

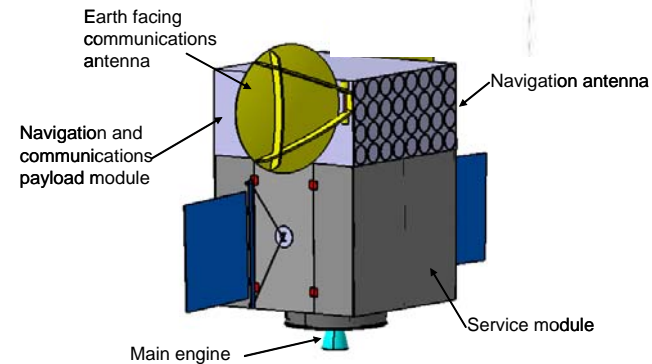
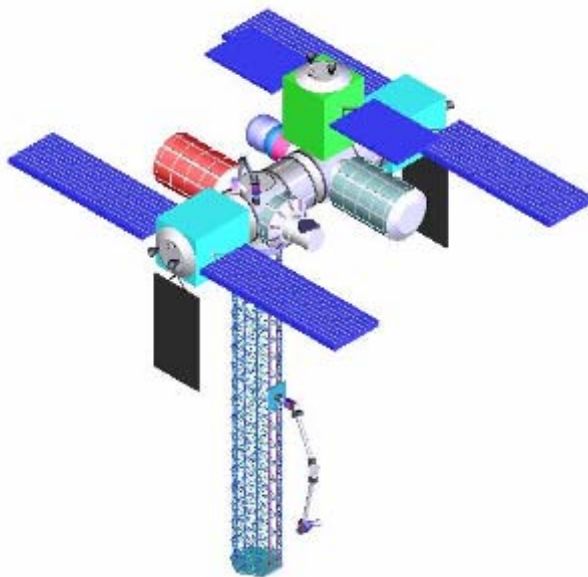
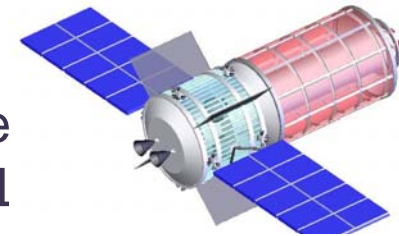


# **Human Operations In LEO**

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- **LEO Man Tended Station**
- Lunar Scientific Orbiter
- Moon Communication/Navigation Satellite
- Assembly & Servicing Manned Station in L
- Mars Transit Hab
- Mars Scientific Orbiter
- Mars Communication Relay Satellites



- The minimum LEO I/F configuration is a combination of Service Module, which provides all the needed resources, and a Research Module Habitation/Laboratory), similarly to the old MTFE concept.
- Launch scenario: the two modules on a single A5 launch.
- Crew size of 3. Crew visits are periodic, lasting 15-30 days every 6-12 months (TBC).
- Pressurized volume: 25 m<sup>3</sup> per crew member.



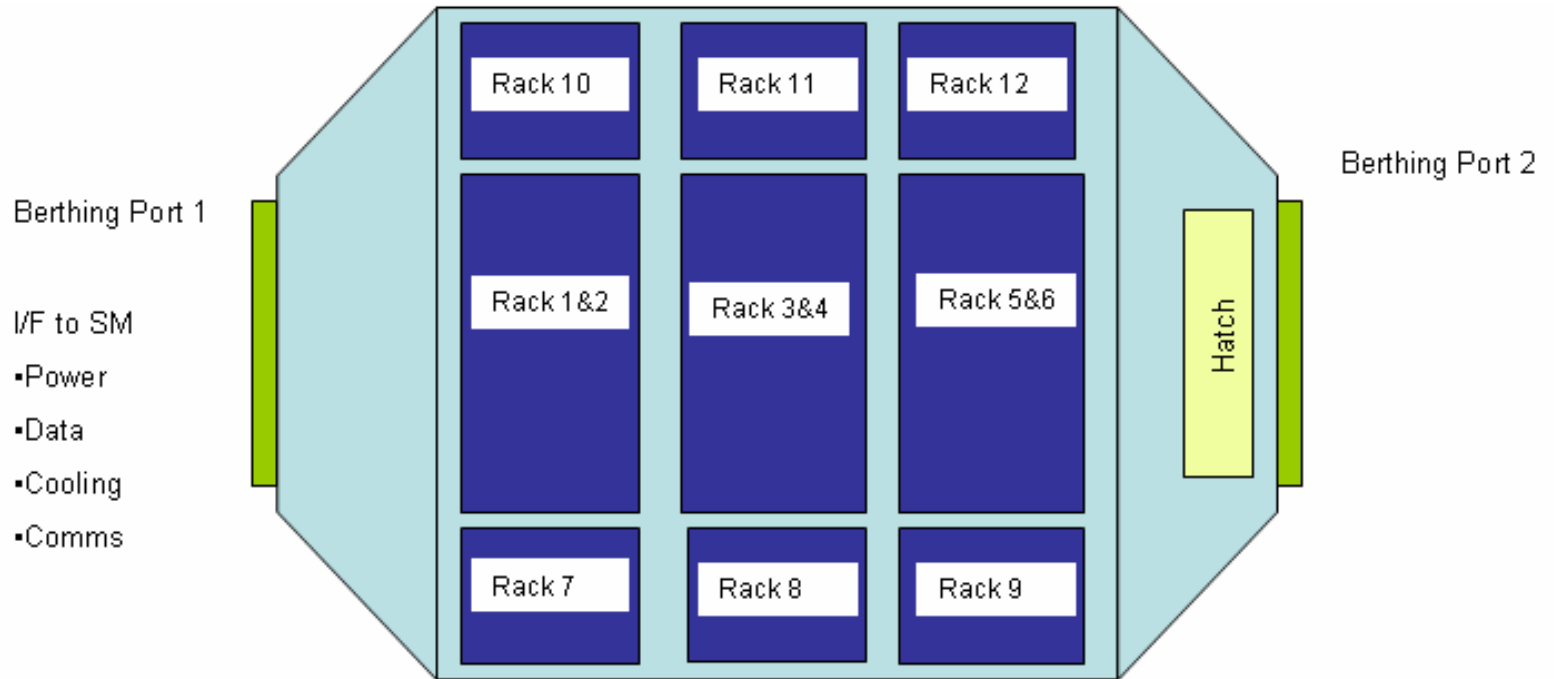
- Research Module subsystem requirements:

Subsystems	IPRS's
DMS, EPDS, TCS, ECLSS, DMS, Comms, Video, Illumination	5
Harness, Lines, Air Ducts, ECLSS & TCS valves	Distributed in stand offs and cone areas
Atmosphere Revitalization (ARES)	1,3
Liquid & Waste Management System	1,25
Personal Hygiene, Health, Galley	0,75
Total	~ 9

*IPRS: International Payload Rack Standard (1.57 m<sup>3</sup>)*



- Research Module IPRS's Accommodation (similar to LSS Node-Hab designed by Astrium D):



- Research Module Mass Budget:

Dry mass contributions	Without Margin	Margin		Total	% of Total Dry
		%	kg	kg	
Structure	4909.09 kg	10.00	490.91	5400.00	48.47
Thermal Control	500.00 kg	10.00	50.00	550.00	4.94
Mechanisms	500.00 kg	10.00	50.00	550.00	4.94
Crew Accomodation	227.27 kg	10.00	22.73	250.00	2.24
Communications	45.45 kg	10.00	4.55	50.00	0.45
Data Handling	200.00 kg	10.00	20.00	220.00	1.97
AOCS	0.00 kg	-	-	-	-
GNC	0.00 kg	-	-	-	-
Propulsion	0.00 kg	-	-	-	-
Power	154.55 kg	10.00	15.45	170.00	1.53
Harness	409.09 kg	10.00	40.91	450.00	4.04
Payloads	1909.09 kg	10.00	190.91	2100.00	18.85
DLS	0.00 kg	-	-	-	-
Life support	1272.73 kg	10.00	127.27	1400.00	12.57
<b>Total Dry(excl.adapter)</b>	<b>10127.27</b>			<b>11140.00 kg</b>	
<b>System margin (excl.adapter)</b>		<b>20.00 %</b>		<b>2228.00 kg</b>	
<b>Total Dry with margin (excl.adapter)</b>				<b>13368.00 kg</b>	
<b>Other contributions</b>					
Astronauts	0.00 kg	-	-	-	
Consumables	1363.64 kg	10.00	136.36	1500.00	
<b>Wet mass contributions</b>					
Propellant	0.00 kg	-	-	-	
Adapter mass (including sep. mech.)	0.00 kg	-	-	-	
<b>Total wet mass (excl.adapter)</b>				<b>14868.00 kg</b>	
<b>Launch mass (including adapter)</b>				<b>14868.00 kg</b>	

- The Service Module provides resources to the Research Module:
  - Power supply 6 kW to the Research Module
  - Attitude and orbit control
  - Propulsion
  - Thermal energy rejection (heat radiation)
- Orbit altitude is mainly derived from the requirements of keeping a microgravity environment of about  $10^{-6}$  g. The orbit altitude should be above 350 km. The strategy could be to launch to an initial orbit altitude of about 400-500 km, and then to perform orbit raising manoeuvre when the altitude is approaching 350 km.
- Orbit Maintenance Delta-V: 50 m/s per year
- Propellant requirements: 290 kg per year (10 years lifetime assumed).

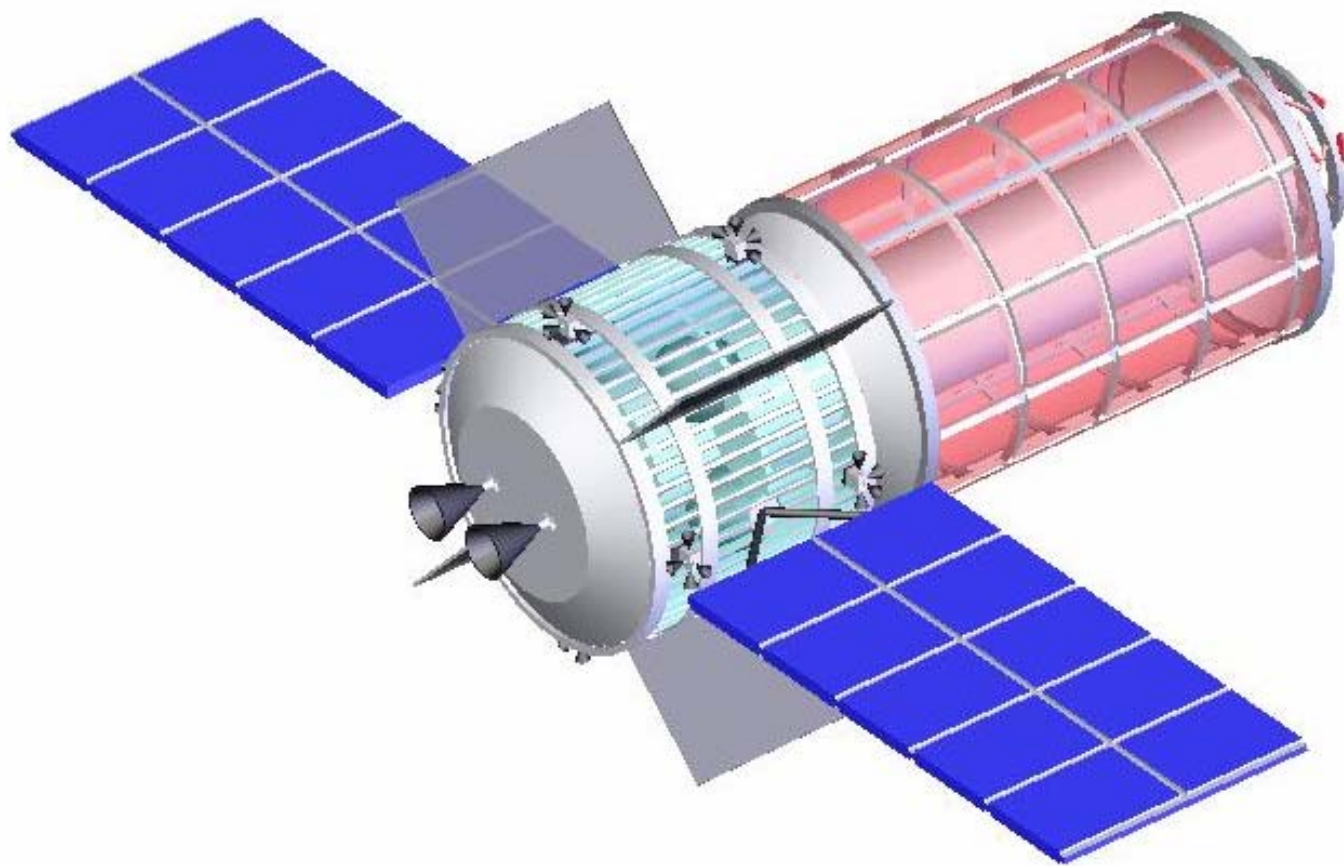


- Service Module mass budget:

	Without Margin		Margin		Total	% of Total Dry
	Dry mass contributions		%	kg	kg	
Structure	845.45 kg	10.00	84.55	930.00	31.69	
Thermal Control	295.45 kg	10.00	29.55	325.00	11.07	
Mechanisms	263.64 kg	10.00	26.36	290.00	9.88	
Pyrotechnics	0.00 kg	-	-	-	-	
Communications	0.00 kg	-	-	-	-	
Data Handling	68.18 kg	10.00	6.82	75.00	2.56	
AOCS	0.00 kg	-	-	-	-	
GNC	0.00 kg	-	-	-	-	
Propulsion	609.09 kg	10.00	60.91	670.00	22.83	
Power	404.55 kg	10.00	40.45	445.00	15.16	
Harness	181.82 kg	10.00	18.18	200.00	6.81	
Instruments	0.00 kg	-	-	-	-	
DLS	0.00 kg	-	-	-	-	
Life support	0.00 kg	-	-	-	-	
<b>Total Dry(excl.adapter)</b>	<b>2668.18</b>			<b>2935.00 kg</b>		
<b>System margin (excl.adapter)</b>		<b>20.00 %</b>		<b>587.00 kg</b>		
<b>Total Dry with margin (excl.adapter)</b>				<b>3522.00 kg</b>		
<b>Other contributions</b>						
Astronauts	0.00 kg	-	-	-	-	
Consumables	0.00 kg	-	-	-	-	
<b>Wet mass contributions</b>						
Propellant	2761.90 kg	5.00	138.10	2900.00		
Adapter mass (including sep. mech.)	0.00 kg	-	-	-		
<b>Total wet mass (excl.adapter)</b>				<b>6422.00 kg</b>		
<b>Launch mass (including adapter)</b>				<b>6422.00 kg</b>		

- The Research Module + Service Module will have (15 days consumables):
  - Length:  $6.6 \text{ m} + 4.4 \text{ m} = 11 \text{ m}$
  - Mass:  $14118 \text{ kg} + 6422 \text{ kg} = 20540 \text{ kg}$
- The LEO I/F is fitting the launcher envelope also considering that the Service Module have a smaller diameter.
- In terms of mass, the resulting value slightly exceed the current A5 launcher performance for about 500 kg.
- For the LEO I/F launch this problem could be faced by assuming that the consumables can be carried along by the first crew, and by outfitting part of the payloads during the logistic missions.
- Also, the propellant can be reduced by considering a station keeping capability for less then 10 years.
- Finally, better launcher performance can be expected by the time of station launch.

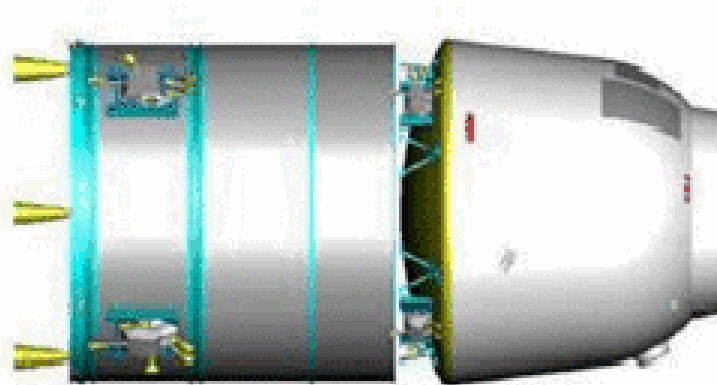




- Today European heritage for these module is:
  - ATV for the Service Module
  - Columbus Laboratory for the Research Module
- Both systems have been launched successfully in 2008 and have marked a major milestone for European space activities. It would be a natural consequence for Europe to built up on the competences gained with these initiative, and the LEO I/F is a straightforward evolution. In addition, the LEO I/F could be a contribution to a larger international I/F but based on autonomous module.



- Logistics missions for payloads and consumables can be accomplished with:
  - Upload with CTS(\*) and/or ATV derived cargo
  - Download with CTS and/or ATV derived Capsule
- In case cargo and crew fly separately, the RM should have a second port (with tunnel), or a node have to be present.



(\*) More info in Astrium/TASI Presentations

- High level requirements:

Function	Requirement
Mission	<ol style="list-style-type: none"><li>1. The Crew Transportation Vehicle (CTS) shall be able to transport a crew of 3 at the LEO Station.</li><li>2. The CTS shall have a cargo upload capability to the LEO Station of up to 1300 kg (1 complete P/L rack + 2 racks refurbishment), and a similar download capability.</li></ol>
Interface	<ol style="list-style-type: none"><li>3. The CTS shall have compatible docking I/F with LEO Station. LEO Station is equipped with the IBDM passive part. The visiting vehicle shall be equipped with the active part of IBDM.</li></ol>
Safety	<ol style="list-style-type: none"><li>4. When docked with the LEO Station. the visiting CTS shall provide additional failure tolerance for functions vital to the crew.</li><li>5. The CTS shall provide safe haven and rescue functions for the crew visiting the LEO Station.</li></ol>
Servicing	<ol style="list-style-type: none"><li>6. The CTS shall be able to perform servicing (maintenance or replacement) of component placed externally to the LEO Station by means of its robotic arm. In addition, EVA activities should be foreseen.</li><li>7. The CTS shall be able to perform servicing of internal items by astronauts.</li></ol>

- Servicing Tasks:
  - As the LEO Station have to operate on orbit for periods considerably longer than the life of conventional satellites, it is therefore designed to allow on-orbit replacement of life limited or failed items.
  - Replacement of external component will be by robotics manipulators of the servicing base (CTS), but need, for complex items (e.g. solar array), the support of astronauts by extra vehicular activities (EVA).
  - Support items are equipment transfer aids and EVA tools. Furthermore permanent handrails and foot restraints are located on the LEO Station.
  - Replacement of internal items will be by astronauts only i.e. without any robotics support. Internal servicing is enhanced by proper attention to design details, allowing good access to the P/L and S/S equipments, that is by mounting it in standard racks.
  - For replacement of large and heavy items, the utilization of special support/handling devices may be foreseen.



- Prolonged Experimentation:
  - For a LEO Station / CTS mission lasting up to 30 days, the crew would, in addition to servicing of the LEO Station, perform manned scientific experimentation.
  - The basic idea is to utilize the internal volume, the electrical power and data transfer capability of the LEO Station for manned experimentation and the habitability, safe haven and rescue capability of CTS in a combined manner.
  - Categories of P/L which are of interest for manned scientific operation are e.g.:
    - ◆ Human physiology with crew member as test object
    - ◆ Short duration hands-on experiments in the biology and material science
    - ◆ Experiments which requires a short turn-around (storage time is critical)
  - In this case the crew need to be supported by a general purpose work bench. Its purpose is to provide means to analyse, check and evaluate the results of the P/L processes in order to get results as early as possible and eventually to modify the process parameters for the next P/L cycle.
  - The General Purpose Work Bench (GPWB) therefore includes e.g. a glove box, micro cutter, microscope, centrifuge, cromatograph, tools etc., besides a terminal to control P/L parameters.

