

European Architecture for Lunar Exploration

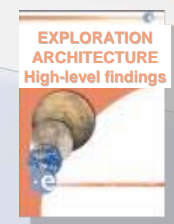
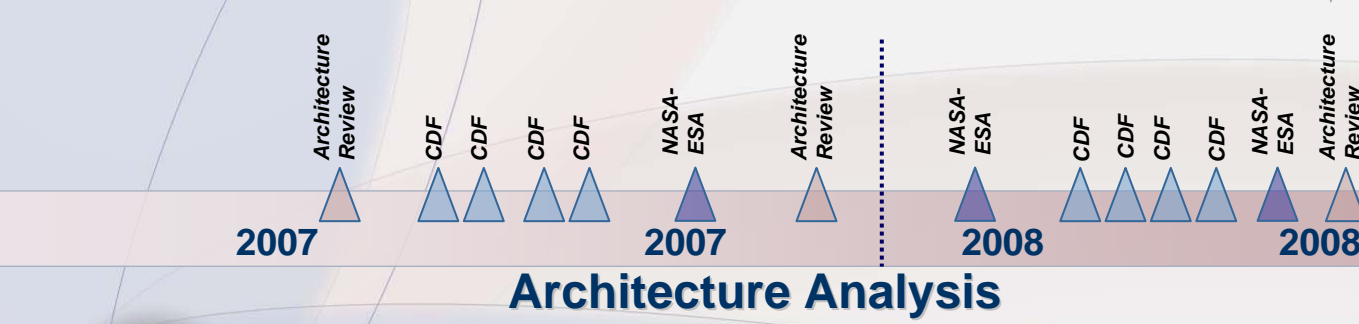
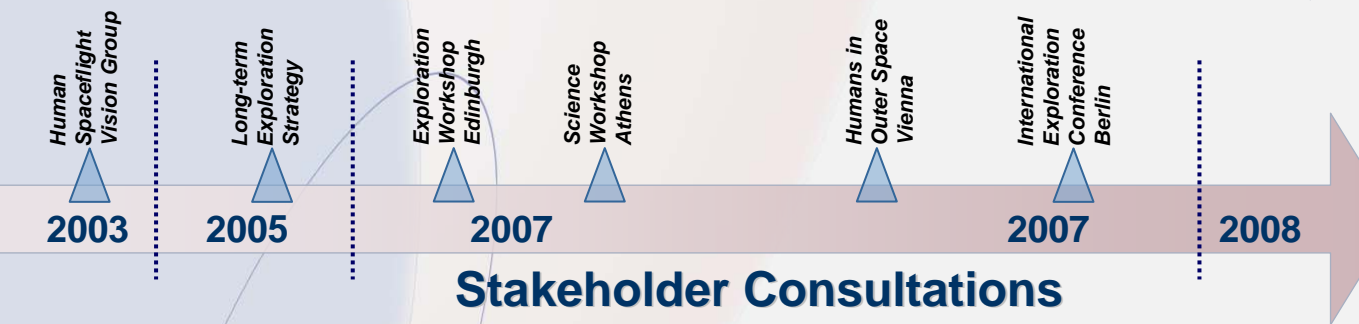
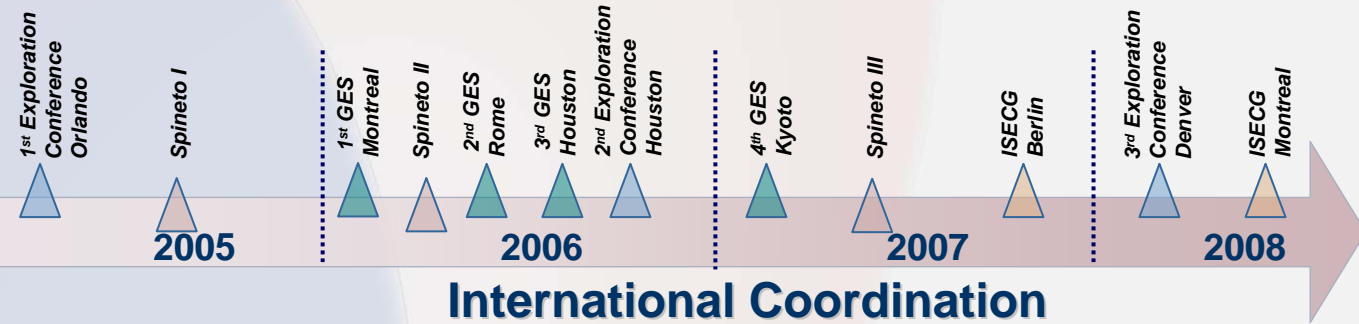
LEAG – ICEUM - SRR

29 October 2008

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website: <http://www.esa.int/explorationstrategy>

Analysis Process and Products



Scenario Studies and Stakeholder Consultations



Science	Economy	Policy
Co-evolution of Life with its Planetary Environment	Applied Research in Space	European Ambition
Lunar Observatories	Space Services	Lisbon Agenda
Life Sciences	Entrepreneurial Activities	Global Partnership



Exploration Phases



LEO



MOON



MARS



<p>ISS Operations</p> <ul style="list-style-type: none"> • On-orbit Research • Risk mitigation for exploration 	<p>Sustained Human Operations – Research</p> <ul style="list-style-type: none"> • On-orbit research • Risk mitigation for exploration 	<p>Sustained Human Operations – Exploration</p> <ul style="list-style-type: none"> • On-orbit research • Risk mitigation for exploration • Services for human Moon missions • Commercial initiatives (tourism) 	<p>Sustained Human Operations – Exploitation</p> <ul style="list-style-type: none"> • On-orbit research • Risk mitigation for exploration • Services for human Moon/Mars missions • Commercial initiatives • Power plants
<p>Robotic Missions</p> <ul style="list-style-type: none"> • Mapping • Landing site preparation • ISRU demonstration • Lunar science 	<p>Initial Human Surface Operations (Short Visits)</p> <ul style="list-style-type: none"> • Limited Life/Physical sciences research • Capability demonstrations for sustained presence • Base construction • Limited geological fieldwork • Sortie support tasks • Limited laboratory analysis 	<p>Sustained Human Surface Operations (Base)-Exploration</p> <ul style="list-style-type: none"> • Life/Physical sciences research • Mars forward capability demonstration • Geological fieldwork • ISRU processing • Base support tasks • Laboratory analysis 	<p>Sustained Human Surface Operations (Base)-Exploitation</p> <ul style="list-style-type: none"> • Tourism • Large observations • Resources
<p>Robotic Missions</p> <ul style="list-style-type: none"> • Science 	<p>Mars Sample Return</p> <ul style="list-style-type: none"> • Science 	<p>Extended Robotic Surface Operations</p> <ul style="list-style-type: none"> • Science 	<p>Human Mars Mission</p>

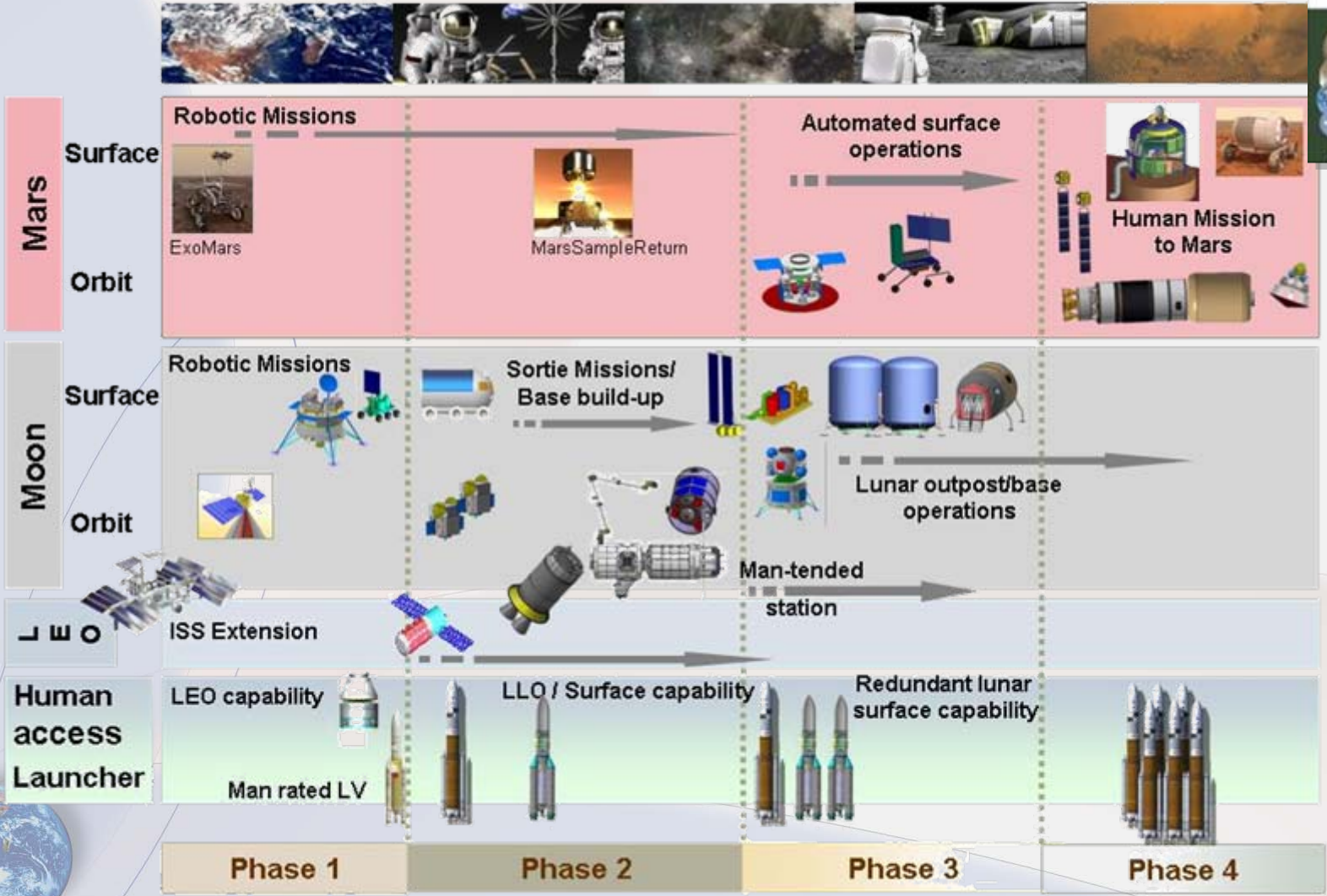
PHASE 1

PHASE 2

PHASE 3

PHASE 4

Phased Approach to Architecture Development

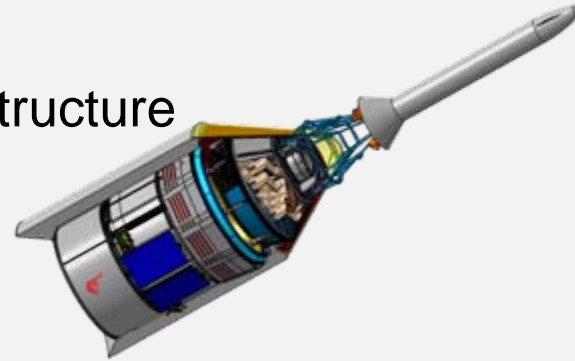


Operations in Low Earth Orbit



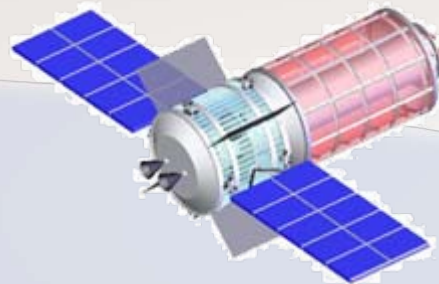
- **Development of crew transportation capability**

- Secure access to existing and future research infrastructure in LEO
- Enable participation to human exploration



- **ISS lifetime extension up to 2020 assumed for research continuation and exploration preparation**

- **Minimum configuration for research continuation post-ISS is a Man-Tended Free Flyer**



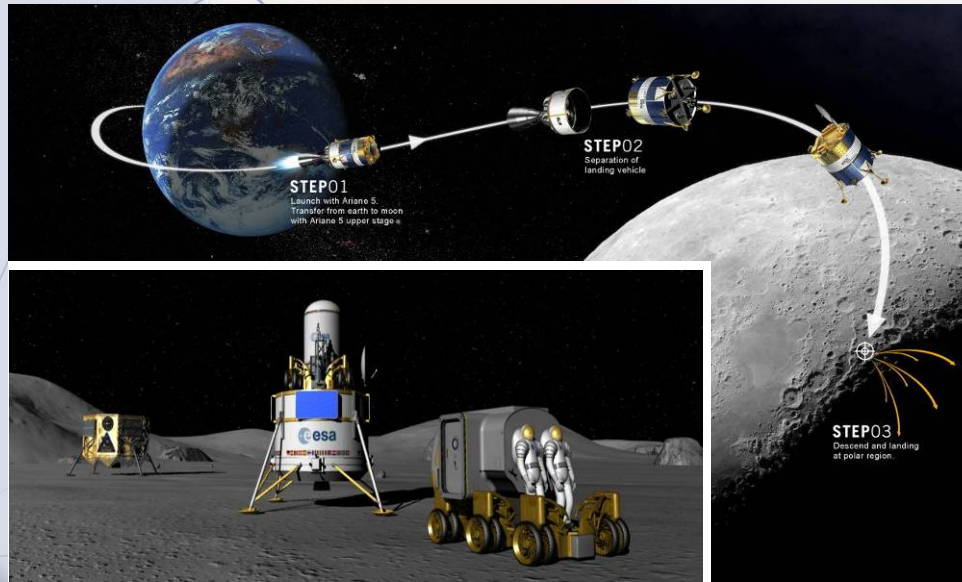
Total mass 20540 kg
Support crew 2-3 for 15 days
Lifetime 10 years



Lunar Cargo Lander



- Use the full Ariane 5 performance capability
- Deliver payloads to any location on the lunar surface
- Perform soft precision landing (500m)
- Deploy payloads on lunar surface
- Provide resources to the P/L (power, comm's etc)



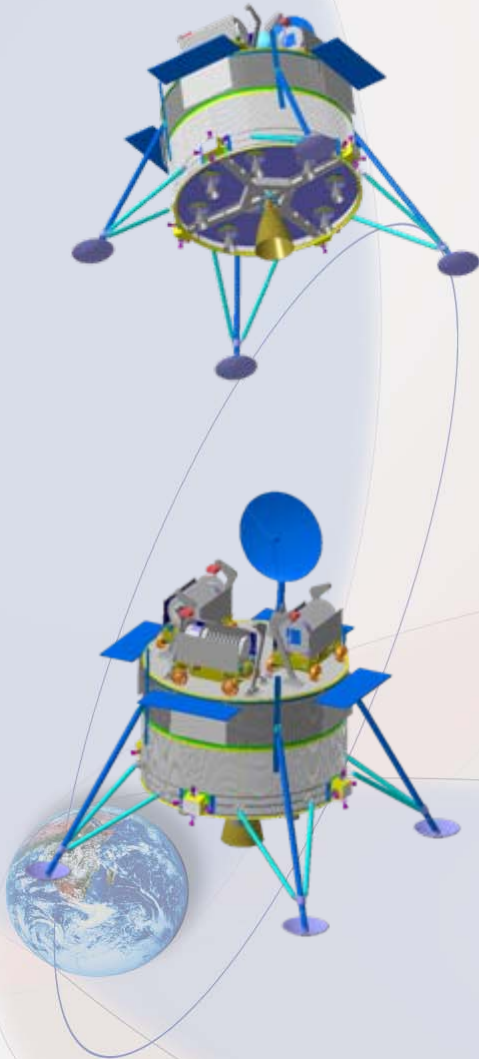
- Gross payload performance (A5 ECA) ~1.2 ton



Lunar Cargo Lander Mission Scenarios



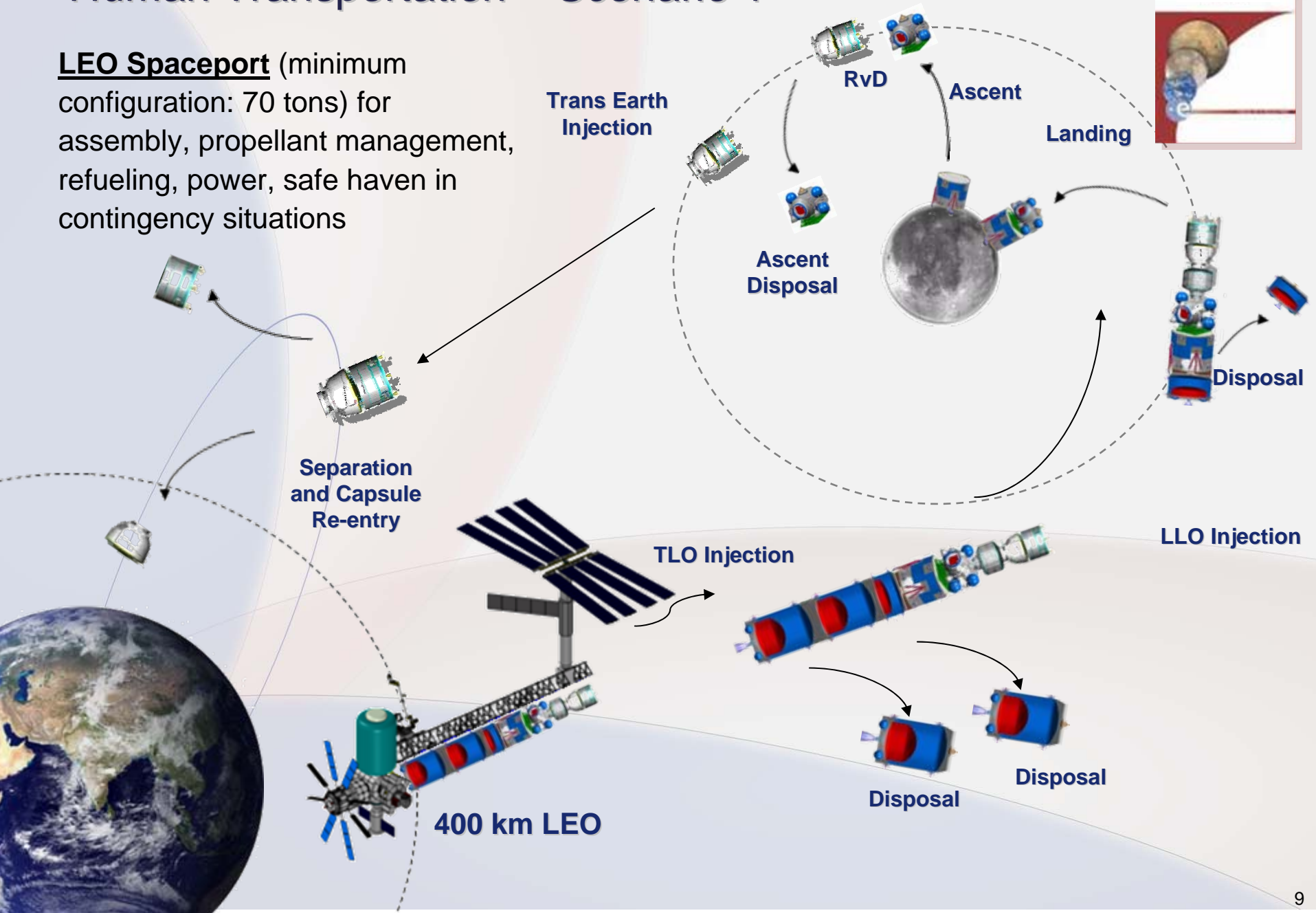
- Technology demonstration and potential human landing preparation;
- Delivery of surface assets, be they stationary or with mobility, in order to support and accelerate the international lunar outpost build-up or for science and technology demonstration in sustained human operations.
- Provision of consumables for extended human surface exploration range and duration;
- Delivery of regular logistics to an international lunar base;
- (Automated lunar surface operations (e.g. ISRU) and exploration



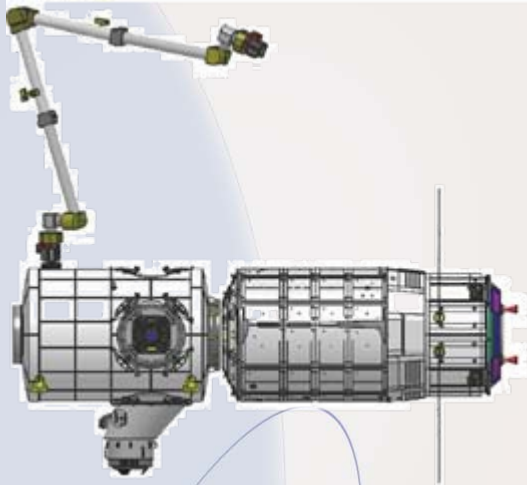
Human Transportation – Scenario 1



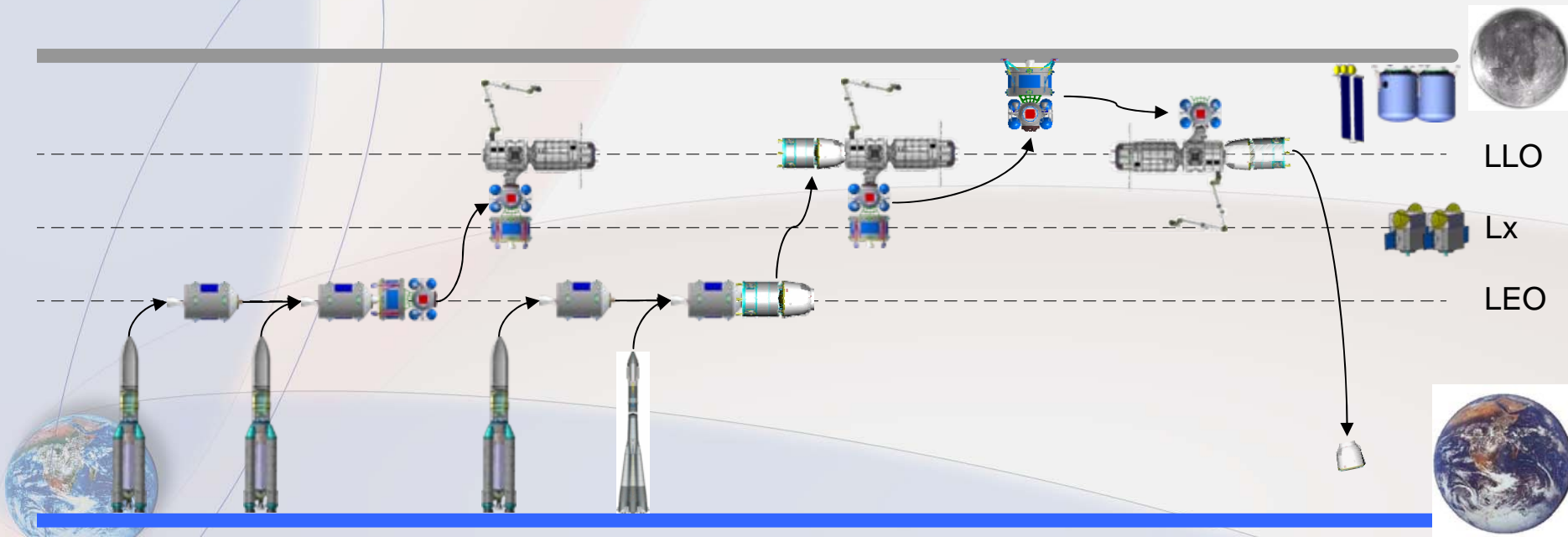
LEO Spaceport (minimum configuration: 70 tons) for assembly, propellant management, refueling, power, safe haven in contingency situations



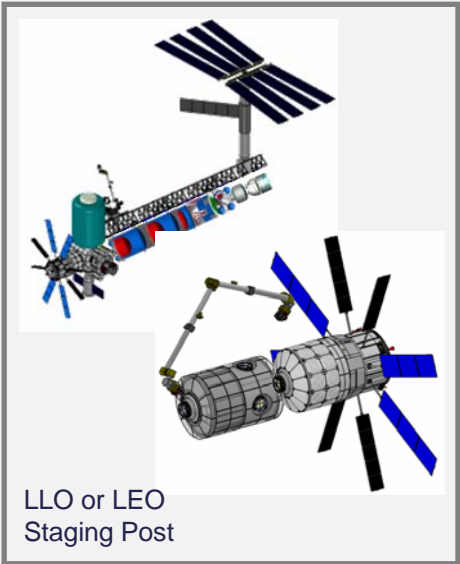
Human Transportation – Scenario 2



LLO Staging Post in polar quasi-circular frozen orbit (minimum configurations 28 tons) providing also crew rescue (anytime return, safe haven) and provision of power, attitude control, communications, refuelling to crew vehicle in LLO.



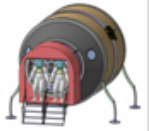
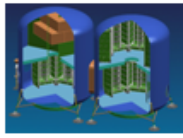




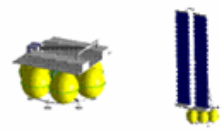
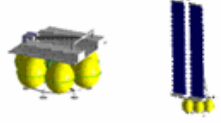

Transportation Infrastructure





Lunar Surface Exploration Scenarios



Scenario		Sortie (short)	Sortie (long)	Outpost	Lunar Base
Crew Number		4	4	2	4+
Duration		7-14 days	14-42 days	14-42 days	180 days
Characteristics		Apollo-like. One visit to a particular landing site.	Longer duration Apollo-like. Multiple visits to a region requiring high mobility.	Multiple visits to a region of high interest (e.g. science, telescope maintenance).	Permanent human presence at a lunar base.
Surface Infrastructure	Habitat				
	Mobility				
	Power plant				
	ISRU plant				

Lunar Surface Infrastructure



Pressurized rover

7600 kg



Provide long-range mobility for human surface exploration

Mini-habitation module

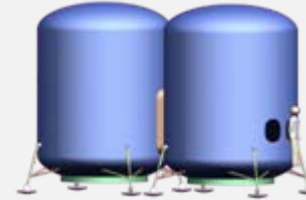
6960 kg



Support crew of two for short duration missions (14 days)

Lunar Base Modules

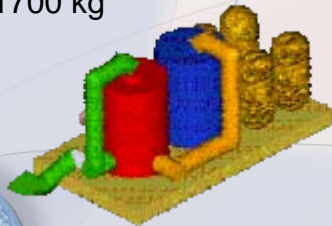
13 t each



Support up to 4 astronauts to survive on Lunar Surface for extended stays (several months)

ISRU plant

1700 kg



Provide O₂ from regolith

Utility vehicles

350 kg



Terrain management vehicle

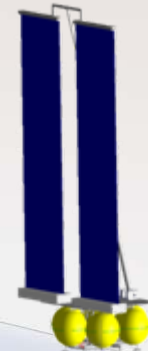
350 kg



Tanker and services vehicle

Large solar power plant

1500 kg



Provide power to outpost/base

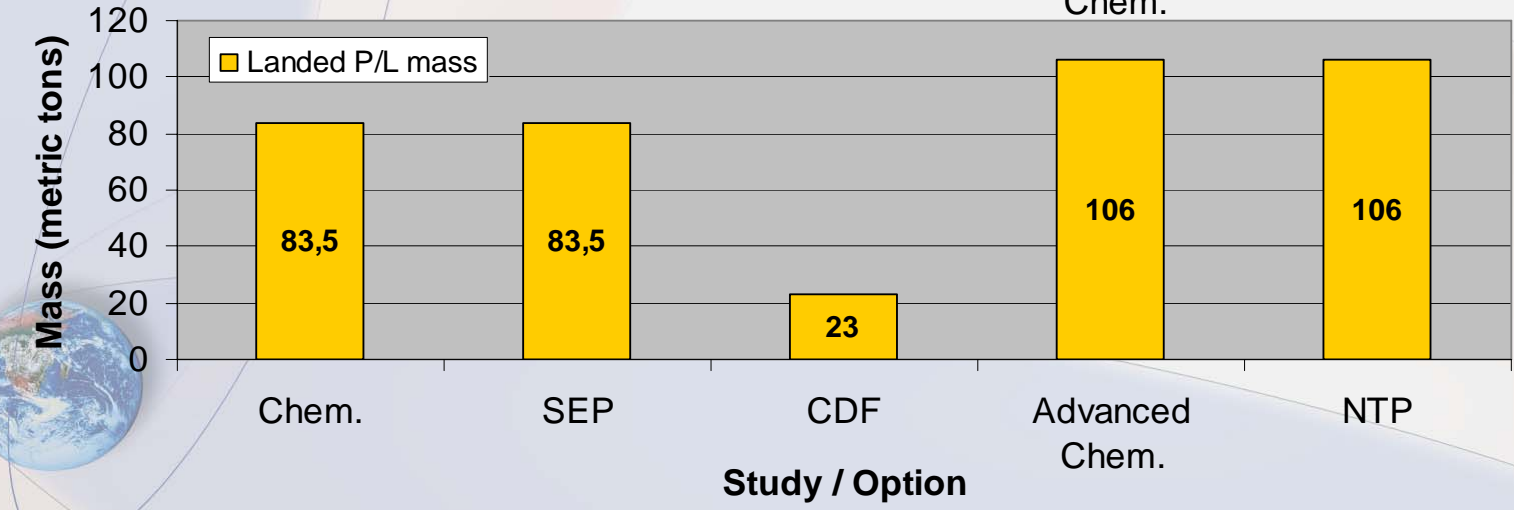
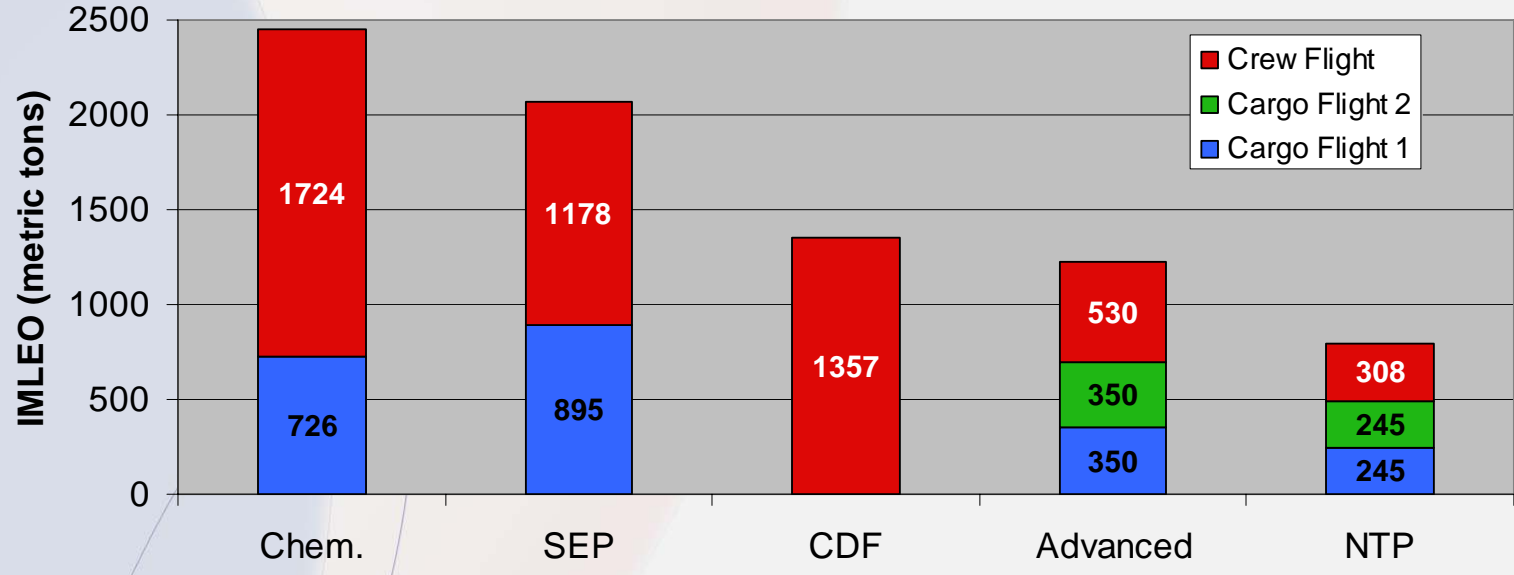




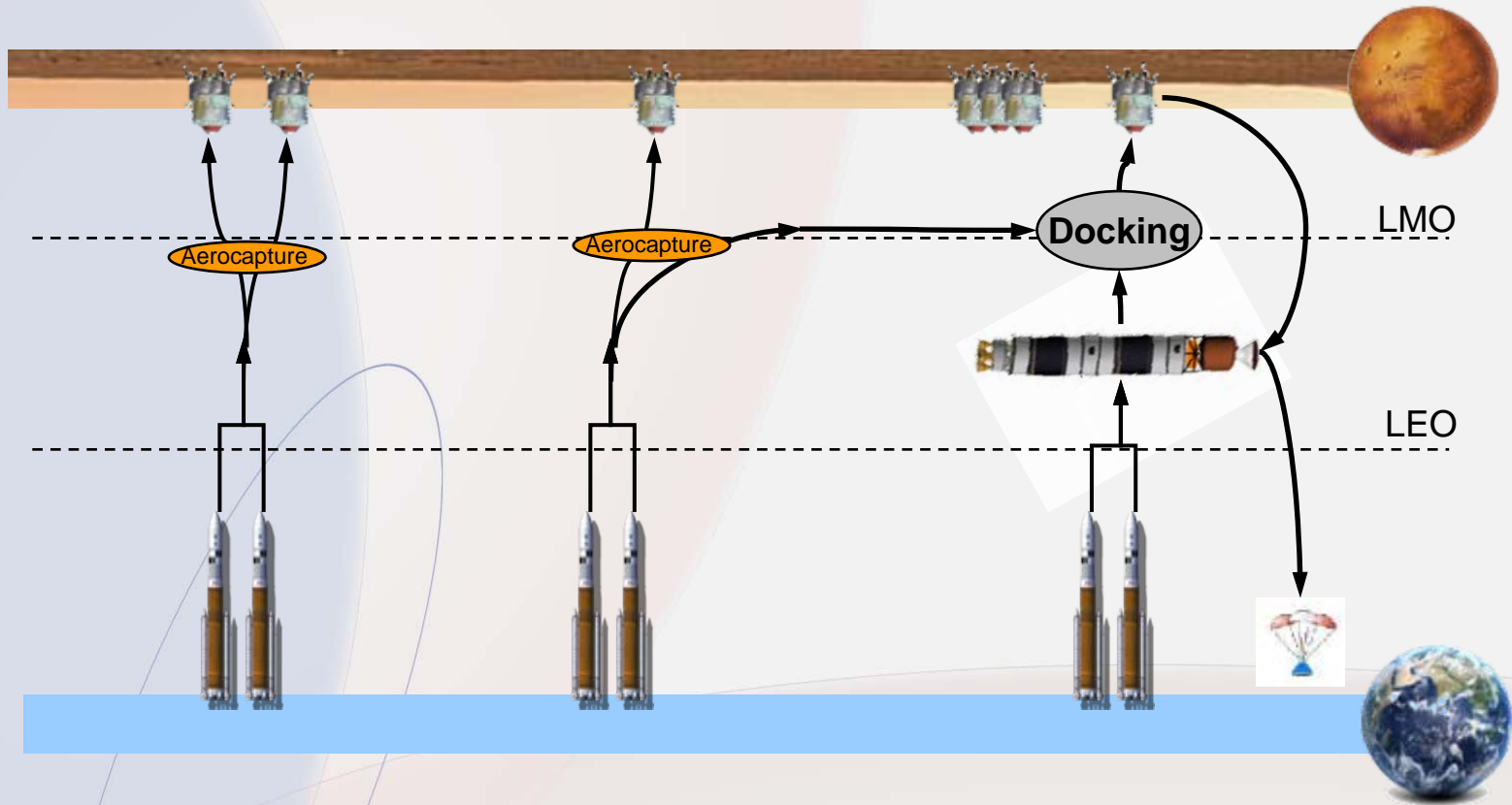
Human Mars Mission Trade-Off

Number of ARES V

Launchers: 21 17 – 19 11 7



Human Mars Mission Reference Architecture



<p>Pressurised Rover 8 tons</p>	<p>Transit Hab 38 – 50 tons</p>	<p>Surface Hab 32 tons</p>	<p>Nuclear Power Plant 12 tons</p>	<p>Ascent Vehicle 30 tons</p>	<p>Descent Vehicle 24 tons</p>	<p>Nuclear Transfer stage 120 tons</p>	<p>LEO Tug 22 tons</p>	<p>Payload Tug 5,8 tons</p>
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High-level Findings

- Heavy-lift launcher with 50 tons payload capability enable human mission beyond LEO
- Human operations in Low Earth orbit of continued strategic interest beyond ISS programme
- Orbital infrastructure (a) enhance robustness of human exploration transportation architecture providing safe haven in contingency situation and services to the transportation system (assembly, maintenance, inspection, cryo-management, re-fueling, power) and (b) open opportunities for innovations in the transportation architecture
- Lunar surface architecture strongly depends on exploration scenario
- Interest in utilisation of Lunar ISRU for consumables (break-even in 2nd year of operations)
- Advanced propulsion required for Human mission to Mars
- Moon-Mars synergies for advanced robotics, long-range exploration, long-term surface habitation, soft precision landing, surface operations, in-space operations, communications and navigations

