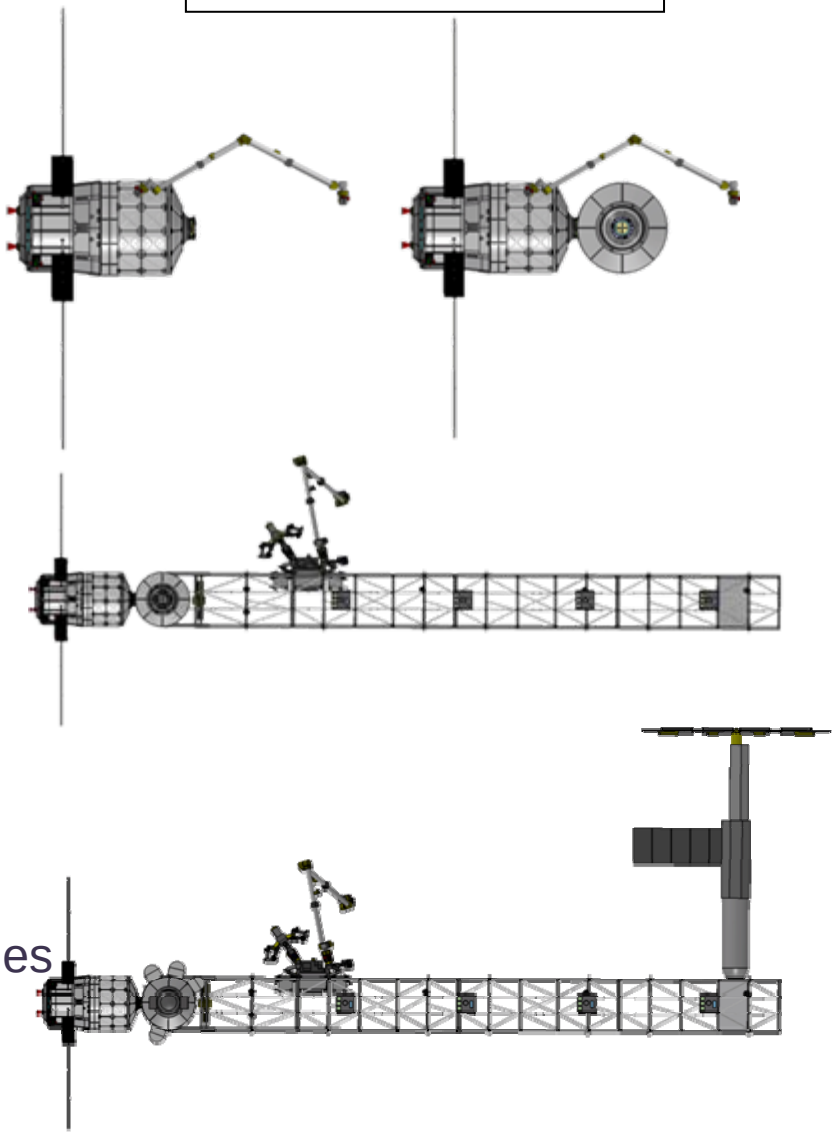
Functionalities

- Assembly Earth-Mars and Earth-Moon S/C
- Staging area
  - Moon and Mars spacecraft checkout
  - Orbital station-keeping before departure
  - Space Tug (orbital altitude/plane change vehicle) parking
- Mechanics facility
  - Develop capability to operate with astronauts and advanced space robots throughout the entire Earth-Moon system and Mars for long periods of time.
- Propellant depot
  - cryogenic transportation systems re-fueling
- Bridging point between the chemical propulsion vehicles from Earth and the high power nuclear vehicles for long duration mission

LEO I/S Detailed Design

- **Service Module**
  - Supply initial resources
  - Station-keeping
- **Node**
  - Connecting modules
  - Habitable capabilities
- **Truss**
  - Attachment points - SA and radiators
  - Support mobile transporter rails
- **Mobile Robotic Platform**
  - Grasp the modules with the Arm
  - Move modules allowing assembly
- **Solar Arrays and Radiators**
  - power and heat rejection capabilities
- **Airlock**
  - Enable extra vehicular activities

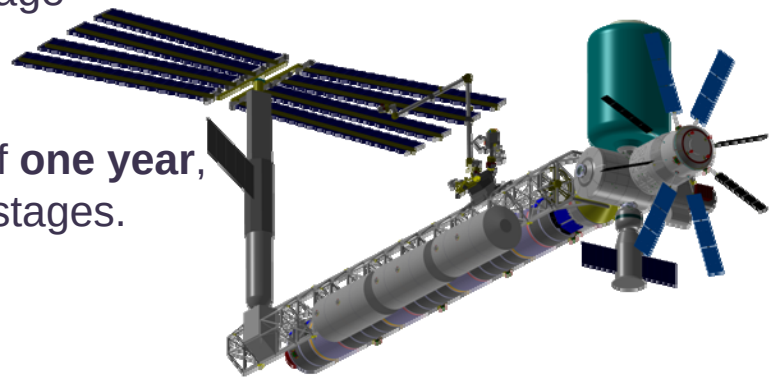
Assembly Sequence

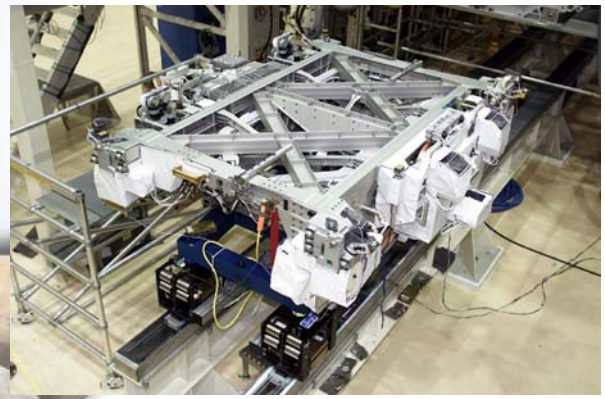


LEO I/S Assessment Capabilities

Re-fuel

- **Concept 1**: 18t fuel after storage period of **3 months**, cryo fuel amount to re-fuel **one** transfer stage
  - Mass of LOX tank incl. fuel: ~16t
  - Mass of LH2 tank incl. fuel: 3.5t
- **Concept 2**: 54t fuel after storage period of **one year**, cryo fuel amount to re-fuel **three** transfer stages.
  - Mass of LOX tank incl. fuel: ~49t
  - Mass of LH2 tank incl. fuel: ~ 14t





Robotics

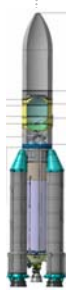
- Remote Manipulator System (Robotic Arm)
  - Can manipulate (at controlled speeds) payloads from 50-100t
- Mobile Base/Transporter System
  - Operable by crew members located in LEO station or remotely by operators on the ground
- Dexterous Tool Set for Servicing, Refueling and Maintenance

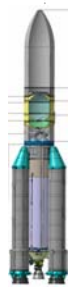
Tourism

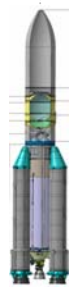
- use of an Inflatable Module
  - comfortable and private ‘cocoon’ cabin
  - flexible, expandable wardroom table
- vista point ‘cupola-like’

LEO I/S Building Scenario

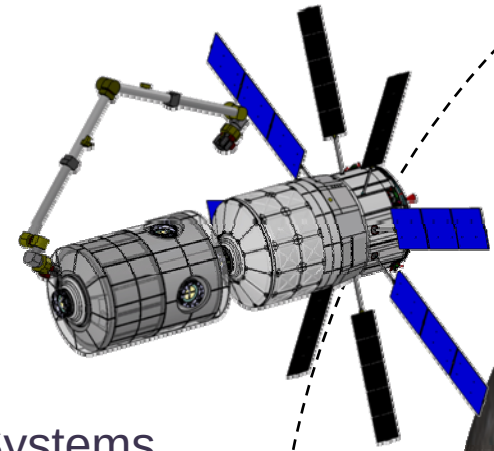
Launcher	Elements			Launch Date
50 t class	Service Module + Robotic Arm	Node	ATV Service Module	2018
	21000	16000	Up to 8000	
50 t class	Truss	Robotic Mobile	ATV Service Module	2019
	17500	1700	Up to 8000	
50 t class	Solar Panel + Radiators	Airlock + Truss	ATV Service Module	2020
	8200	7000	Up to 8000	

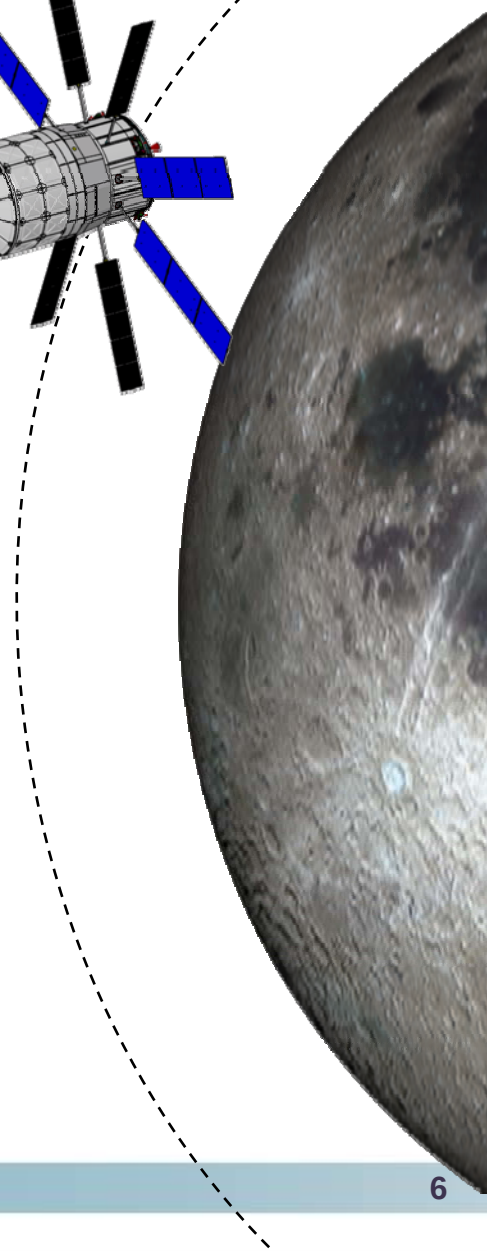






LLO Space Station (LSS)



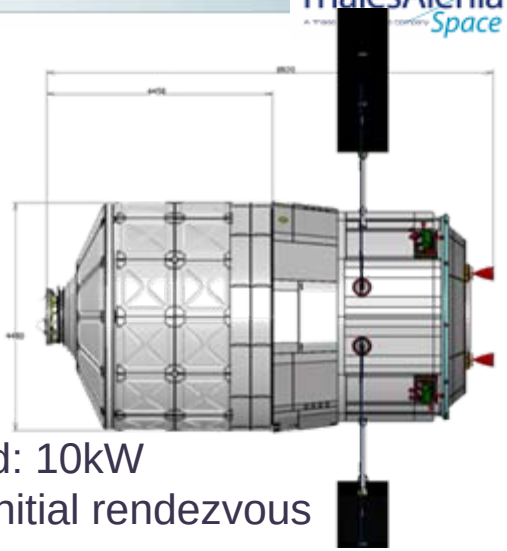


Functionalities

- Provide docking capabilities for:
  - Transfer Stages
  - Landers and Ascent Vehicles
  - Crew Transportation and Rescue Systems
- Provide crew support and housing
- Provide Lunar surface rescue capabilities
- Supply services to international partners meeting in LLO:
  - Power
  - Attitude Control
  - Communications
  - Re-fuelling
- Enable Science in Low Lunar Orbit

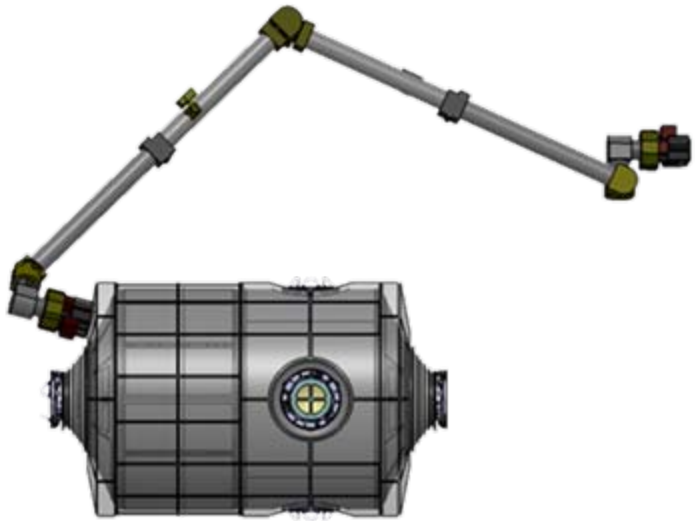
LSS Detailed Design

Service Module



- Main characteristics:
  - Mass at Launch: 14600 kg
  - Overall length: 10 m
  - External diameter: 4.5 m
  - Habitable volume: 10 m³
  - 4 solar wings: 40 m² → installed power: 10 kW
  - 4 radiators arrays: 40 m² → max heat load rejected: 10kW
  - 3 tons of propellants for LSS station-keeping and initial rendezvous
  - Lifetime:10 years

Node



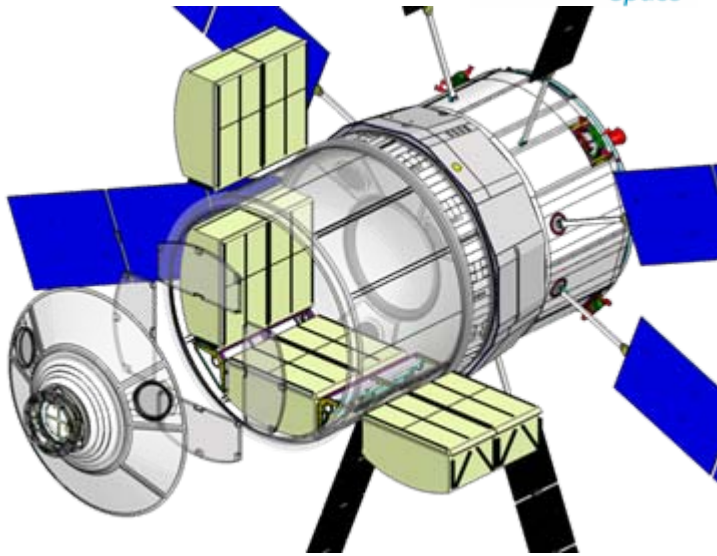
- Main characteristics:
  - Mass at Launch: 13400 kg
  - Overall length: 7 m
  - External diameter: 4.4 m
  - Habitable volume: 23 m³
  - Docking ports:6
  - Lifetime:10 years

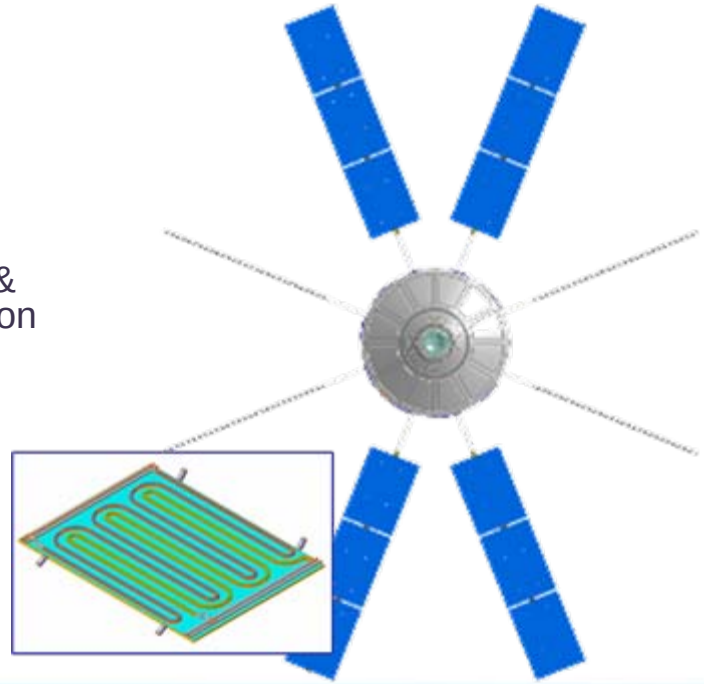
Arm

- Main characteristics:
  - Mass at Launch: 1100 kg
  - 7 degrees of freedom and 14m reach
  - Operable by crew members in LSS or remotely by operators on the ground

Service Module

- Structures & Mechanisms
  - External unpressurized compartment – S/Ss
  - Internal pressurized bay – Racks
  - IBDM
- Propulsion
  - 4 OMCS Bi-propellant Main Engines
  - 28 ACS Bi-propellant thrusters, 4 MON/MMH tanks
- GN&C
  - Star Trackers, IMUs, Telegoniometer, Videometer, LIDAR
  - 12 Hydrazine RCS thrusters, 4 N_2H_4 tanks
- Power
  - deployable, sun-tracking arrays
  - PVA: light rigid panels - “thin” GaAs TJ cells
  - Secondary Power: Litium-Ion batteries
- ECLS
  - Atmosphere Control & Supply, Temperature & Humidity Control, Fire Detection & Suppression
- Thermal Control
  - deployable radiators, 3 panels per wing, both sides radiating
  - Fluid vector: HFE-7300, Heat rejection modulated with valve
- Communications & Data Handling
  - S/Ka-band, direct Earth 10Mbit/s
  - Distributed CMUs

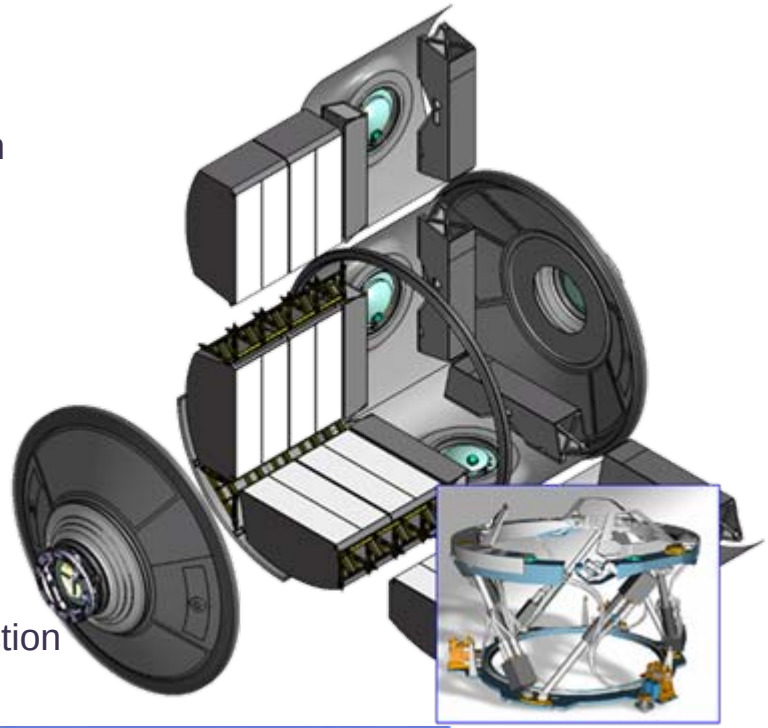


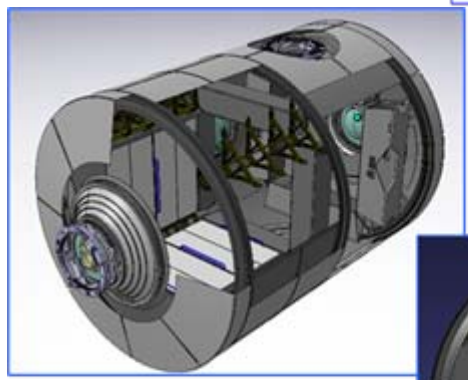


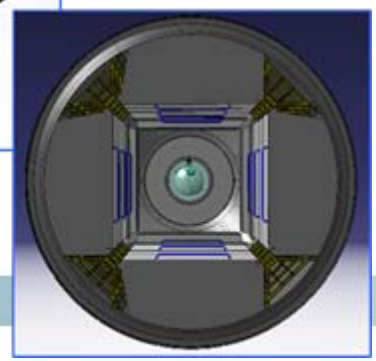
LSS Subsystems Description

Node

- Structures & Mechanisms
  - Meteoroids and Debris shielding system
  - Racks
  - IBDM
  - Flight Releasable Grapple Fixture - Arm
- Power
  - Power Conversion Distribution Units
  - Nominal and emergency illumination
  - Utility Outlet Panels
- ECLS
  - Atmosphere Revitalization System
- Thermal Control
  - Water loops coupled with SM heat rejection
- Data Handling
  - Space wire
  - Master Command Control
  - distributed Monitoring units
- Audio & Video
  - Space wire
  - Caution & Warning
  - Audio Terminal Units
  - Internal and External Video Cameras
  - Video Switching Unit
  - Video Display Unit



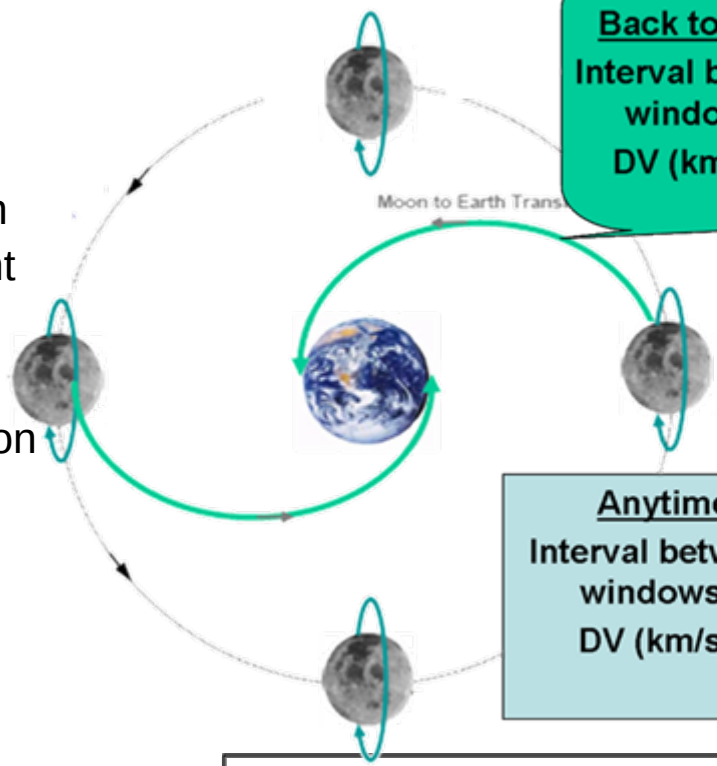




LSS Assessment Capabilities

Any time return:

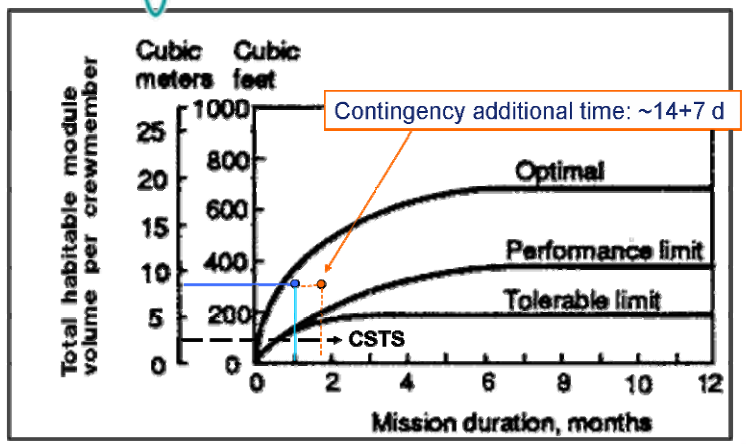
- Option1: refuel the crew transportation system
  - tanks oversized by design
  - extra dry mass every flight
- Option 2: provide staging post for a propulsion stage
  - docking/berthing system on the back of the crew transportation system, carried in every flight.



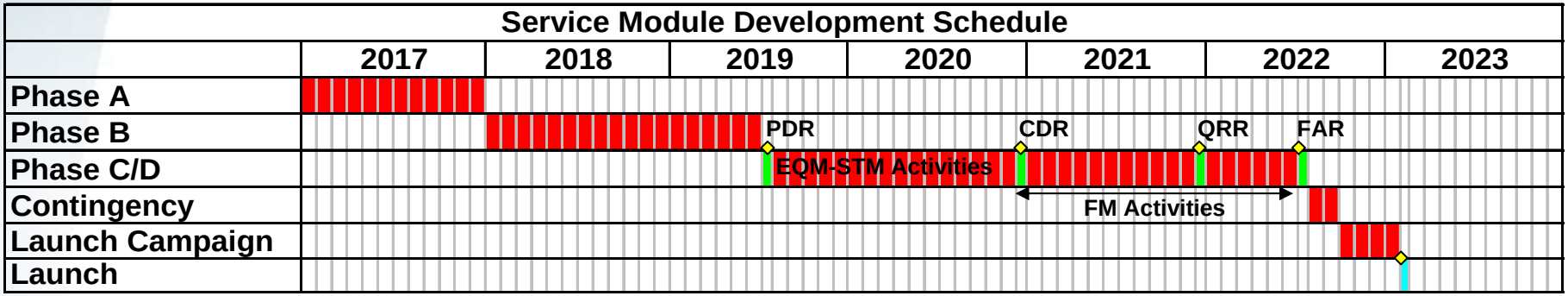
Safe haven:

- Habitable Volume: 33 m^3
- Crew: max 4 Astronauts
- Mission Duration: 1 month

→ Dedicated rack on the Service Module to contingency food and clothes stowage.

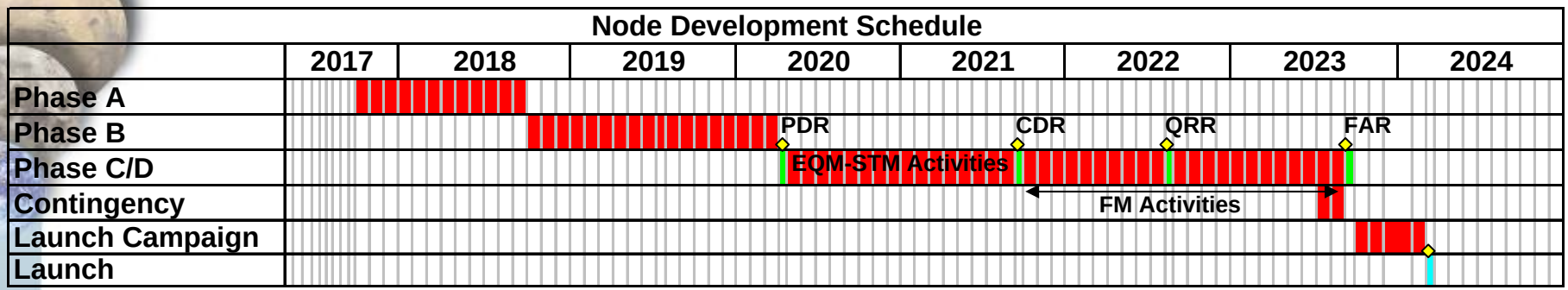


Service Module

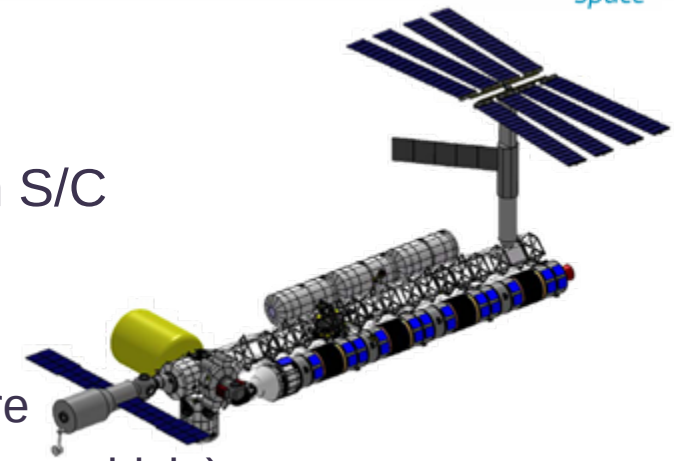


Duration: 1571 days

Node



Duration: 1623 days



Functionalities

- Assembly Earth-Mars and Earth-Moon S/C
- Staging area
  - Moon and Mars spacecraft checkout
  - Orbital station-keeping before departure
  - Space Tug (orbital altitude/plane change vehicle) parking
- Mechanics facility
  - Develop capability to operate with astronauts and advanced space robots throughout the entire Earth-Moon system and Mars for long periods of time.
- Propellant depot
  - cryogenic transportation systems re-fueling
- Bridging point between the chemical propulsion vehicles from Earth and the high power nuclear vehicles for long duration mission

LEO I/S Detailed Design

ThalesAlenia Space

Service Module
- Supply initial resources
- Station-keeping

Node
- Connecting modules
- Habitable capabilities

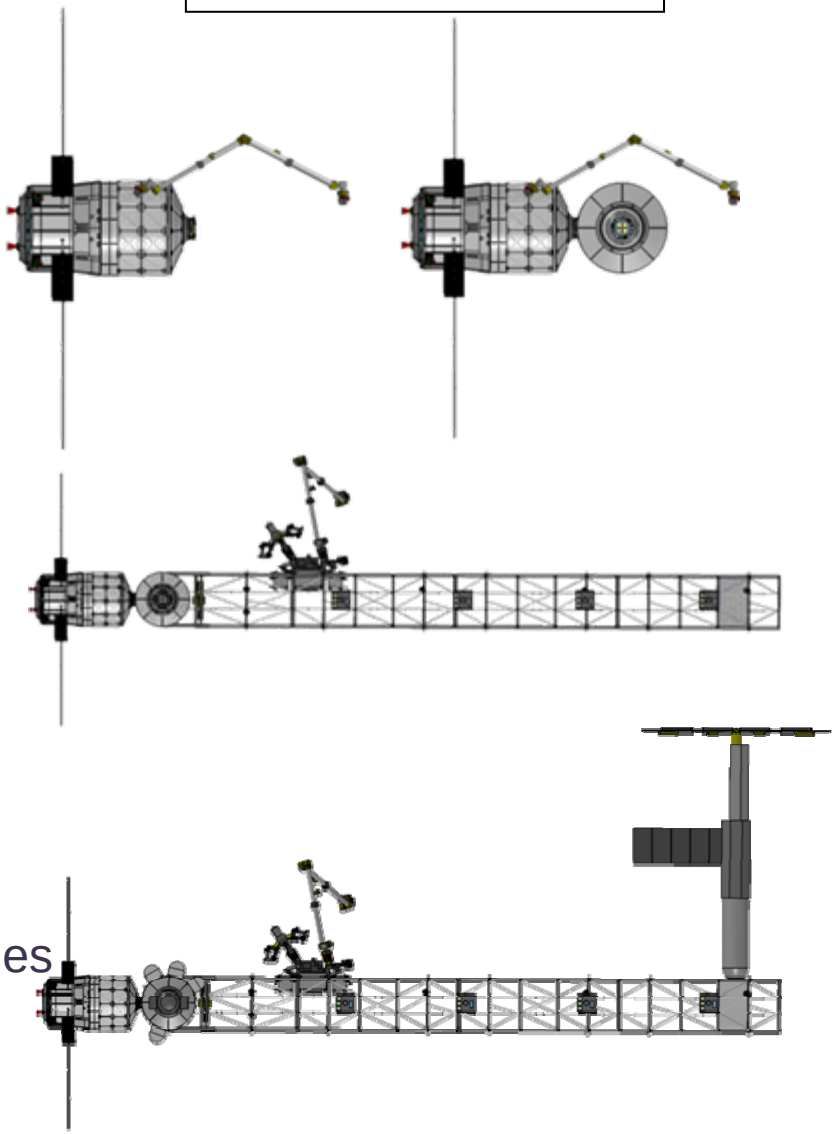
Truss
- Attachment points - SA and radiators
- Support mobile transporter rails

Mobile Robotic Platform
- Grasp the modules with the Arm
- Move modules allowing assembly

Solar Arrays and Radiators
- power and heat rejection capabilities

Airlock
- Enable extra vehicular activities

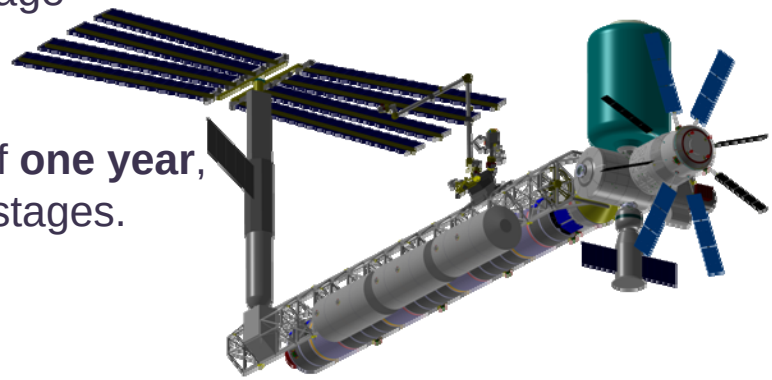
Assembly Sequence

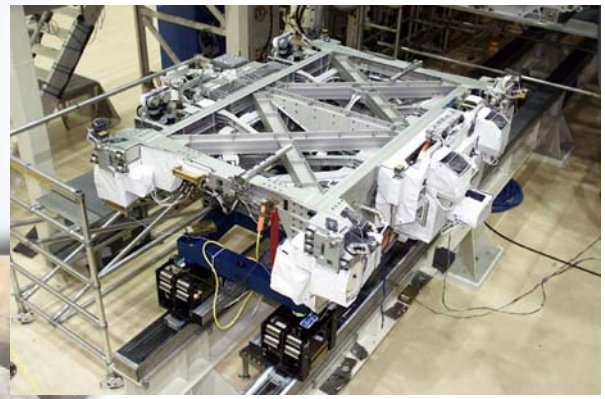


LEO I/S Assessment Capabilities

Re-fuel

- **Concept 1**: 18t fuel after storage period of **3 months**, cryo fuel amount to re-fuel **one** transfer stage
  - Mass of LOX tank incl. fuel: ~16t
  - Mass of LH2 tank incl. fuel: 3.5t
- **Concept 2**: 54t fuel after storage period of **one year**, cryo fuel amount to re-fuel **three** transfer stages.
  - Mass of LOX tank incl. fuel: ~49t
  - Mass of LH2 tank incl. fuel: ~ 14t





Robotics

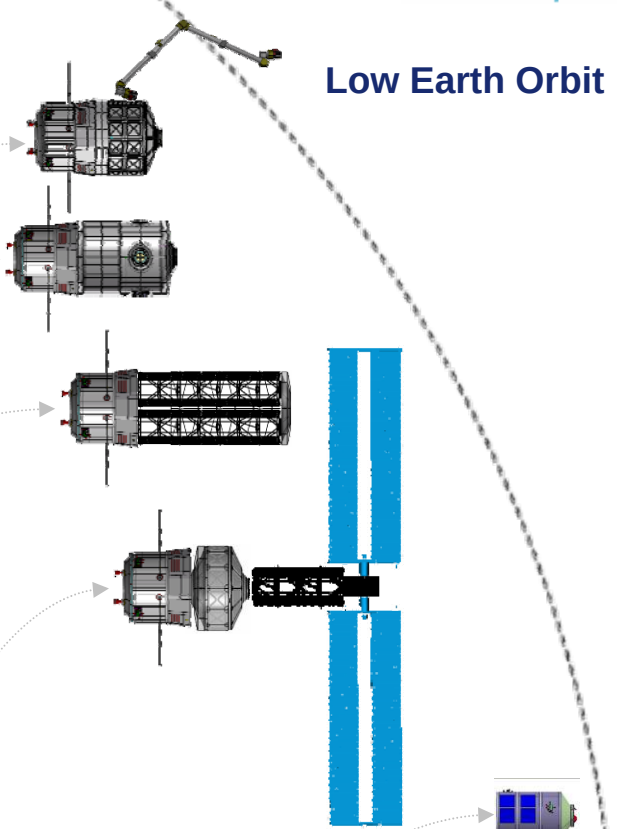
- Remote Manipulator System (Robotic Arm)
  - Can manipulate (at controlled speeds) payloads from 50-100t
- Mobile Base/Transporter System
  - Operable by crew members located in LEO station or remotely by operators on the ground
- Dexterous Tool Set for Servicing, Refueling and Maintenance

Tourism

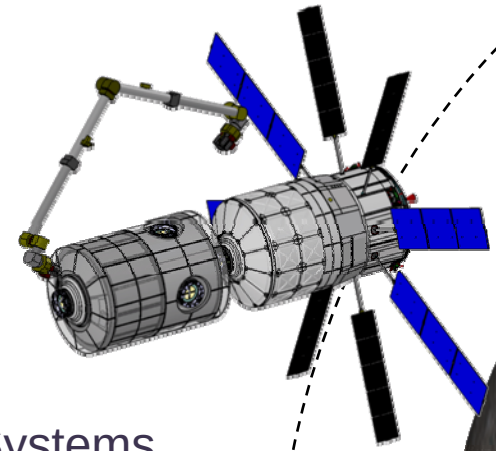
- use of an Inflatable Module
  - comfortable and private ‘cocoon’ cabin
  - flexible, expandable wardroom table
- vista point ‘cupola-like’

LEO I/S Building Scenario

Launcher	Elements			Launch Date
50 T class	Service Module + Robotic Arm	Node	ATV Service Module	2018
	21000	16000	Up to 8000	
50 T class	Truss	Robotic Mobile	ATV Service Module	2019
	8.75 x 4 x 500 = 17500	1700	Up to 8000	
50 T class	Solar Panel + Radiators	Airlock + Truss (2m)	ATV Service Module	2020
	8200	7000	Up to 8000	



LLO Space Station (LSS)

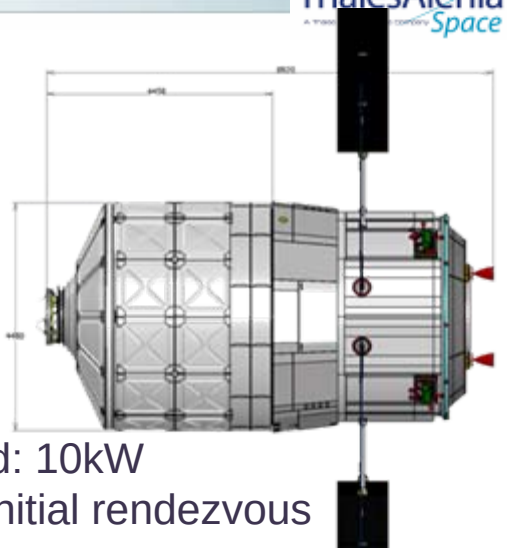


Functionalities

- Provide docking capabilities for:
  - Transfer Stages
  - Landers and Ascent Vehicles
  - Crew Transportation and Rescue Systems
- Provide crew support and housing
- Provide Lunar surface rescue capabilities
- Supply services to international partners meeting in LLO:
  - Power
  - Attitude Control
  - Communications
  - Re-fuelling
- Enable Science in Low Lunar Orbit

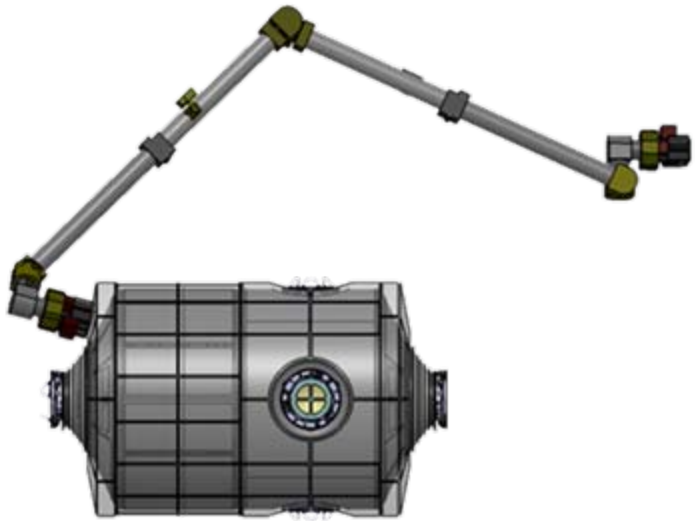
LSS Detailed Design

Service Module



- Main characteristics:
  - Mass at Launch: 14600 Kg
  - Overall length: 10 m
  - External diameter: 4.5 m
  - Habitable volume: 10 m³
  - 4 solar wings: 40 m² → installed power: 10 kW
  - 4 radiators arrays: 40 m² → max heat load rejected: 10kW
  - 3 tons of propellants for LSS station-keeping and initial rendezvous
  - Lifetime:10 years

Node



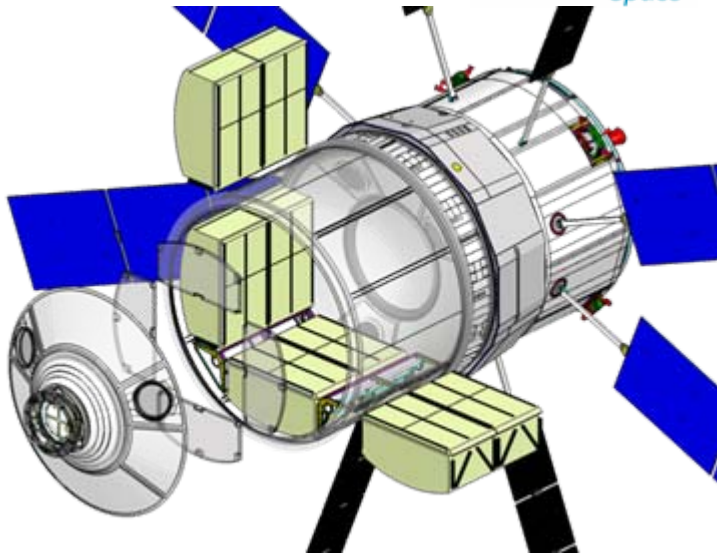
- Main characteristics:
  - Mass at Launch: 13400 Kg
  - Overall length: 7 m
  - External diameter: 4.4 m
  - Habitable volume: 23 m³
  - Docking ports:6
  - Lifetime:10 years

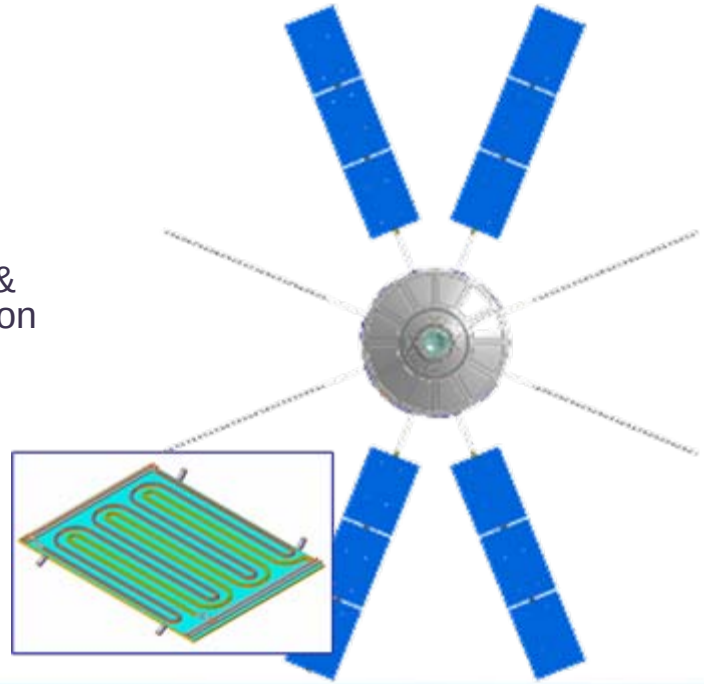
Arm

- Main characteristics:
  - Mass at Launch: 1100 Kg
  - 7 degrees of freedom and 14m reach
  - Operable by crew members in LSS or remotely by operators on the ground

Service Module

- Structures & Mechanisms
  - External unpressurized compartment – S/Ss
  - Internal pressurized bay – Racks
  - IBDM
- Propulsion
  - 4 OMCS Bi-propellant Main Engines
  - 28 ACS Bi-propellant thrusters, 4 MON/MMH tanks
- GN&C
  - Star Trackers, IMUs, Telegoniometer, Videometer, LIDAR
  - 12 Hydrazine RCS thrusters, 4 N_2H_4 tanks
- Power
  - deployable, sun-tracking arrays
  - PVA: light rigid panels - “thin” GaAs TJ cells
  - Secondary Power: Litium-Ion batteries
- ECLS
  - Atmosphere Control & Supply, Temperature & Humidity Control, Fire Detection & Suppression
- Thermal Control
  - deployable radiators, 3 panels per wing, both sides radiating
  - Fluid vector: HFE-7300, Heat rejection modulated with valve
- Communications & Data Handling
  - S/Ka-band, direct Earth 10Mbit/s
  - Distributed CMUs

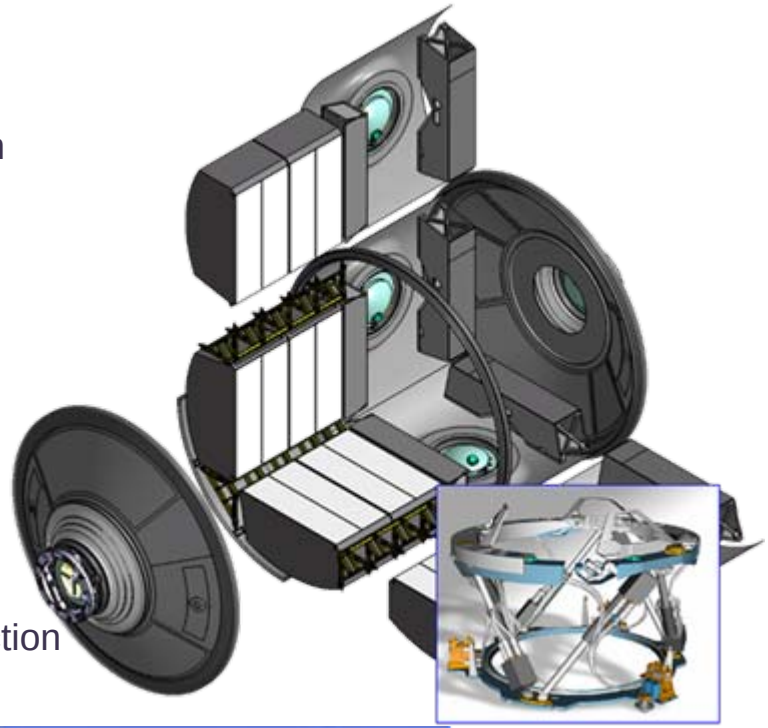


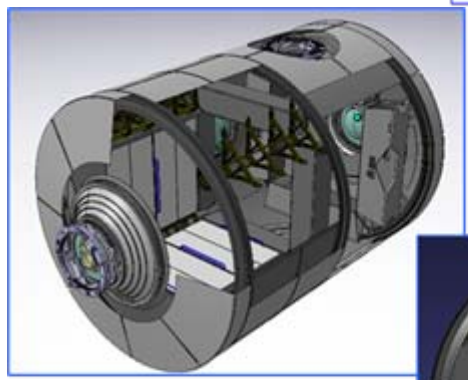


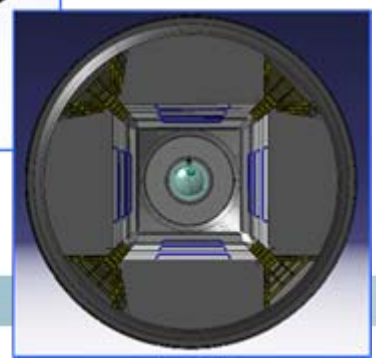
LSS Subsystems Description

Node

- Structures & Mechanisms
  - Meteoroids and Debris shielding system
  - Racks
  - IBDM
  - Flight Releasable Grapple Fixture - Arm
- Power
  - Power Conversion Distribution Units
  - Nominal and emergency illumination
  - Utility Outlet Panels
- ECLS
  - Atmosphere Revitalization System
- Thermal Control
  - Water loops coupled with SM heat rejection
- Data Handling
  - Space wire
  - Master Command Control
  - distributed Monitoring units
- Audio & Video
  - Space wire
  - Caution & Warning
  - Audio Terminal Units
  - Internal and External Video Cameras
  - Video Switching Unit
  - Video Display Unit



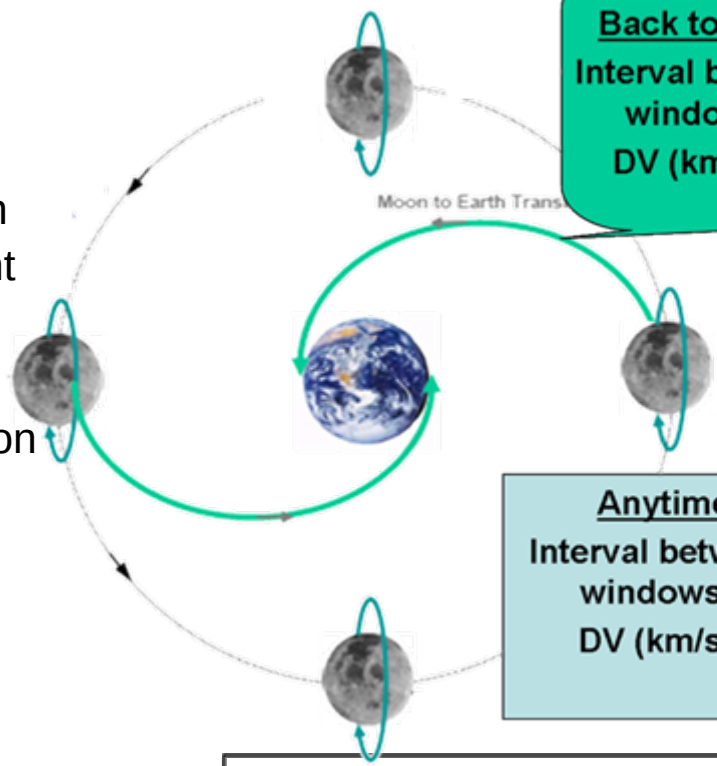




LSS Assessment Capabilities

Any time return:

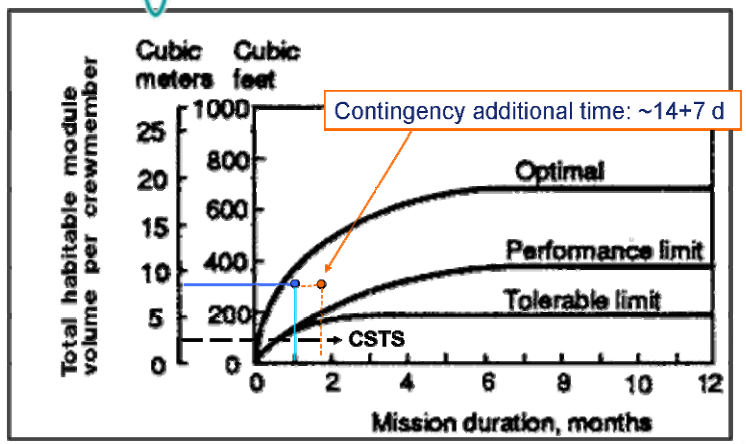
- Option1: refuel the crew transportation system
  - tanks oversized by design
  - extra dry mass every flight
- Option 2: provide staging post for a propulsion stage
  - docking/berthing system on the back of the crew transportation system, carried in every flight.



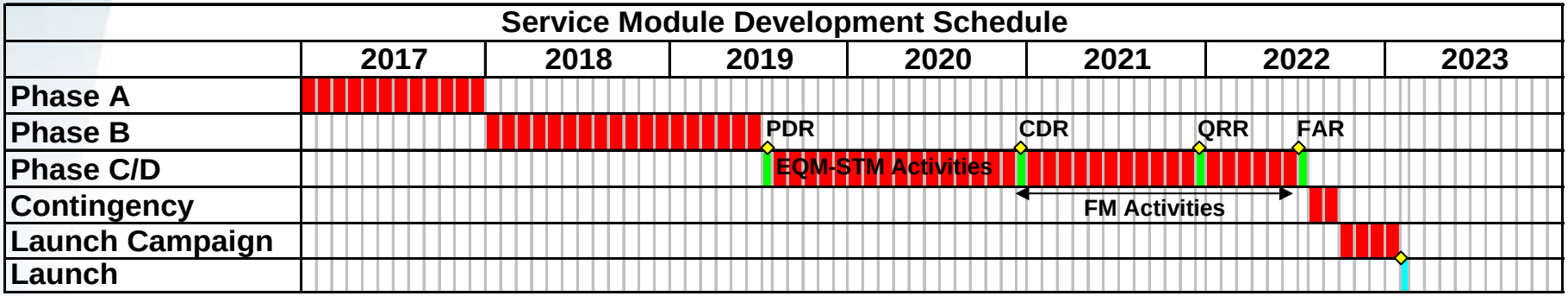
Safe haven:

- Habitable Volume: 33 m3
- Crew: max 4 Astronauts
- Mission Duration: 1 month

→ Dedicated rack on the Service Module to contingency food and clothes stowage.

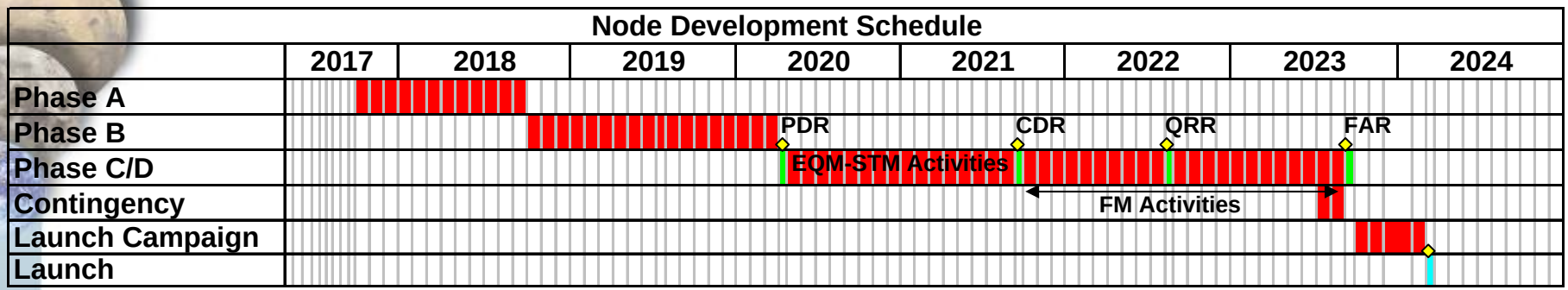


Service Module



Duration: 1571 days

Node



Duration: 1623 days