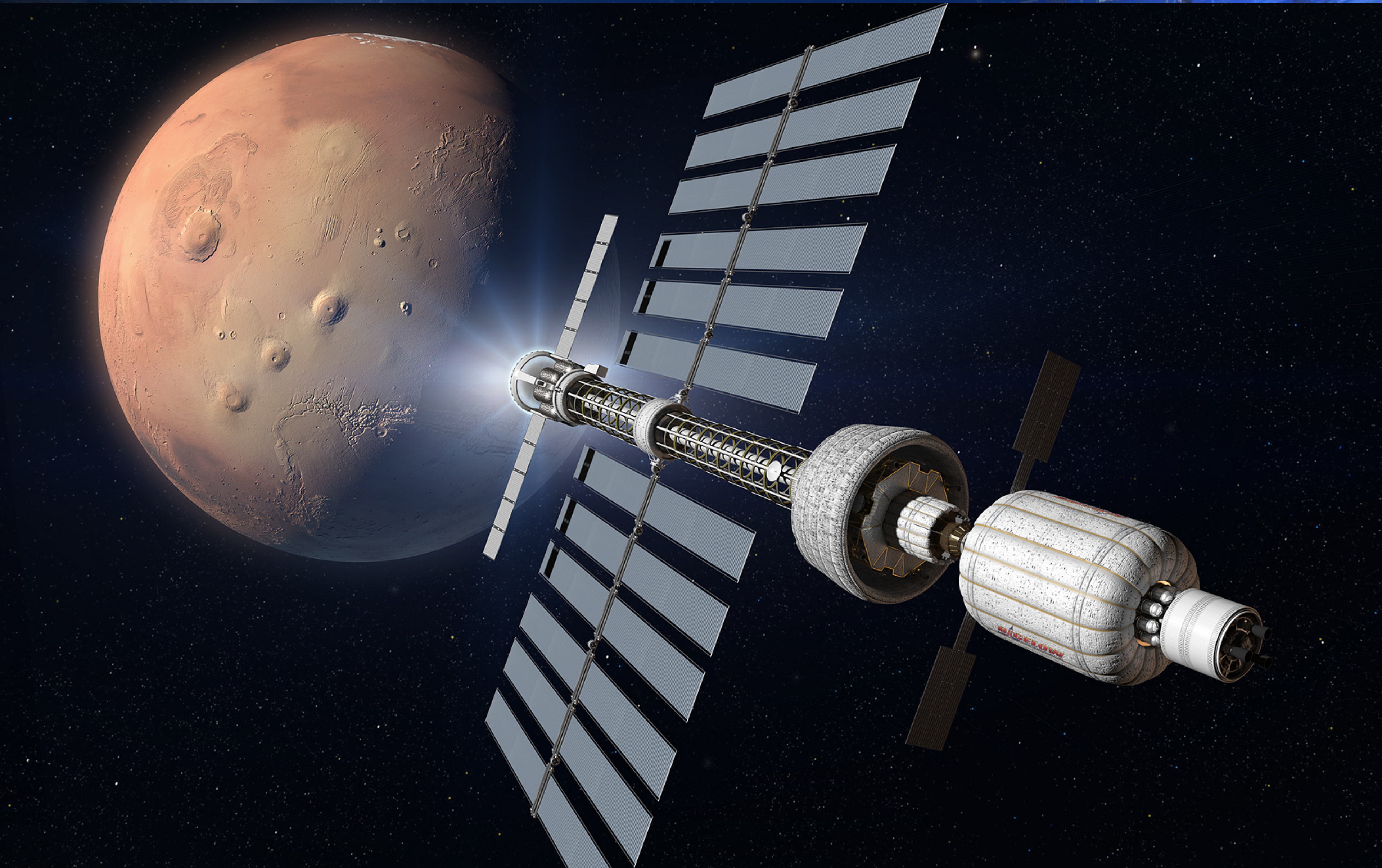
SLS and Lunar Missions

Kurt Klaus
LEAG
October 15, 2013

BOEING

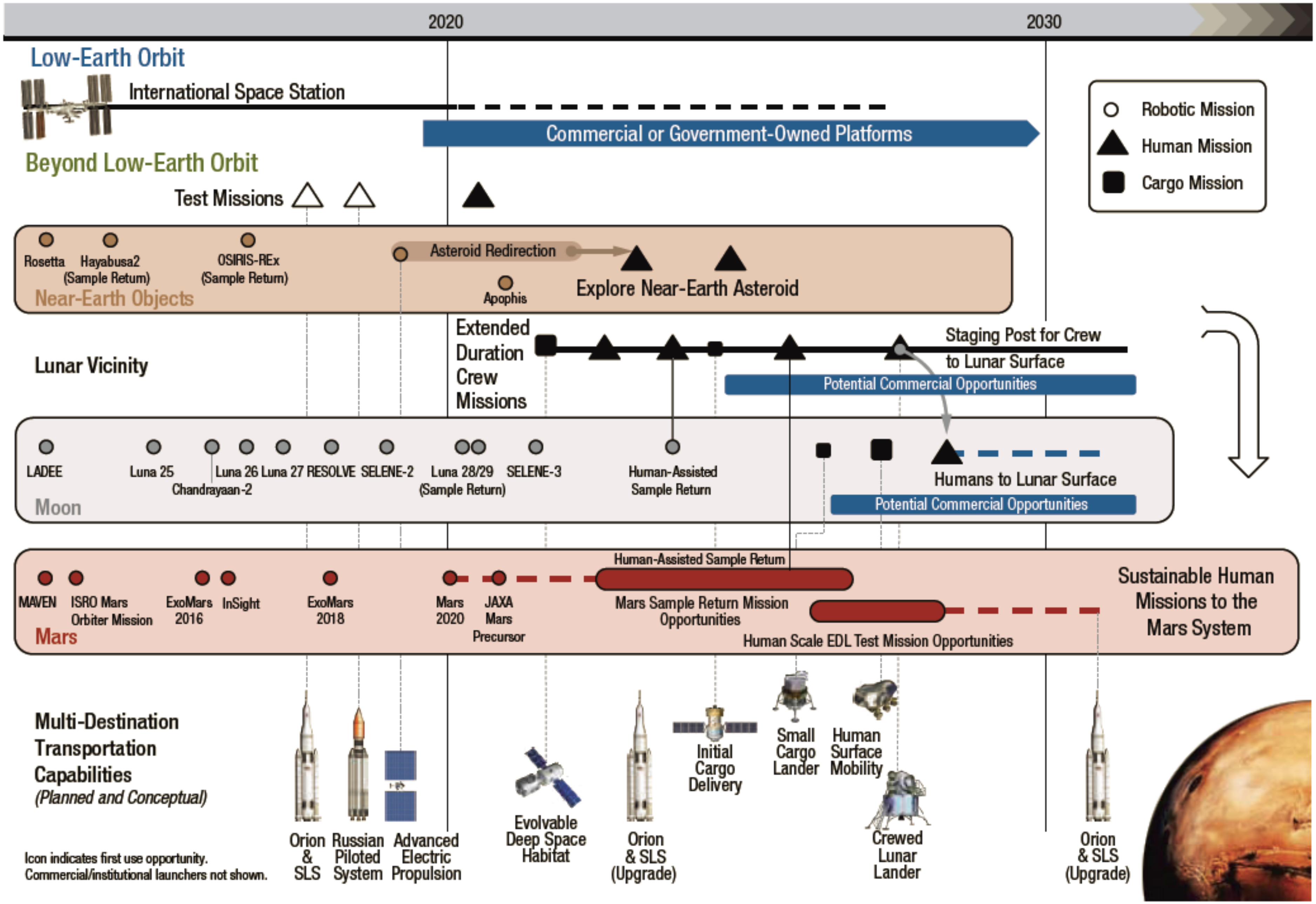
The Ultimate Destination?



Outline

- Introduction
- The Global Exploration Roadmap
- SLS Configurations
- ARM in Lunar Vicinity
- Cislunar Hab
- Payload to Lunar Surface
- Secondary Payloads
- Final Thoughts/Conclusions

ISECG Mission Scenario

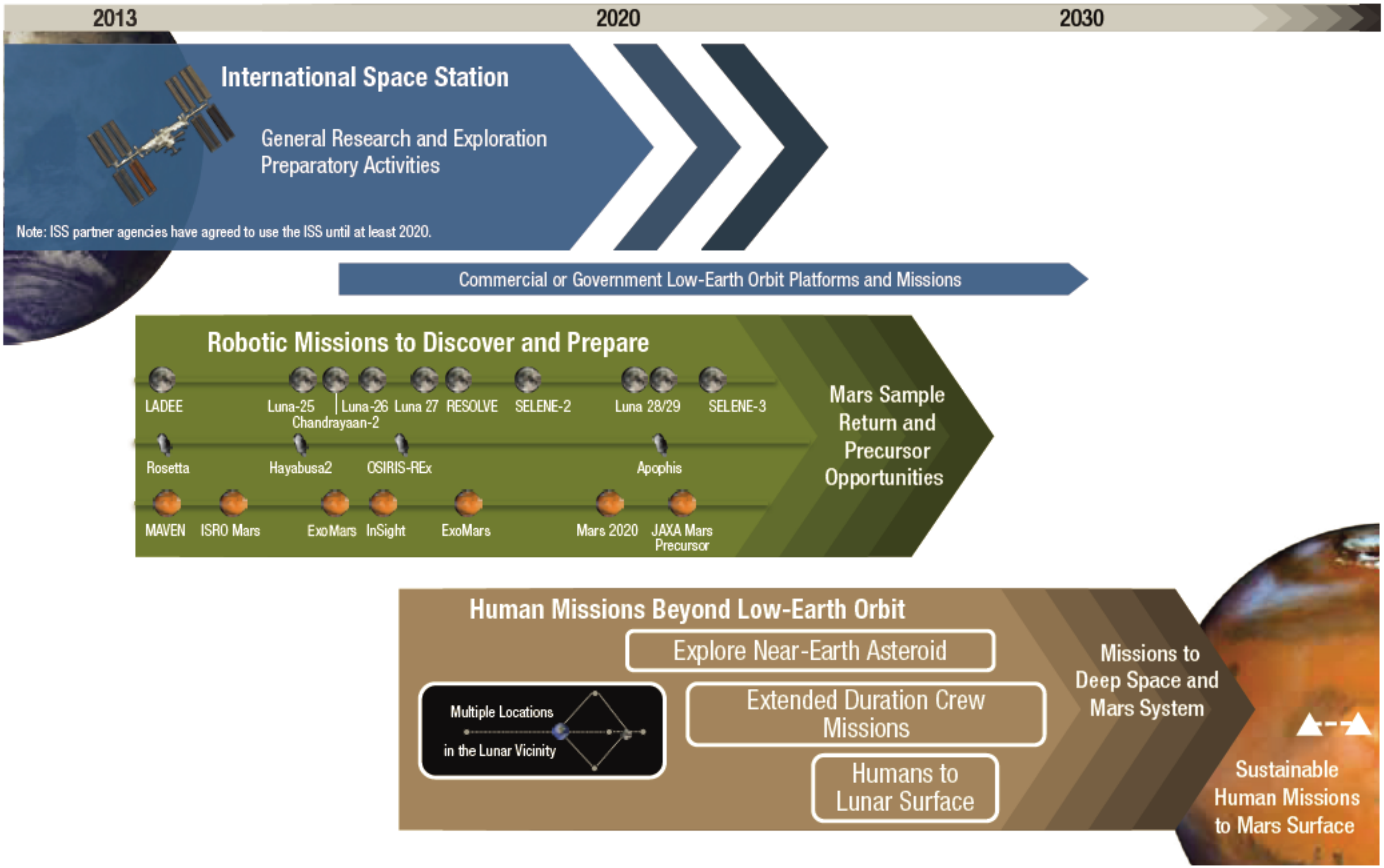


Defense, Space & Security
Space Exploration

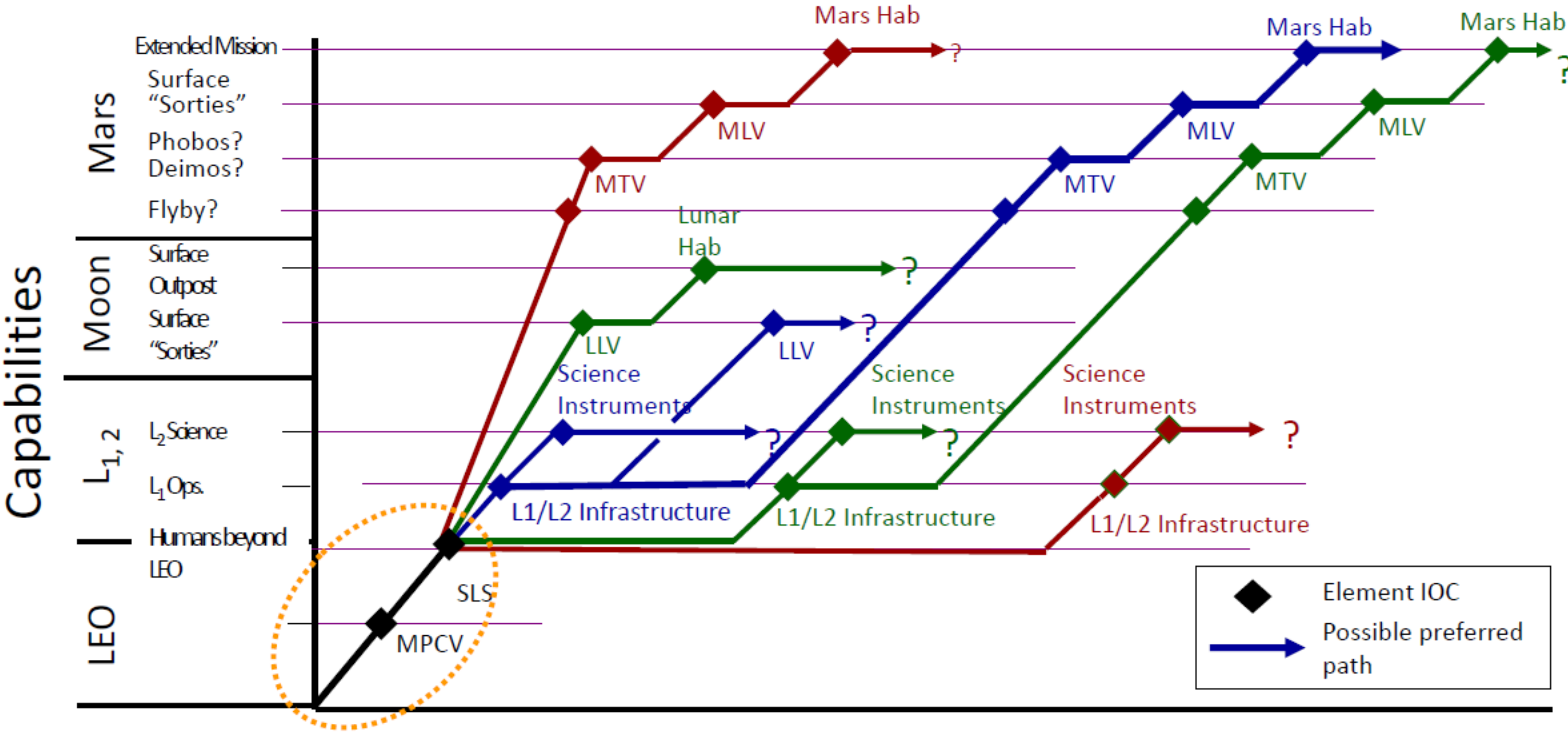
From the GER Mission Scenario

- Ultimate objective is Mars
- Significant precursor activities necessary to prepare required systems
- Several interim destinations are possible
- ISS role in shaping technical basis and managerial model
- Strong partnership between human and robotic exploration programs
- International partners are prepared for and require key mission critical roles

Global Exploration Roadmap

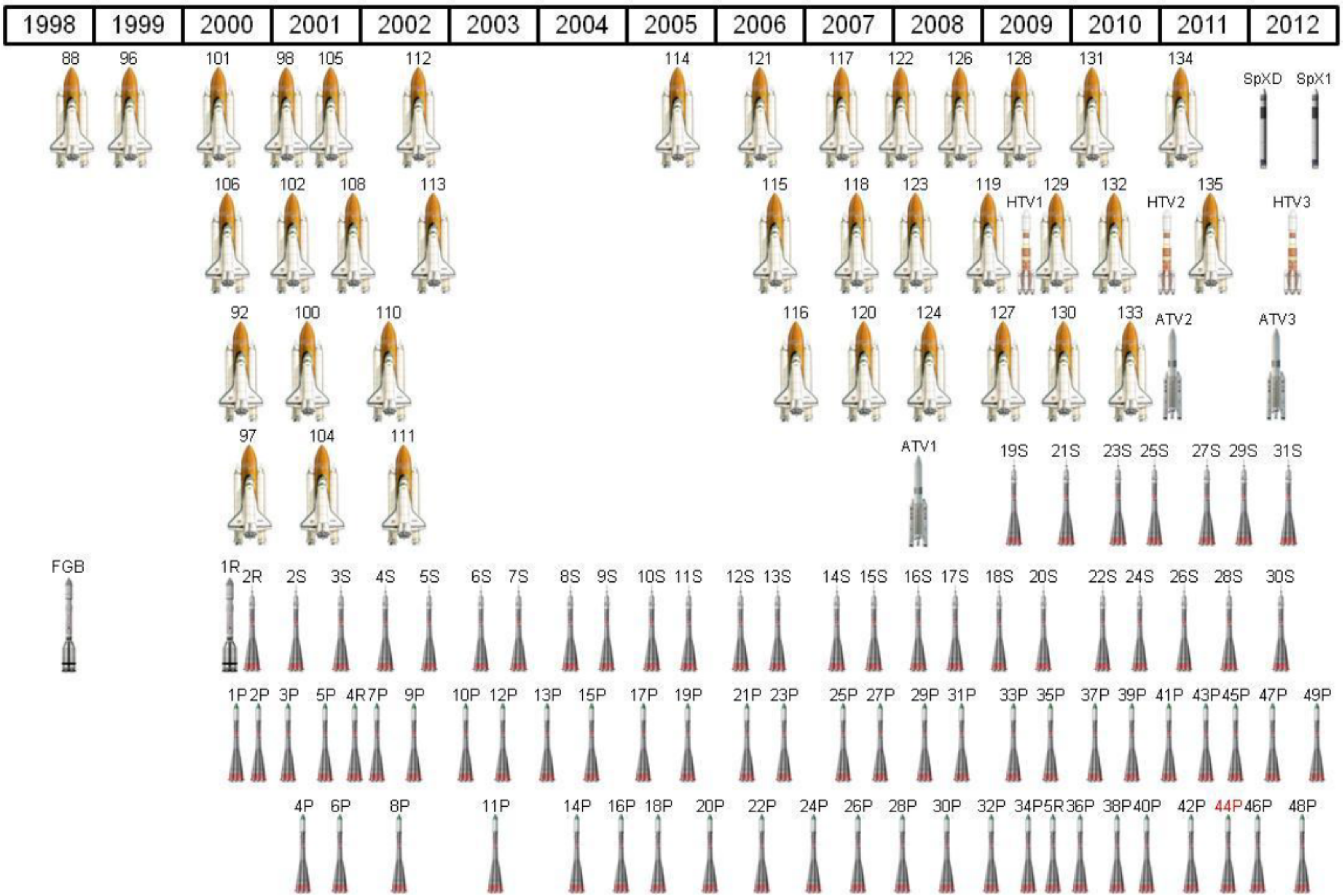


Possible Strategy for Architecture Pathways



Defense, Space & Security
Space Exploration

ISS Assembly and Operations

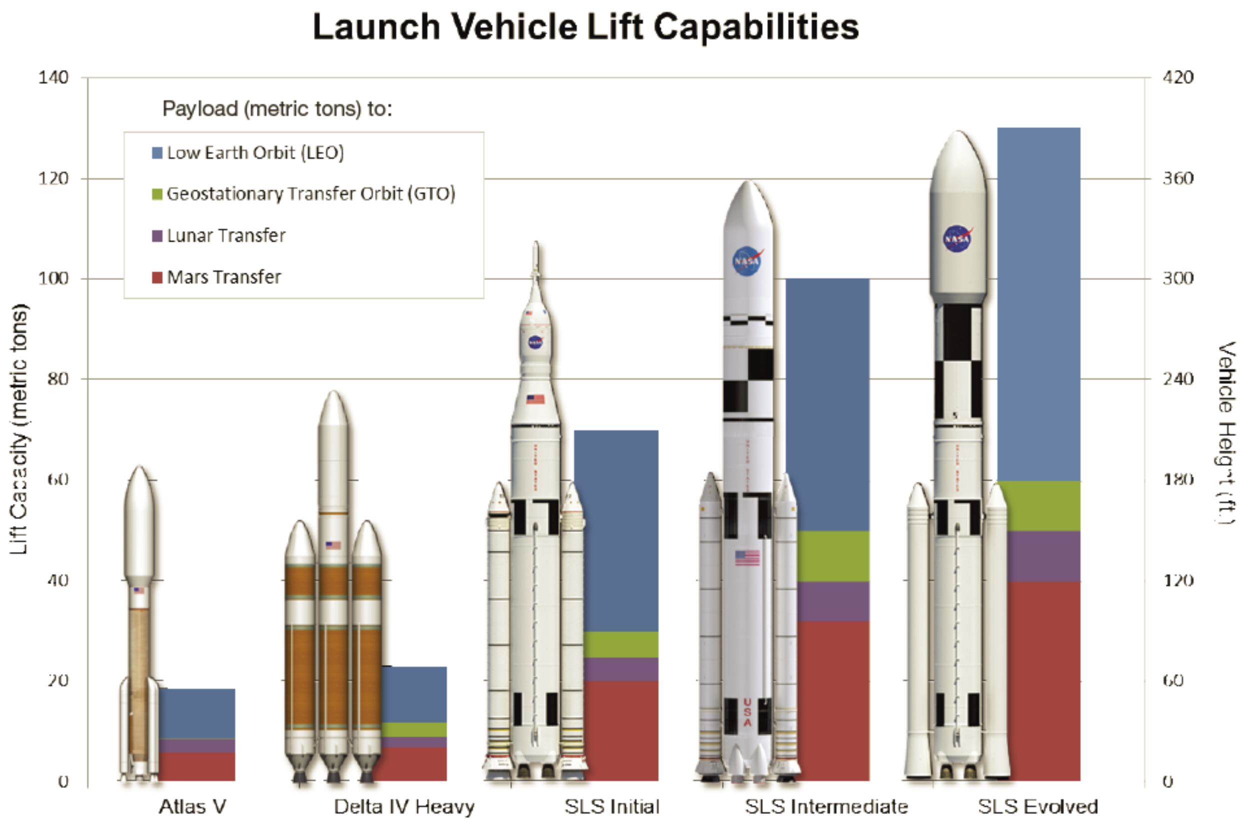


Introduction

Space Launch System (SLS) is the most powerful rocket ever built and provides a critical heavy-lift launch capability enabling diverse deep space missions. The exploration class vehicle launches larger payloads farther in our solar system, faster than ever before.

SLS Configurations and Capability

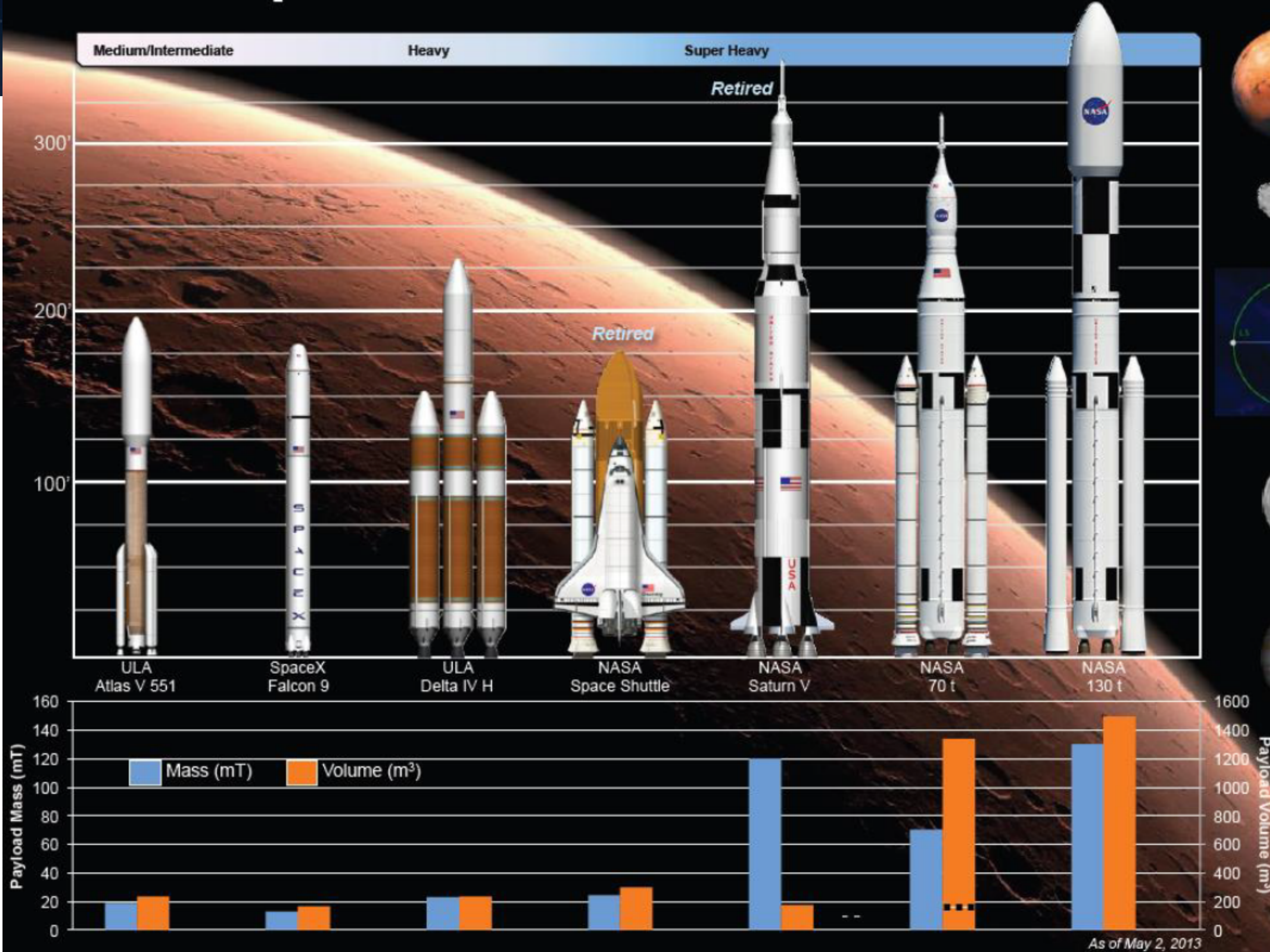
SLS is the first rocket and launch system in history capable of powering humans, habitats and space systems beyond our moon and into deep space.



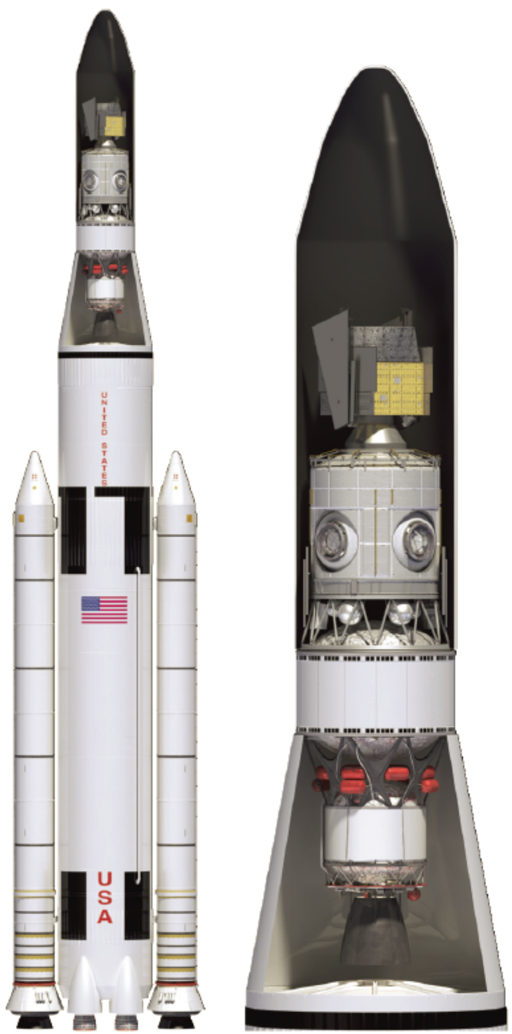
The vehicle's 5 m to 10 m fairing allows utilization of existing systems which reduces development risks, size limitations and costs. SLS lift capacity and superior performance shortens mission travel time.

Enhanced capabilities enable a myriad of missions including human exploration, planetary science, astrophysics, heliophysics, planetary defense and commercial space exploration endeavors.

Most Capable U.S. Launch Vehicle



Asteroid Redirect Mission



Asteroid Redirect Mission (ARM)

Mission Objective

Rendezvous, capture and return a NEA to lunar orbit for long-term future human exploration

Mission Rationale

ARM leverages current investments across NASA directorates to develop innovative technologies, provide a scientifically valuable destination for human exploration beyond low-Earth orbit, advance understanding of our solar system and mitigate asteroid impact risks.

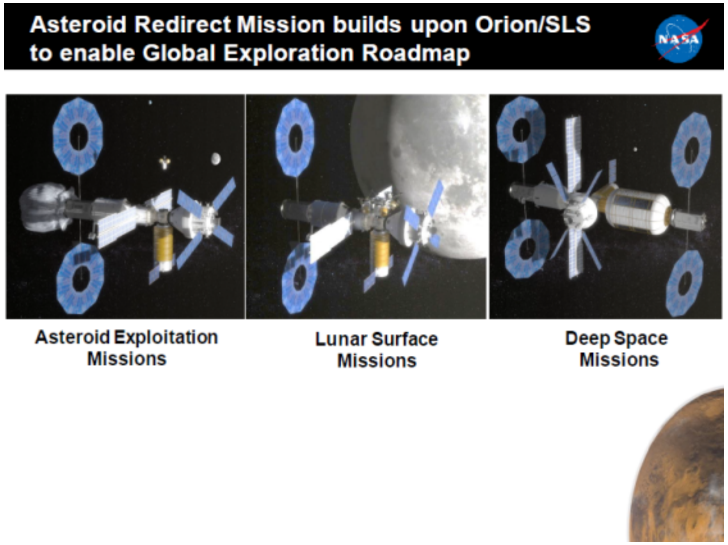
SLS Capabilities

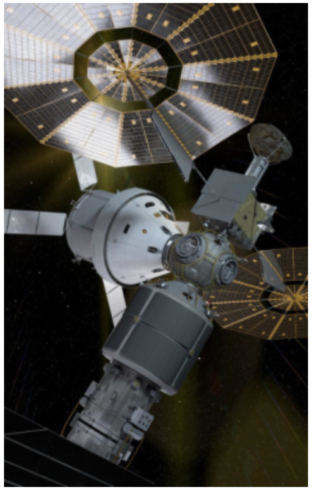
SLS lowers risks by reducing mission time and improving mass margin. SLS lift capacity allows for additional propellant enabling a shorter return or the delivery of a secondary payload, such as gateway component to cislunar space.

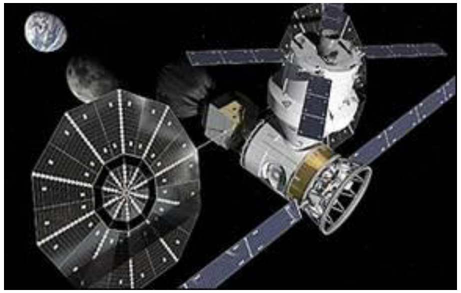
SLS Lift Capacity | 12t to a C3 of 2; 12t to DLRO

Designing for Reusability Maximizes the NASA ROI for ARM

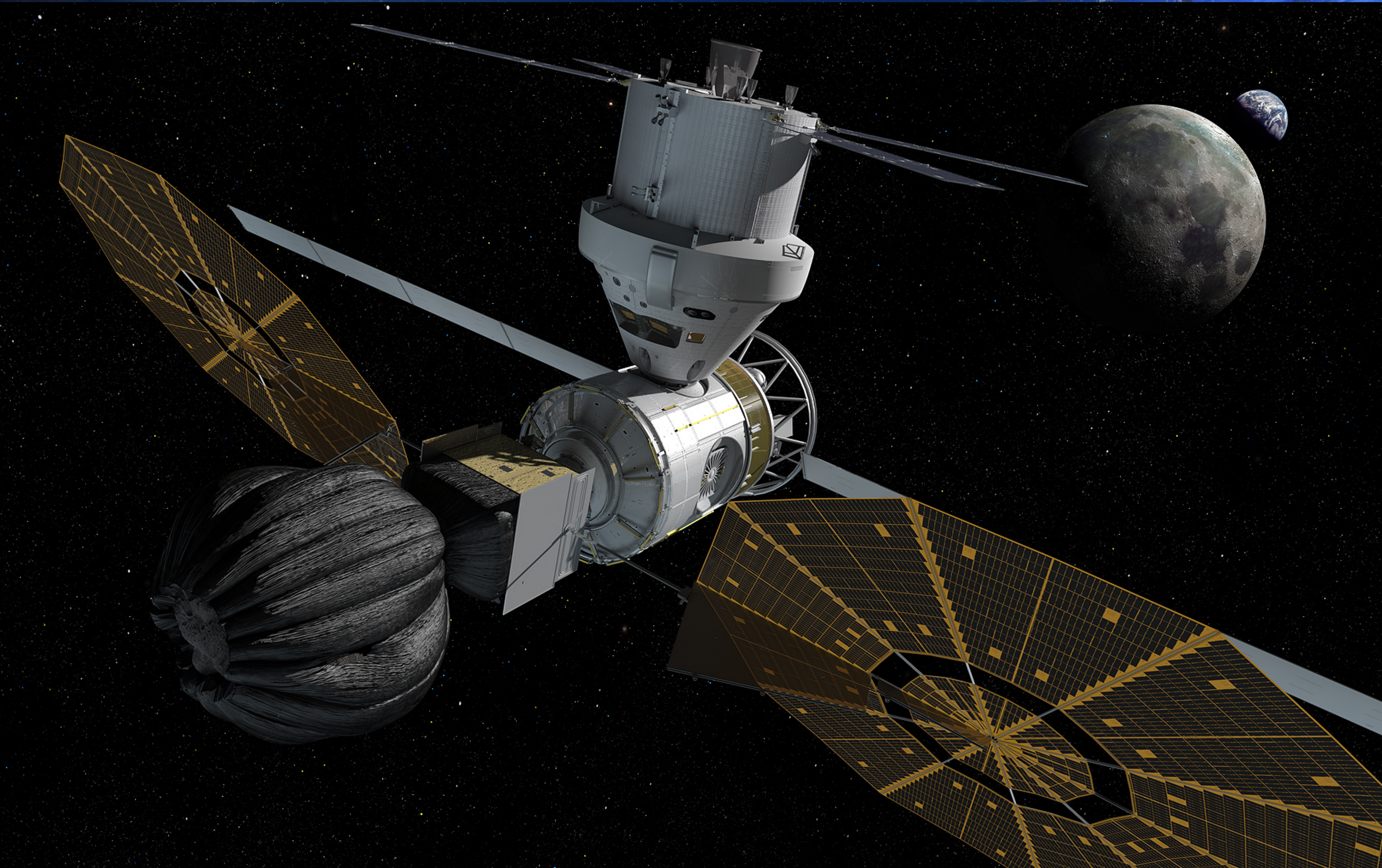
- **Re-use of ARRM Flight System Demonstrates Versatility and Extensibility**
  - ARRM Flight System will likely have 5-10 years remaining lifetime after ARRM
  - Power module still capable of generating ~30-40 kW (50kW BOL)
  - Docking system allows integration into follow on Exploration Architectures
  - Refueling (via SLS) can provide significant (~10-15 km/sec) of DV for future cislunar assets
    - Earth-Moon tug
    - Deep space propulsion stage
    - Upgradable to a In-Space Servicing platform







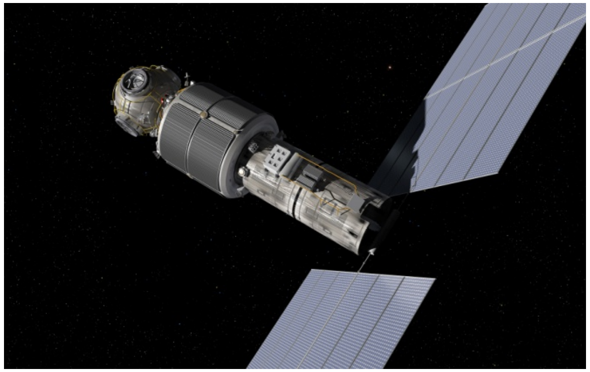
Mission concept including Gateway

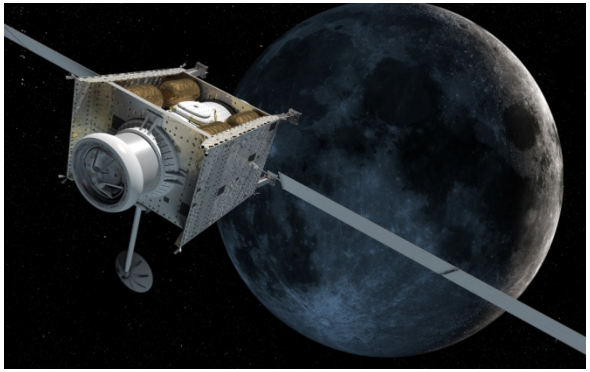


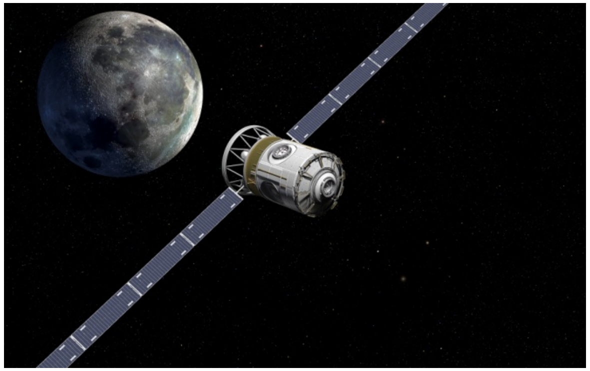
Asteroid Exploration Module

- Crew operations at a redirected asteroid could be significantly enhanced by providing additional systems and EVA capabilities beyond those available from Orion only missions.

- Placing an Asteroid Exploration Module (AEM) at the redirected asteroid would :
  - Extend mission duration – Reduce EVA and consumables mass requirements on Orion
  - Increase capability – Supply additional EVA functions and crew volume
  - Reduce risk - Provide an abort location for Orion





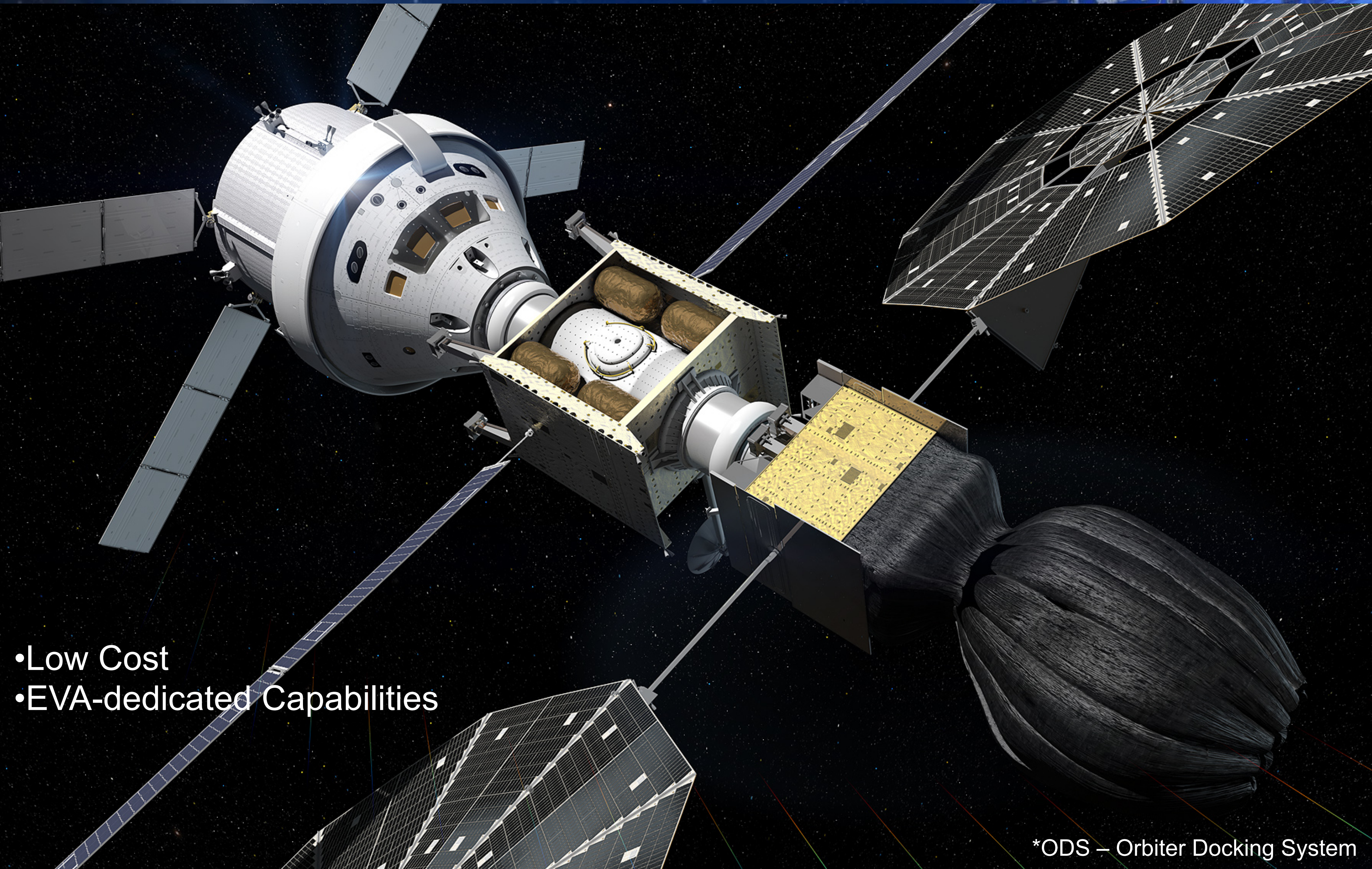


Russian SPM-derived Module

- International Participation
- Robust Capabilities

*SPM – Science Power Module

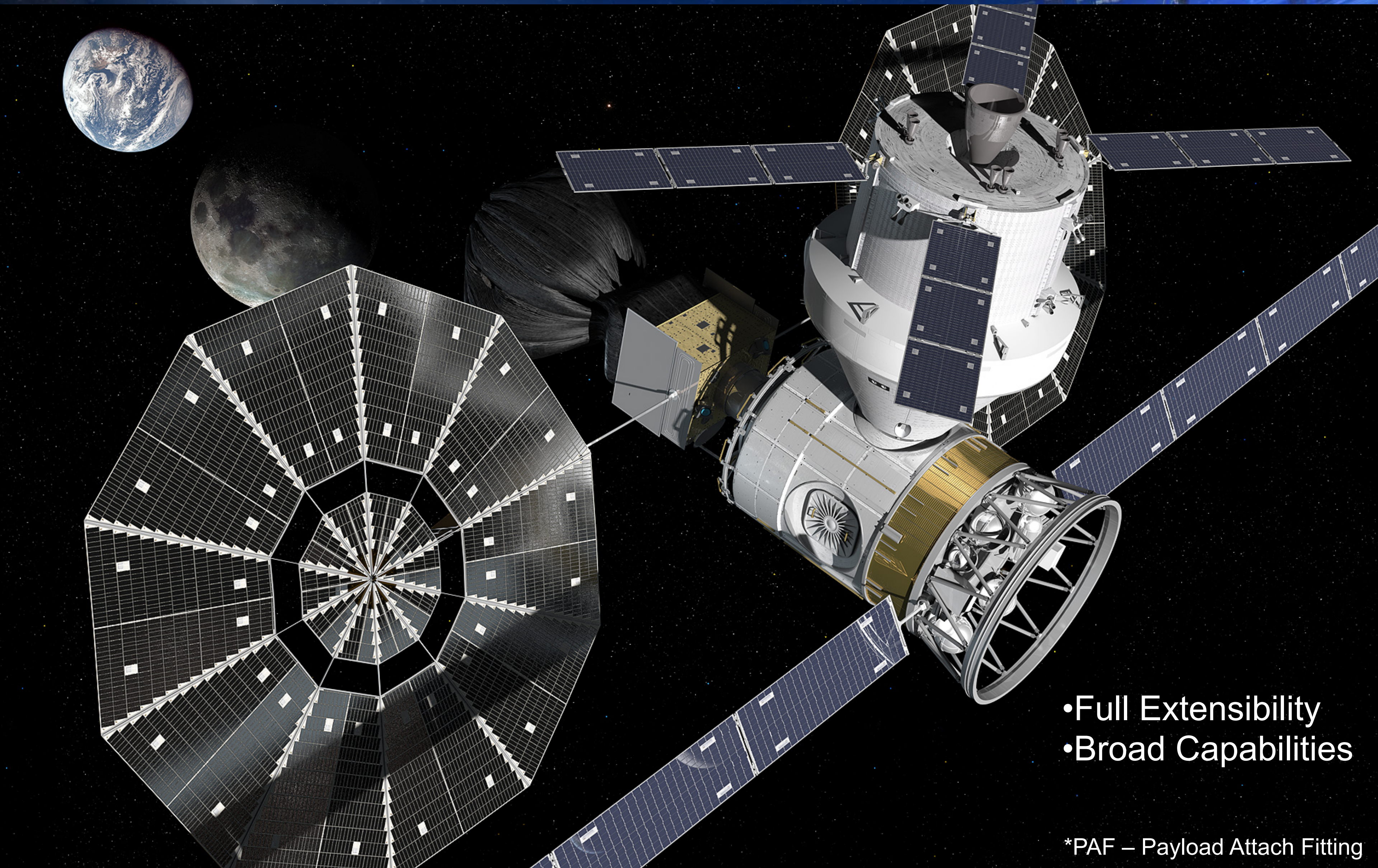
ODS-based Module



- Low Cost
- EVA-dedicated Capabilities

*ODS – Orbiter Docking System

Node/PAF-based Module



- Full Extensibility
- Broad Capabilities

*PAF – Payload Attach Fitting

Comparison of Orion and AEM

Capability	Orion	AEM + Orion
Exobody Interaction • Characterize geology and topography at destinations and collect samples • Test tools and technologies to extract, process, and utilize resources	✓	✓
Science • Earth observation, heliophysics, and astrophysics and other applied research	✓	✓
Crew Health • Evaluate human health and risk mitigation in the deep space environment • Test radiation countermeasures and mitigation technologies and strategies • Monitor and predict radiation	✓	✓
Spacecraft Systems and Operations • Space power generation and storage • High-performance mobility and extravehicular activity capabilities • Autonomous robots to supplement crew activities • Advanced in-space propulsion capabilities • Automated rendezvous and docking and on-orbit assembly capabilities • Space communications and navigation capabilities • Protocols for deep space operations at a large distance from Earth	**Partial**	✓
Cooperation • Opportunities for integrating commercial elements • Opportunities for international space agency cooperation		✓
Extend Orion mission duration in translunar space		✓
Long duration habitability in deep space		✓
Provide a local abort destination for Orion missions		✓
Extensible architecture for future exploration missions		✓

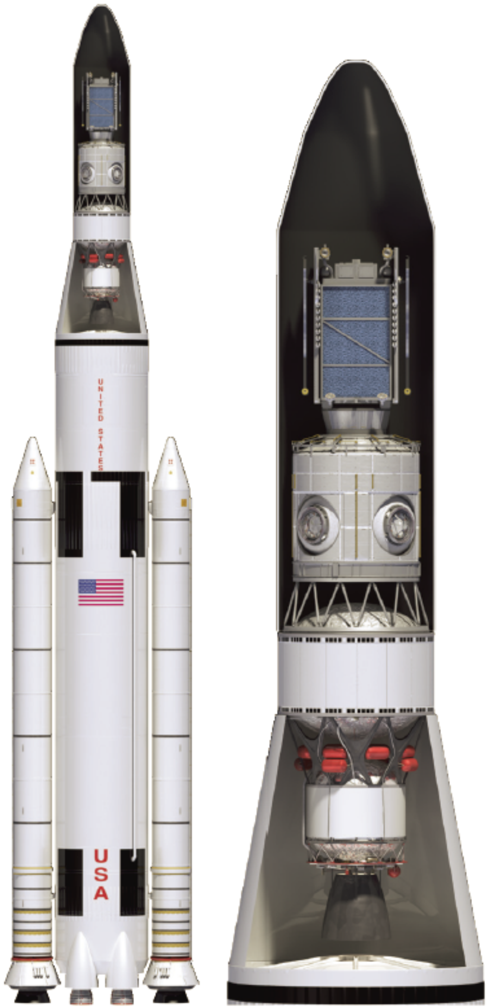
Risk Reduction for Exploration

- **AEM increases science return of the Asteroid Redirect Mission**

- **AEM demonstrates many core capabilities needed for deep space missions**
  - Electric propulsion
  - EVA
  - Deep space navigation and communications
  - Long duration operations beyond low earth orbit
  - Commercial/international interaction
  - Long duration radiation countermeasures and mitigation

- **AEM benefits Exploration as a residual asset**

Cislunar Gateway



Cislunar Gateway

Mission Objective

Place an assembly site at Earth-Moon Libration Point 2 (EML2)

Mission Rationale

The gateway architecture extends the mission duration of the Orion Multi-Purpose Crew Vehicle, enables scientific research of the deep space environment and serves as a transportation node to future human space exploration destinations. Shown here with Orion, a Boeing 702SP-derived utility module and a Russian Scientific-Power Module (SPM), the gateway launched by SLS provides architectural options—each component is a self-sufficient vehicle that can serve as a base for platform expansion.

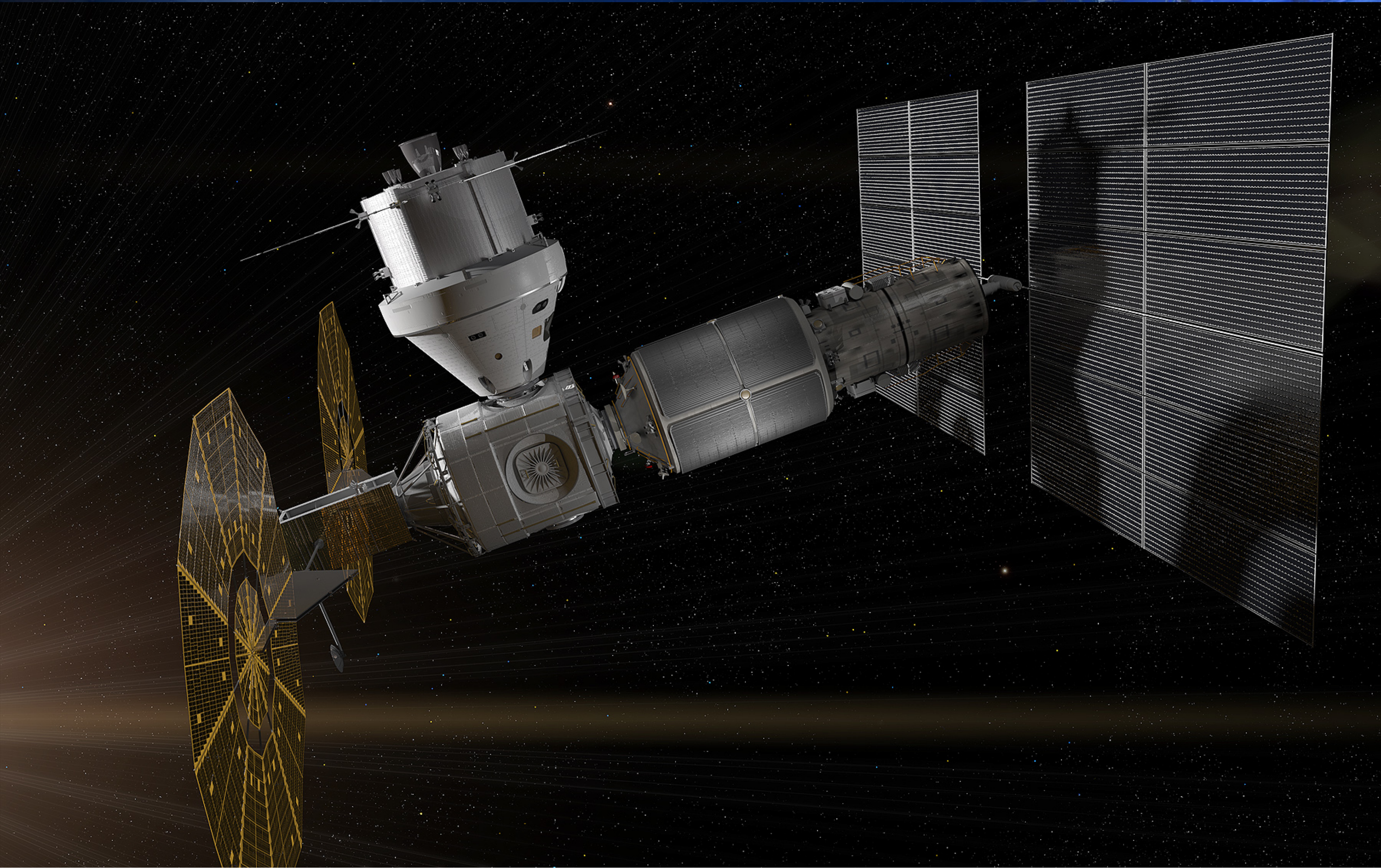
SLS Capabilities

SLS enables the launch of large gateway elements beyond the moon. Leveraging a low-energy transfer that reduces required propellant mass, components are then brought back to a desired cislunar destination. SLS provides a significant mass margin that can be used for additional consumables or a secondary payload.

SLS Lift Capacity (Cargo): 25t to EML2

GLOBAL COLLABORATION | HUMAN EXPLORATION

Evolved gateway with SPM



Lunar Surface Mission

Lunar Surface Mission

Mission Objective

Launch astronauts and a reusable lunar lander to the moon's surface

Mission Rationale

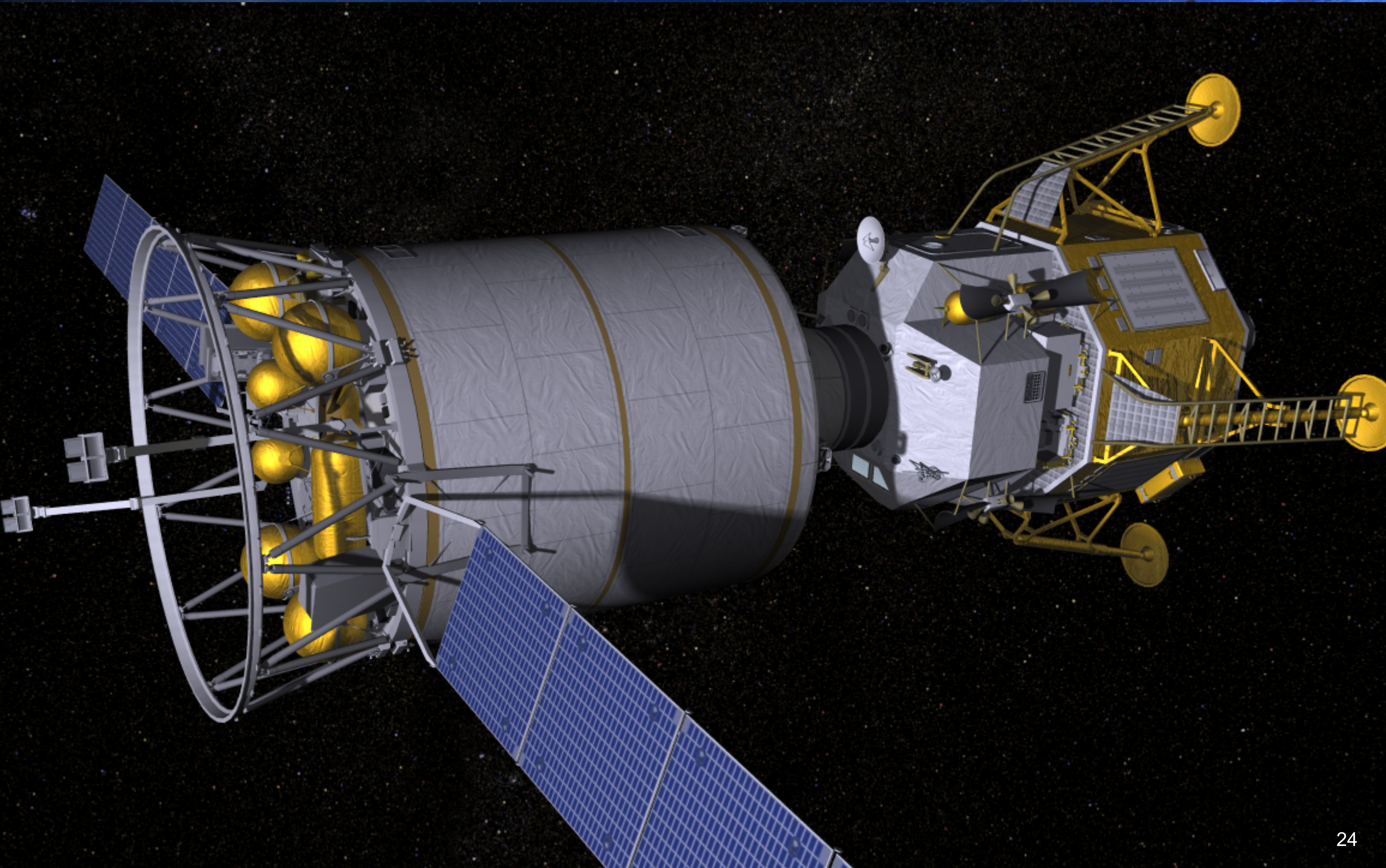
Unlike Earth, the moon remains largely unchanged since the formation of the solar system. Through study of our only natural satellite, scientists can look billions of years into the past for geologic clues while engineers can test systems necessary for future Mars missions. Lunar exploration challenges strengthen international partnerships critical to ambitious deep space endeavors.

SLS Capabilities

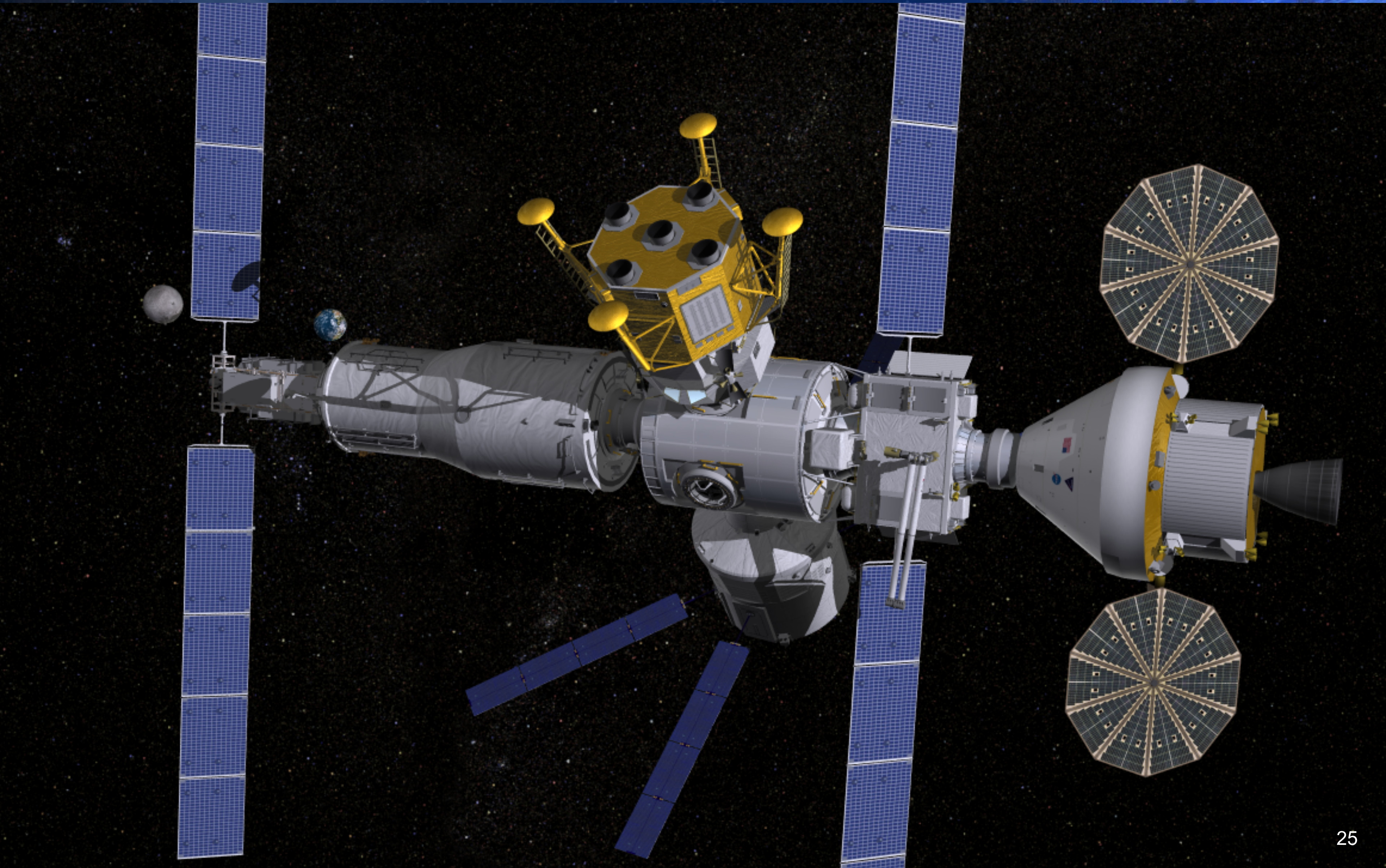
SLS enables human return to the moon. The intermediate SLS capability allows both crew and cargo to fly to translunar orbit at the same time which will simplify mission design and reduce launch costs.

SLS Lift Capacity | 45t to EML2

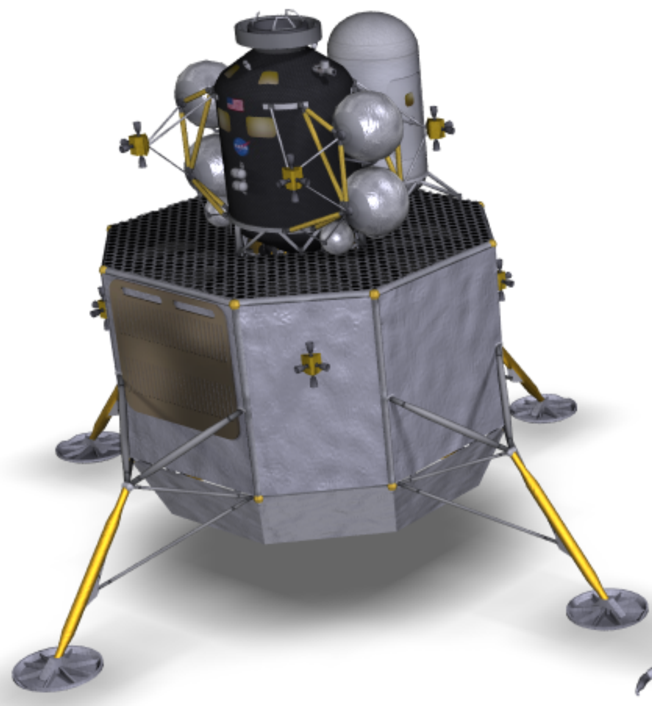
Refueling Tanker



Platform with Lunar Lander System

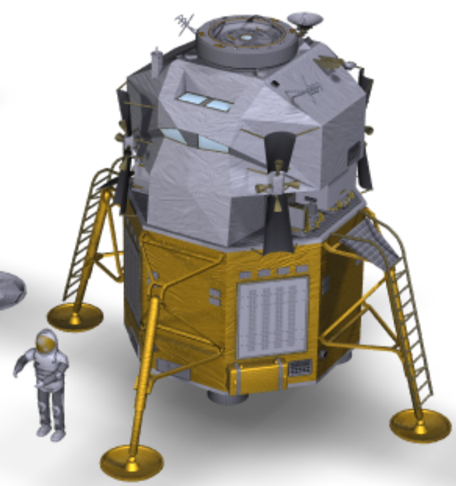


Size Comparisons

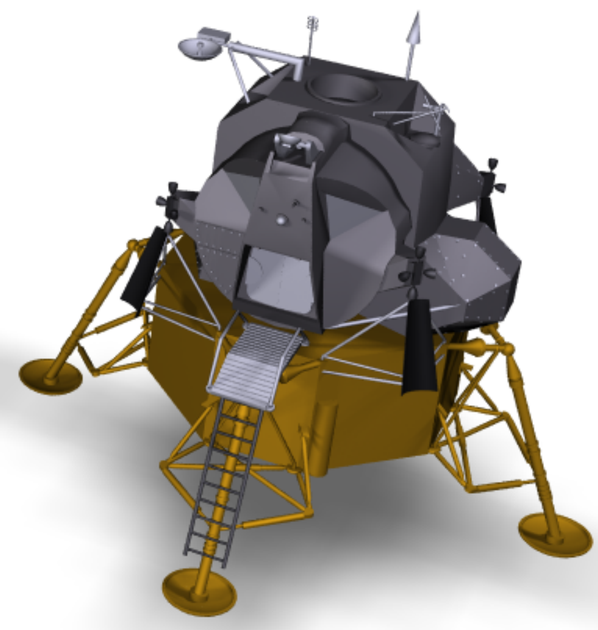


Altair Lander
45t Wet Mass
Crew Hab
Airlock
Expendable
10m Fairing

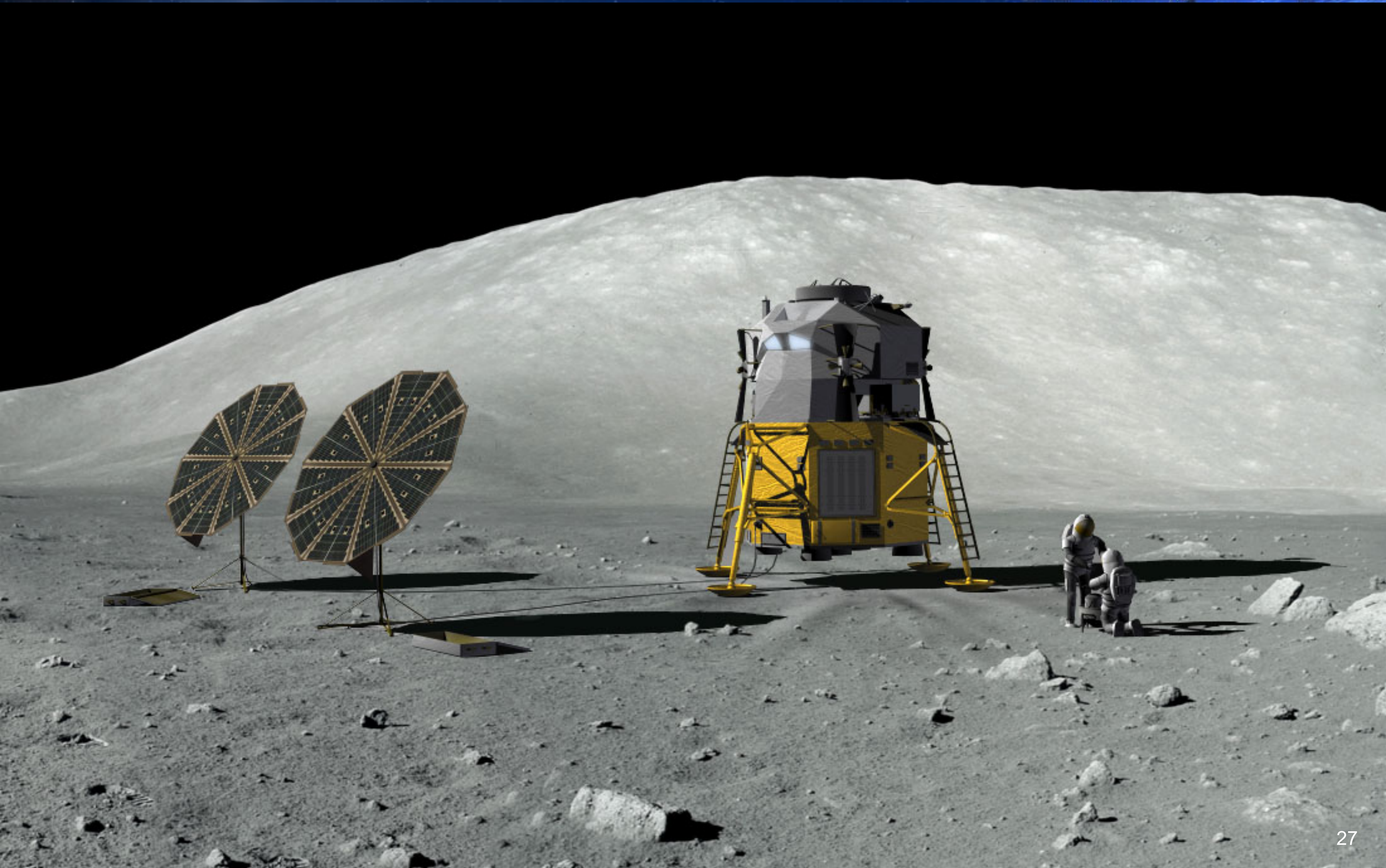
Re-Usable Lander
5.5t Dry Mass
16t Propellant
Crew Hab
Airlock
Re-Usable
5m Fairing



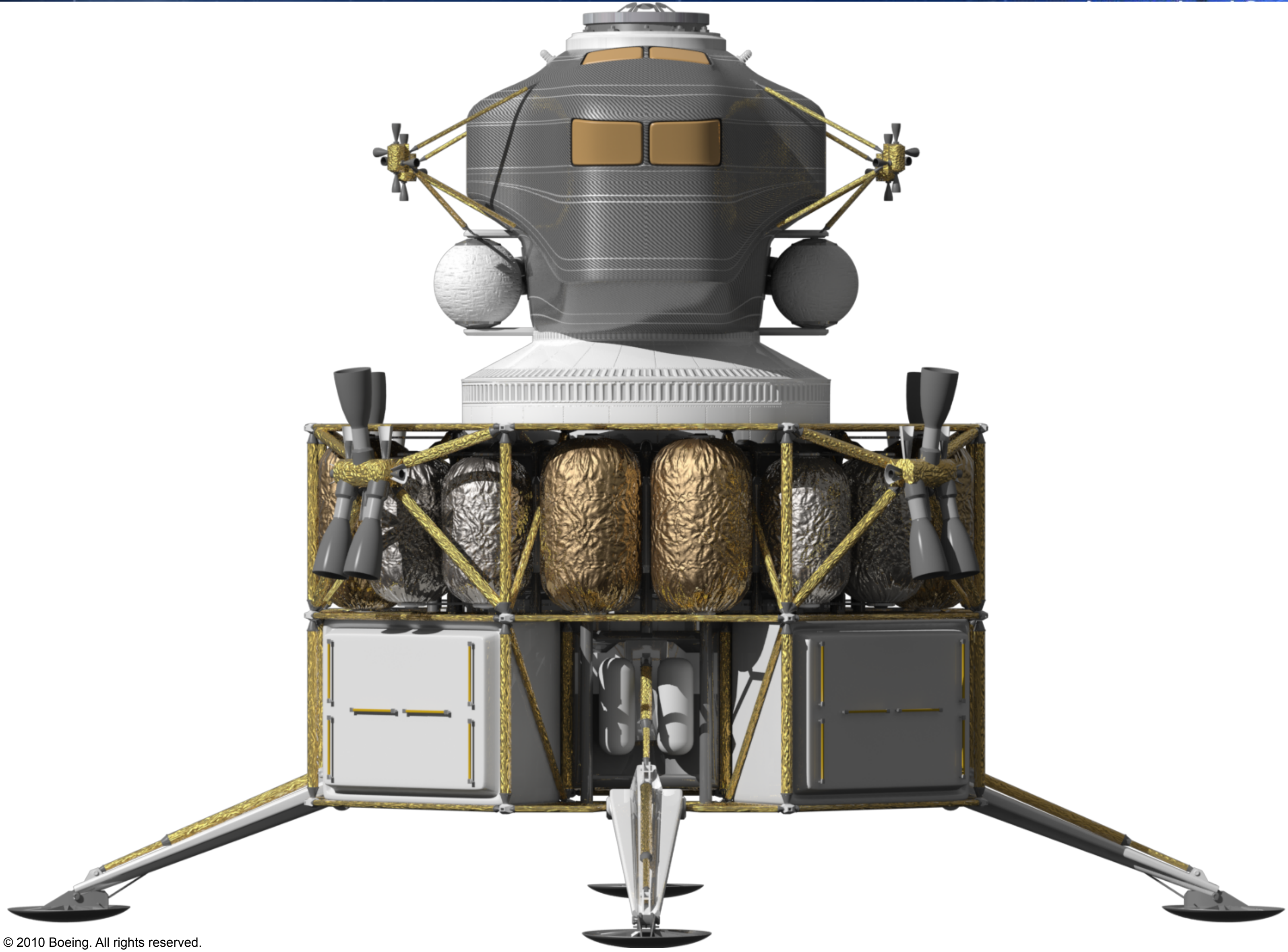
Apollo LM
5.5t Dry Mass
10.8t Propellant
Crew Cab
No Airlock
Expendable
Apollo SLA



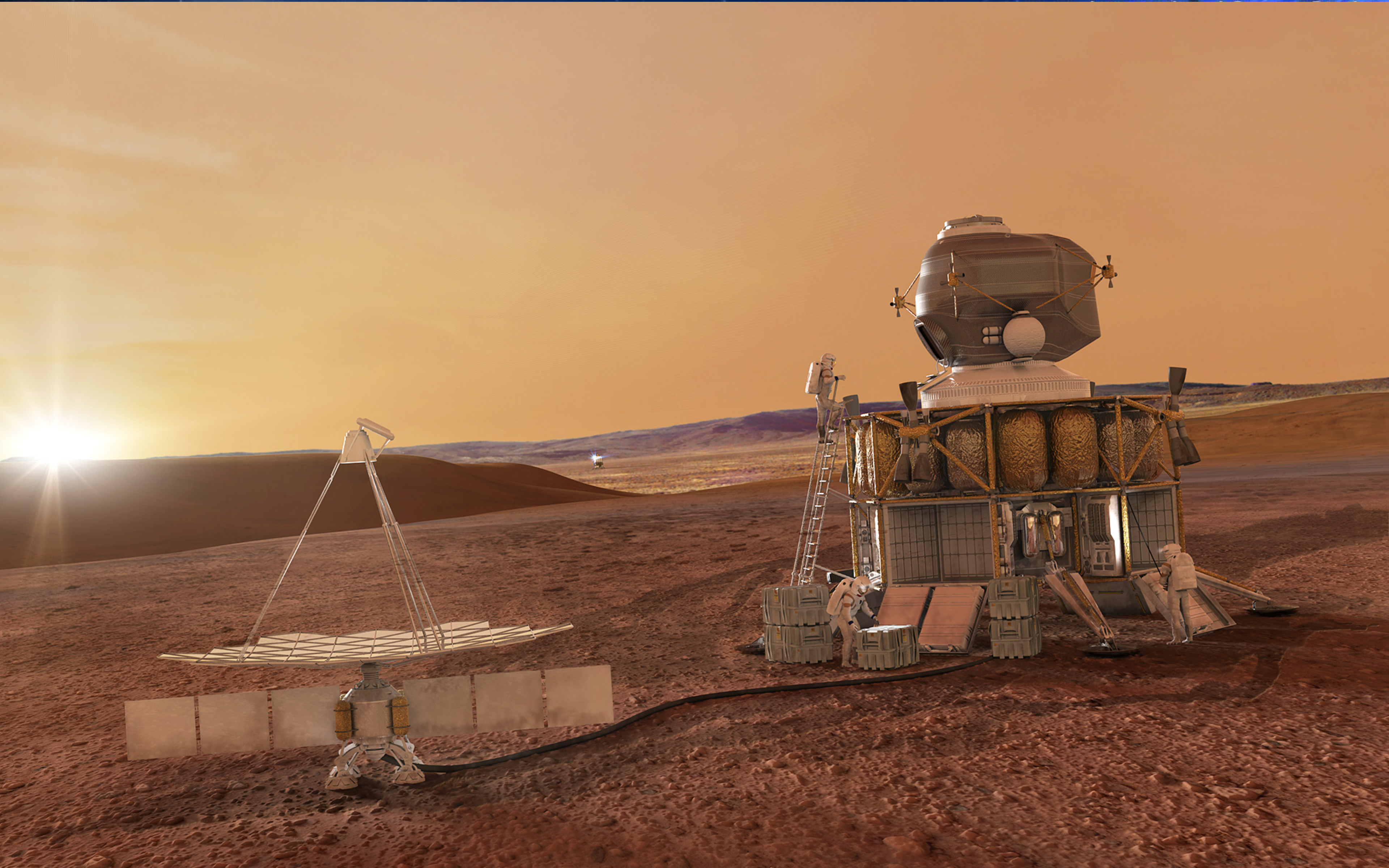
On the Moon



Reusable Lander



On Mars



Deep Space Habitat: Bigelow BA 330

Deep Space Habitat: Bigelow BA 330

Mission Objective

Deliver expandable BA 330 module to cislunar space

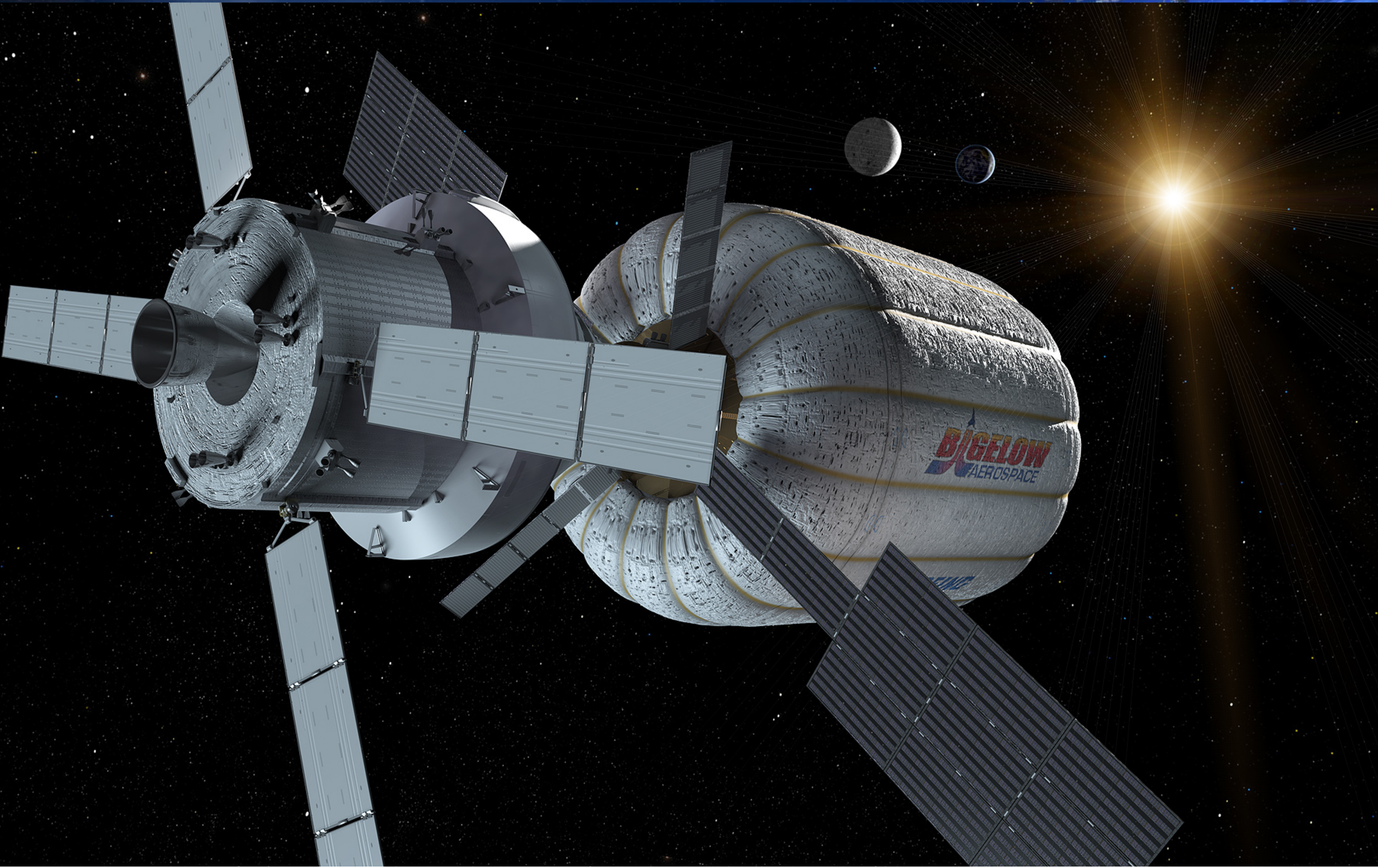
Mission Rationale

SLS supports commercial launch requirements and operations enabling a deep space human presence while extending Orion mission duration. The BA 330 is a stand-alone, self-sufficient module with crew support necessary to sustain long duration human habitation and may serve as a base element for future expansion. It can house up to six people on a long-term basis.

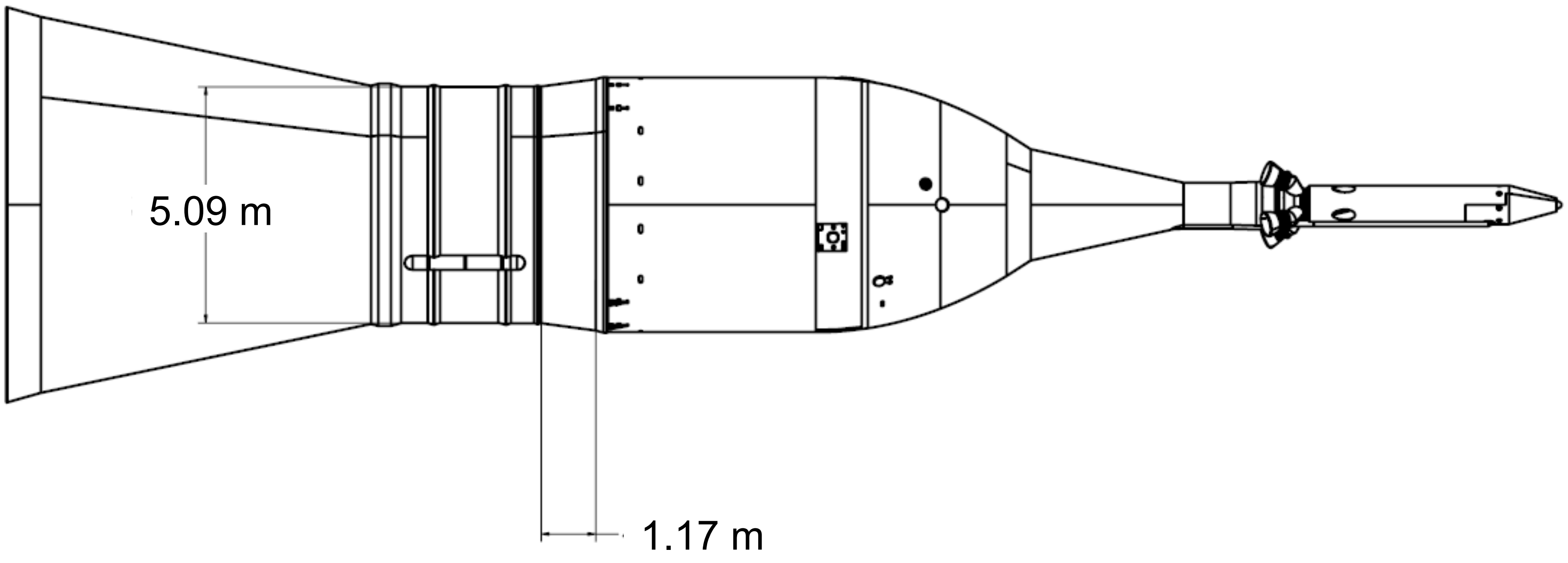
SLS Capabilities

SLS is the only launch vehicle capable of delivering the BA 330 to EML2. The heavy-lift vehicle will transport the habitation module beyond the moon and back to cislunar space via a low-energy transfer that reduces required propellant mass. SLS mass margin allows additional consumables, radiation protection or a secondary payload.

Bigelow Deep Space Habitat Deployed



Potential for Secondary Payloads



International Cooperation

- ISS has established a firm basis for a vibrant exploration program with a proven management model and proven existing designs

- A Deep Space capability based on ISS technology provides flexibility and is an enabling capability for key cost-reducing strategies:
  - Mobility within the libration system
  - Reuse of expensive spaceflight hardware
  - Base for assembly of complex, deep space mission systems

- International collaboration has been proven effective on ISS and could be improved and expanded for exploration
  - Embrace the International Space Exploration Coordination Group (ISECG) Global Exploration Roadmap (GER)
  - Apply the lessons learned from the International Space Station program and the experiences of the current partnership
  - Strong coordinated support from the associated transportation programs (Shuttle, Soyuz, Arianne, H2B)
  - International partnership with strong political support
  - Adequate funding to accomplish the objective
  - Agreements on hardware/software interface and construction standards

Questions?