Concepts Leading to a Sustainable Architecture for Cislunar Development

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LEAG – October 24

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Damn it Jim, I'm a Geologist not an Engineer

http://www.who2.com/blog/2011/09/who-was-the-horta-on-star-trek

Outline

- Introduction
- Assumptions
- Cislunar Development
  - Strategic Missions
  - Standalone Missions
- The 2107 Test Flight and Payload Opportunities
- What Could be Next
- Closing Thoughts

Introduction

- **ISS industry partners working on concepts to develop an Exploration Platform in the Earth-Moon Libration System**
  - Use ISS development methods
  - Use ISS residual assets
  - ISS not just a spacecraft but the expression of what great nations can accomplish working together
- **Technology developed for ISS can be evolved and adapted to new exploration challenges**
- **Concepts have matured along with Space Launch System (SLS) and Multi-Purpose Crew Vehicle (MPCV – Orion)**
- **Exploration Platform provides**
  - Flexible basis for future exploration
  - Reduces cost through re-use of expensive vehicles
  - Reduces number of launches needed to accomplish missions

Assumptions

- The SLS/MPCV will be built and launched per schedule
- A Human Tended Habitat at an Earth-Moon Lagrange Point will be the next human space flight target
- There will be an un-crewed test flight of the SLS/MPCV with an Apollo 8 like free return trajectory in 2017
- There is sufficient mass margin and volume on that launch for 1 or 2 small science/exploration payloads
- There are at least 2 approaches for exploration
  - Strategic
  - Stand Alone
- There are at least 3 approaches for the next step for human exploration (Global Exploration Roadmap uses the first 2)
  - Near Earth Object (NEO) First
  - Moon First
  - Cislunar First
- Whatever we take ought to be refuelable and reusable.

Cislunar First (Strategic Approach)

- Vedda – Space Review Sept/Oct 2012
  - Proposes adding Cislunar-Next to Global Exploration roadmap in addition to evaluating Moon-Next and/or Asteroid-Next
    - On-orbit Servicing
    - Standardization
    - Fuel Storage
    - Materials processing
    - Energy collection and distribution
    - Other in-space utilities
- Spudis-Lavoie – AIAA Space 2011
  - Teleoperations
  - Prospect, Test, Demonstrate and Produce water from Lunar Resources
  - Architecture and Mission Sequence

Science Missions (Stand Alone Examples)

- South Pole Aitken Basin Sample Return
    - MoonRise
        - Human/Robotic/Telerobotic – Alkalai, et.al. this session
        - New Frontiers – Jolliff et.al.
- Schrödinger Telerobotic – Burns, et.al. – GLEX 2012
    - Geologic Exploration
    - Low frequency radio astronomy
- Aristarchus Plateau – Jolliff et.al. – LEAG 2001
    - Strategic/Stand Alone
- Landed Geophysical Package
    - Also strategic/stand alone
    - International Lunar Network (ILN)
    - Lunette – Discovery Class

WHAT NEXT?

(NASA painting by Pat Rawlings.)

- **Lunar Reconnaissance Orbiter (LRO) data enables detailed exploration planning, landing site selection, and safe operations**
  - **Polar Volatile Explorer**
    - Ascertain physical state, composition, and properties of polar volatile OH deposits
  - **Lunar Roving Prospector**
    - Long-duration instrumented rover
      - Arizona State University (ASU) Intrepid Mission
    - Possible L2 role
    - Provide critical ground truth to remote sensing datasets
  - **Automated Sample Returns**
    - South Pole Aitken – Early Solar System History
      - L2 outpost role there, too?
    - Recent lunar basalts – history of lunar interior
  - **In-situ Resource Utilization (ISRU) Demonstration**

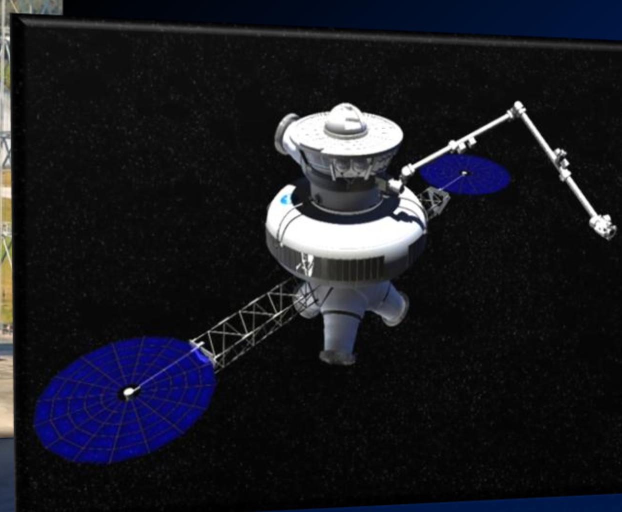
THE NEXT LUNAR LANDING SITES

- **Lunar poles**
  - Sunlight + Volatiles
- **Aristarchus plateau**
  - Major ore deposit
  - Young basalts
- **South Pole-Aitken Basin**
  - Oldest lunar basin?
  - Sample of lunar mantle

S. Lawrence – ASU 2012

Cislunar Development Meets National Needs

- Fuel Depots + dry launch
- L1/L2 Gateway
- Lunar ISRU is cornerstone
- Maximizes commercial opportunities
- Reduces cost of asteroid and Mars system expeditions



S. Lawrence – ASU 2012

From Spudis, Lavoie – AIAA 2012

What are we trying to do?

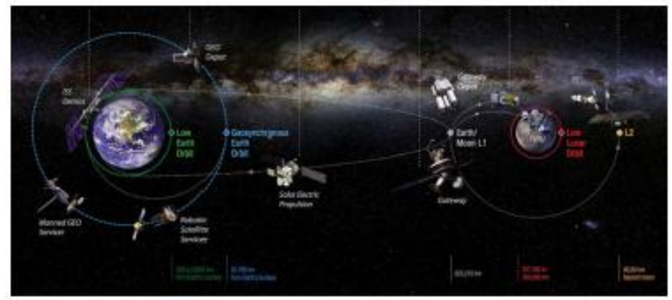
The Vision

Expand human reach* to cislunar and beyond

The Mission

Establish a robotic and human presence on the Moon (as the closest planetary body) to learn how to use local resources of material and energy in order to live affordably off-planet and, in so doing, create new space faring capabilities

*Reach = the ability to send people and machines to any point within a given volume of space to perform whatever tasks are envisioned



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Spudis, Lavoie – AIAA 2012

From Spudis, Lavoie – AIAA 2012

Initial Steps

1. **Communication/navigation satellites**
   Polar areas out of constant Earth LOS; need comm, positional knowledge
2. **Polar prospecting rovers**
   Study and characterize water deposits, other substances, environment
3. **ISRU demo**
   Heat icy regolith to extract water; purify and store as ice in cold traps
4. **Digger/Hauler rovers**
   Excavate regolith, transport feedstock to fixed stations for water extraction
5. **Water tankers**
   Purify and store extracted water

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Spudis, Lavoie – AIAA 2012

Types of Missions

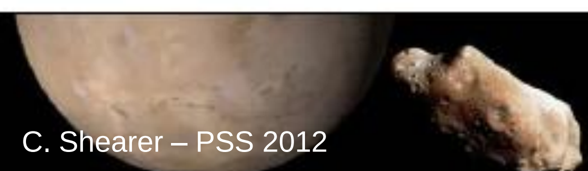
- **Strategic**
  - Resource Prospecting
  - ISRU Production testing
  - ISRU Production
  - Propellant storage and transportation (reusable landers)
- **Standalone**
  - South Pole Aitken (SPA) Sample return
  - Lunar Network
  - Low Frequency Radio observation

Types of payloads

- **Forward compartment**
  - Cubesats
  - Static Lander
    - Geophysical network package
- **Aft compartment**
  - Lander with prospecting rover
    - Discovery class
    - Google Lunar X Prize (GLXP) Class

Proposed Future Robotic Lunar Missions 2013-2019

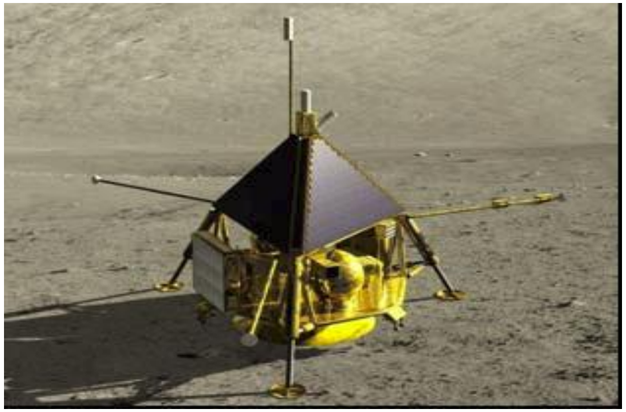
COUNTRY	NAME	TYPE	YEAR
China	Chang'e 3	Lander	2013
USA	LADEE	Orbiter	2013
India	Chandrayaan-2	Lander	2014?
Russia	Lunar Glob	Lander	2014?
Private	GLXP	Landers	2014
China	Chang'e 4	Lander	2015
Russia	Lunar Grunt	Orbiter/Lander	2015
Japan	SELENE-2	Lander	2016
China	Chang'e 5	Lander	2017
Europe	MoonNext	Lander	2015-2018



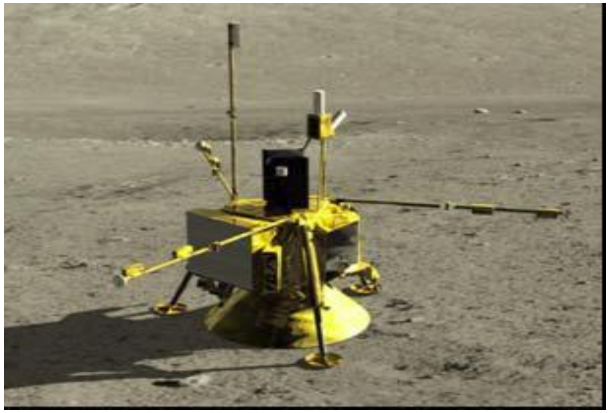
C. Shearer – PSS 2012

MSFC/APL

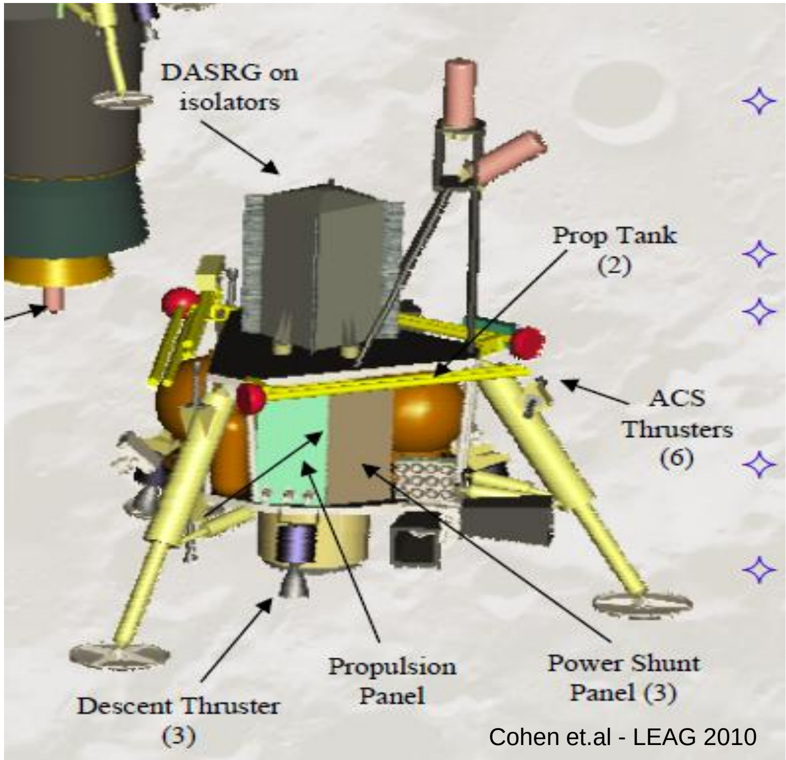
http://www.nasa.gov/mission_pages/lunarquest/robotic/12-085.html



Cohen et.al - LEAG 2010



Cohen et.al - LEAG 2010



Cohen et.al - LEAG 2010

Lunette – A Discovery class mission concept

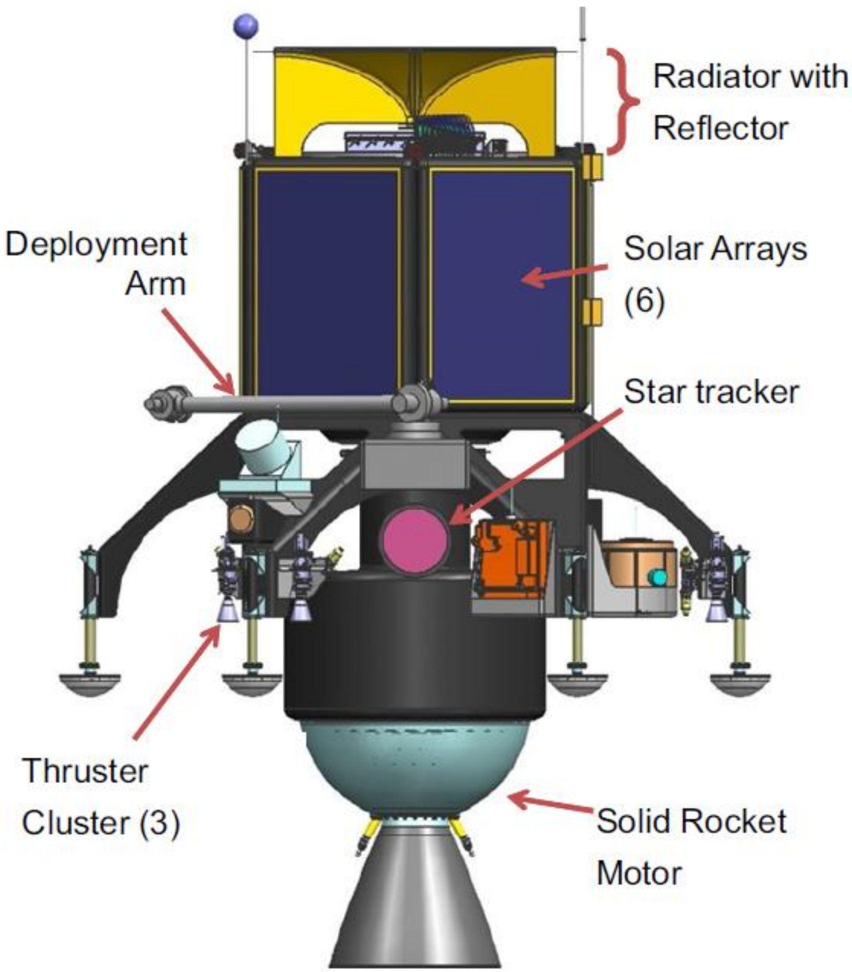
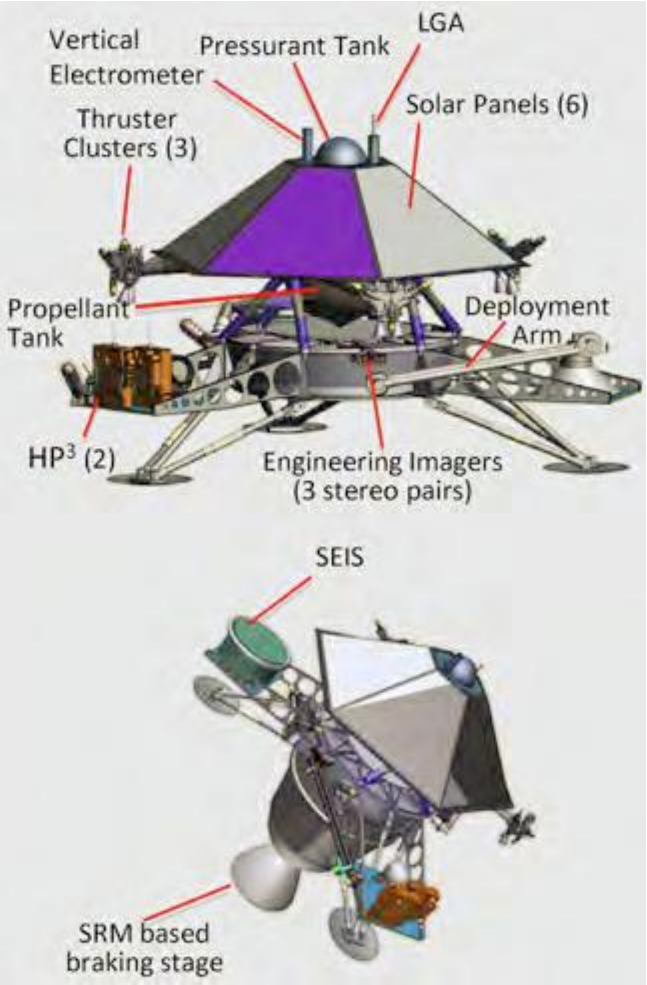


Fig. 5. Conceptual flight system in cruise configuration.



J. Elliot et.al. – IAC 2011

C. Neal et.al – LPSC 2011

Lunette as an ESPA ring class payload

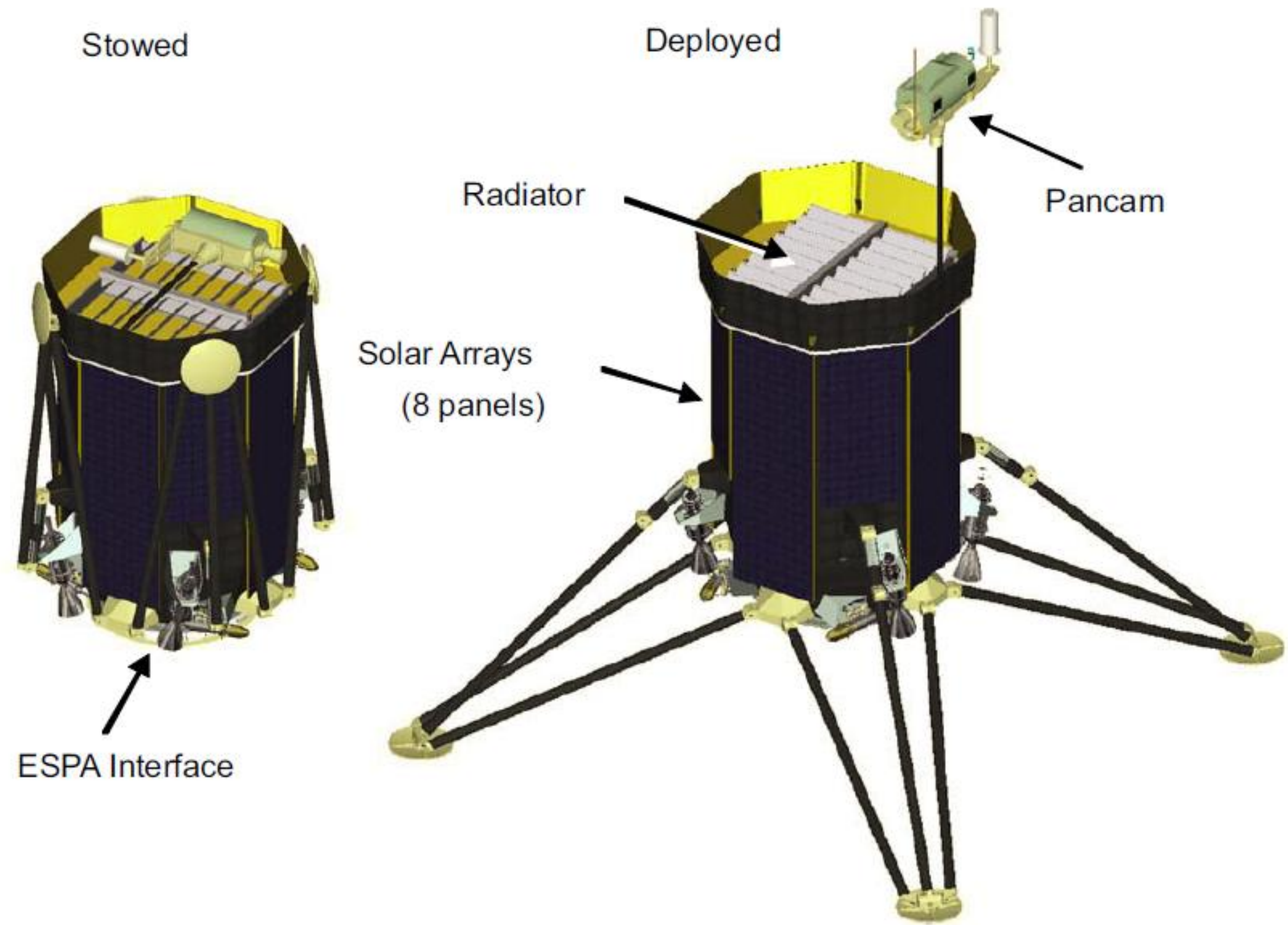


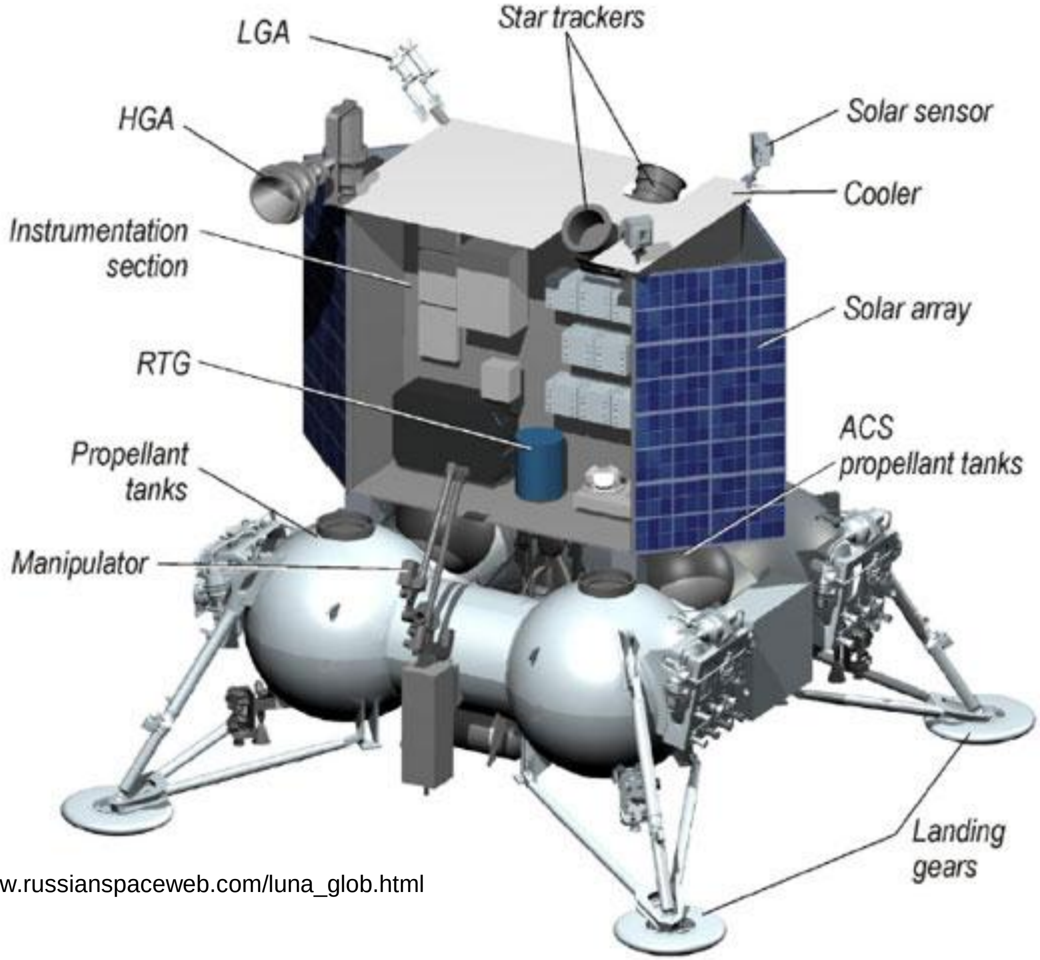
Fig. 7. Lander configuration.

J. Elliot – JPL 2009

Chandrayaan-2 - Russian - Lander/India - Rover

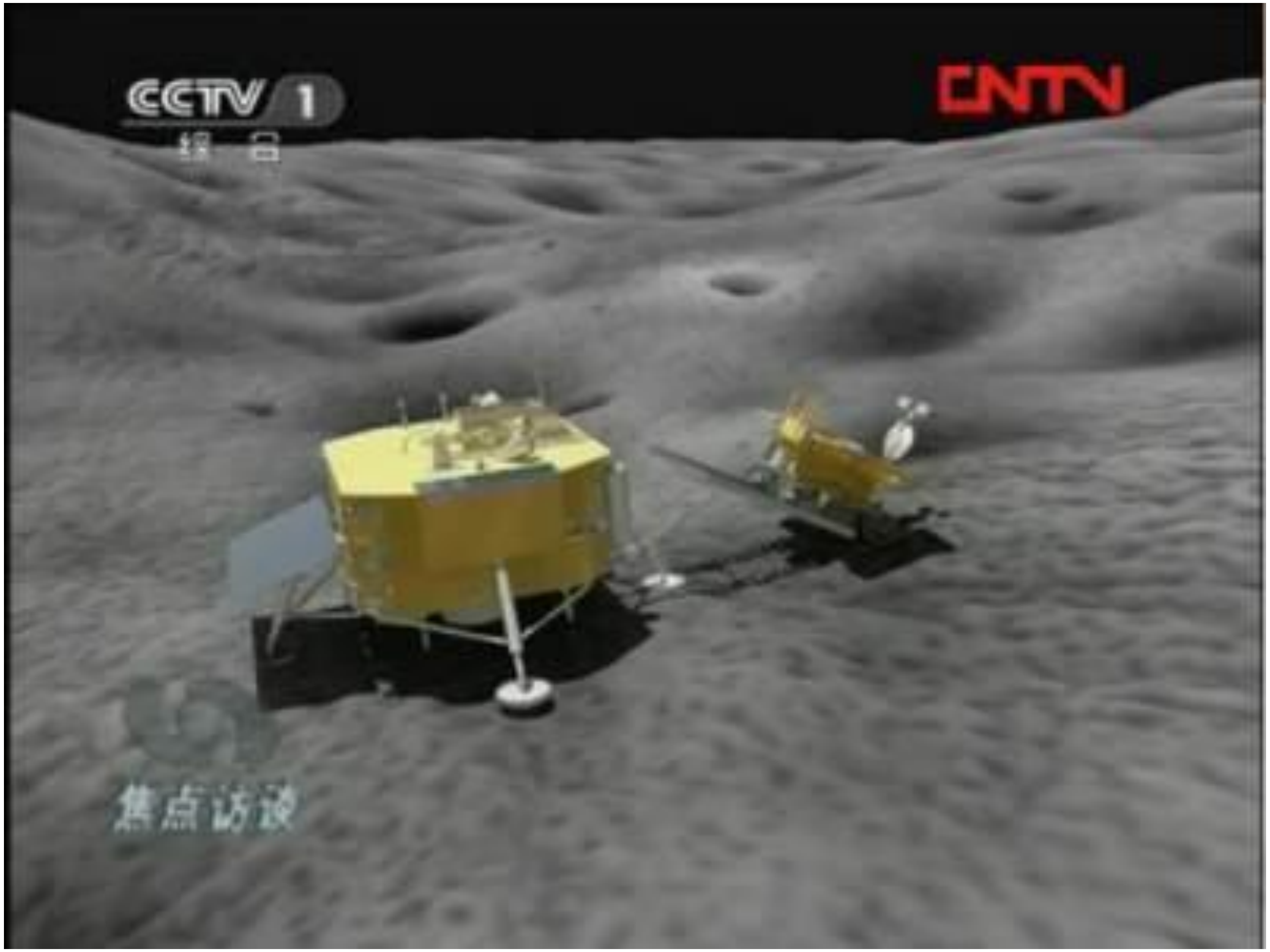
http://www.russianspaceweb.com/luna_resurs.html

Luna Glob - Russia



http://www.russianspaceweb.com/luna_glob.html

Chang’e 3 - China

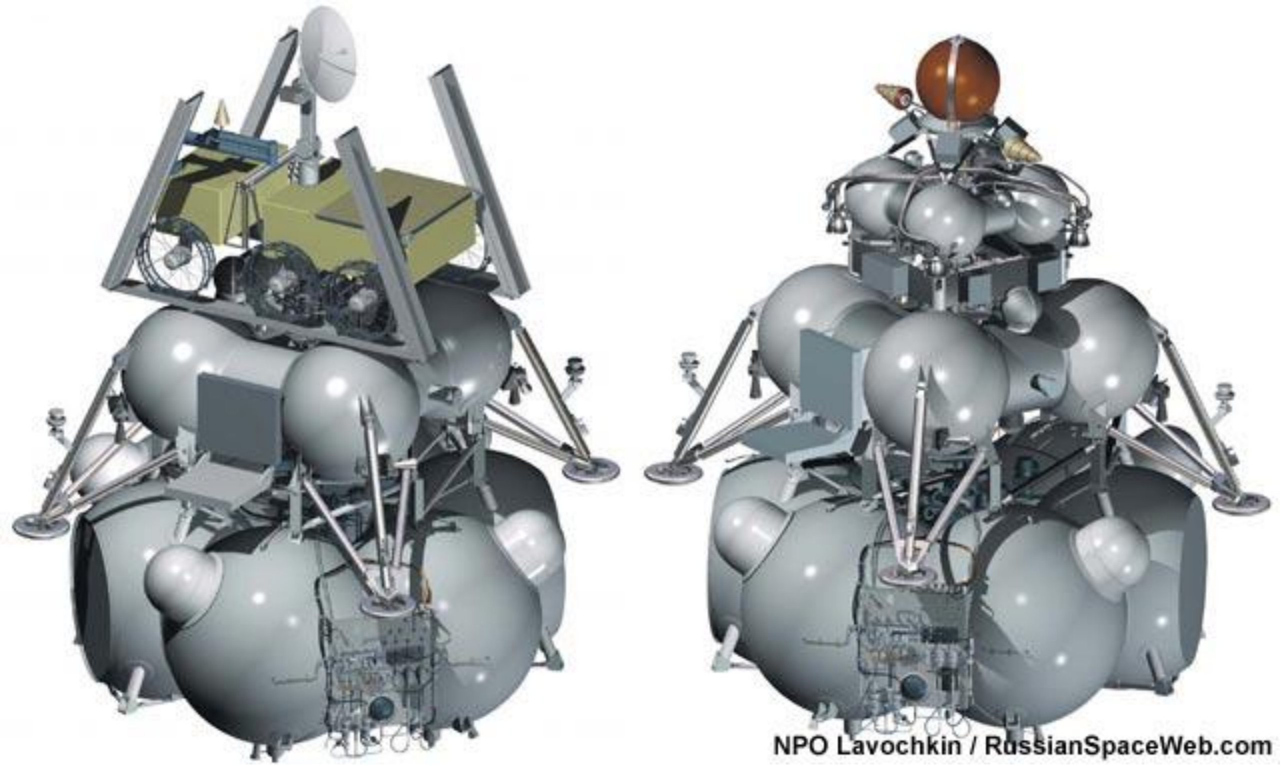


http://forum.nasaspaceflight.com/index.php?topic=26848

Chang’e 4 - China

http://enterspace.typepad.com/blog/2012/03/more-details-on-chinas-chang-e-lunar-sample-return-mission-plans.html

Luna Grunt - Russia



http://www.russianspaceweb.com/luna_grunt.html

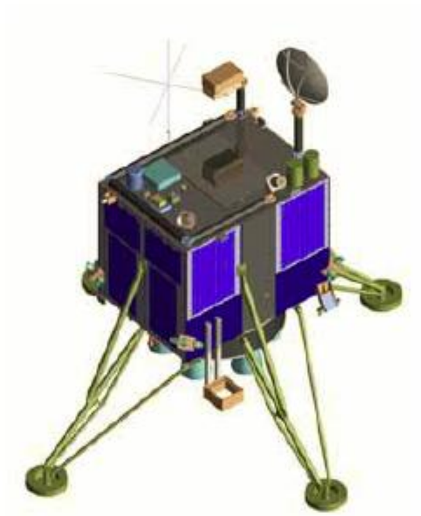
Selene 2 - Japan

http://moon-lore.com/web/mapping_missions.html

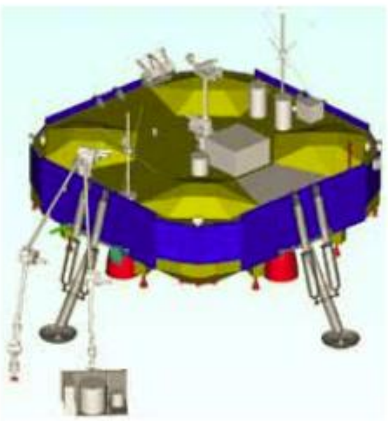
ESA - MoonNext

Astrium Space Transportation

OHB System



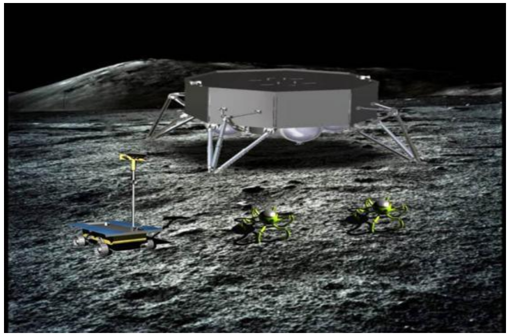
Thales Alenia Space



http://www.lpi.usra.edu/meetings/leagilewg2008/presentations/oct30am/Carpenter4037.pdf


http://upload.wikimedia.org/wikipedia/en/0/0a/LLMoon.jpg
esa

Google Lunar X Prize



http://www.googlelunarxprize.org

Three optional payload locations

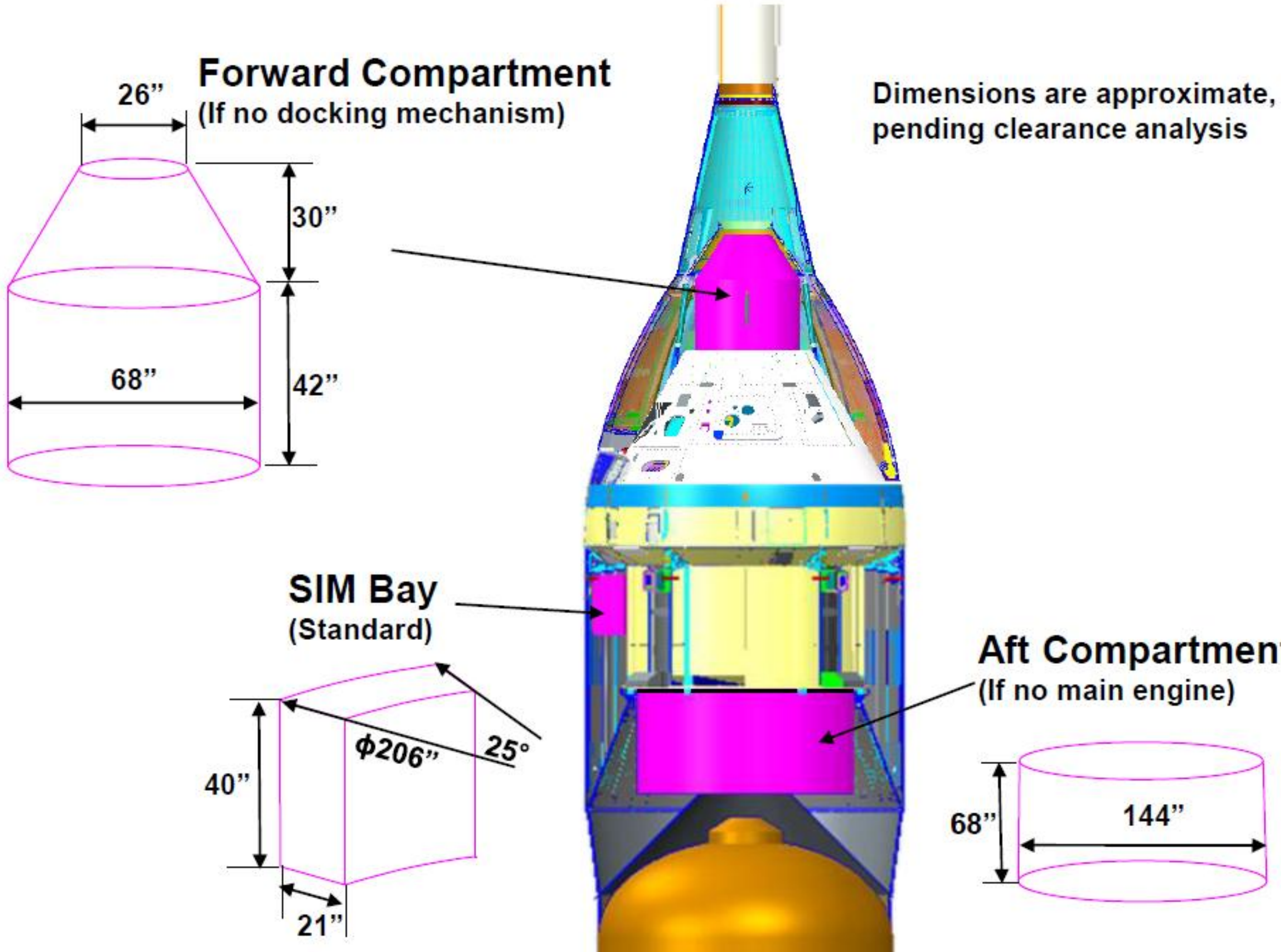
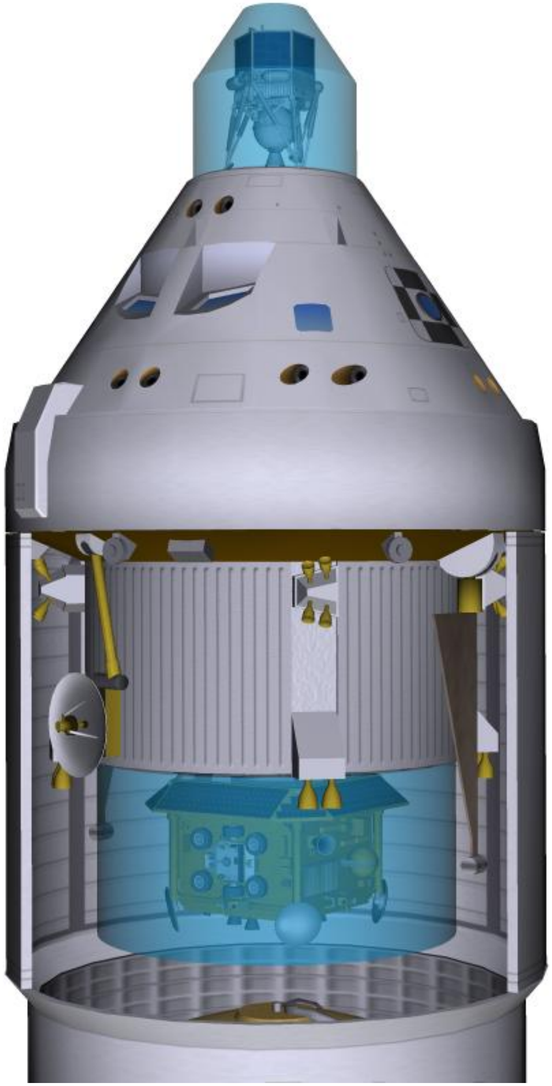
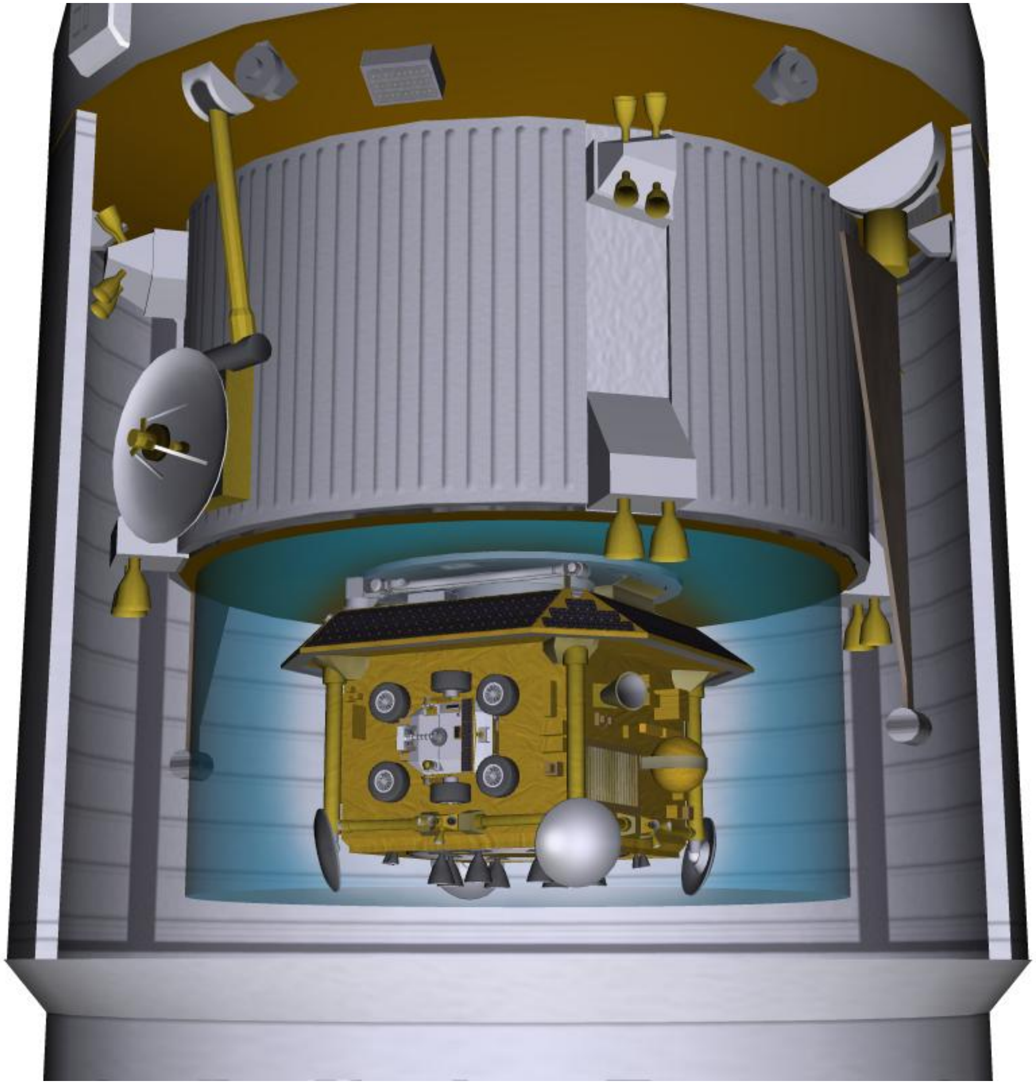


Image courtesy of Lockheed Martin Corporation

Notional Payloads

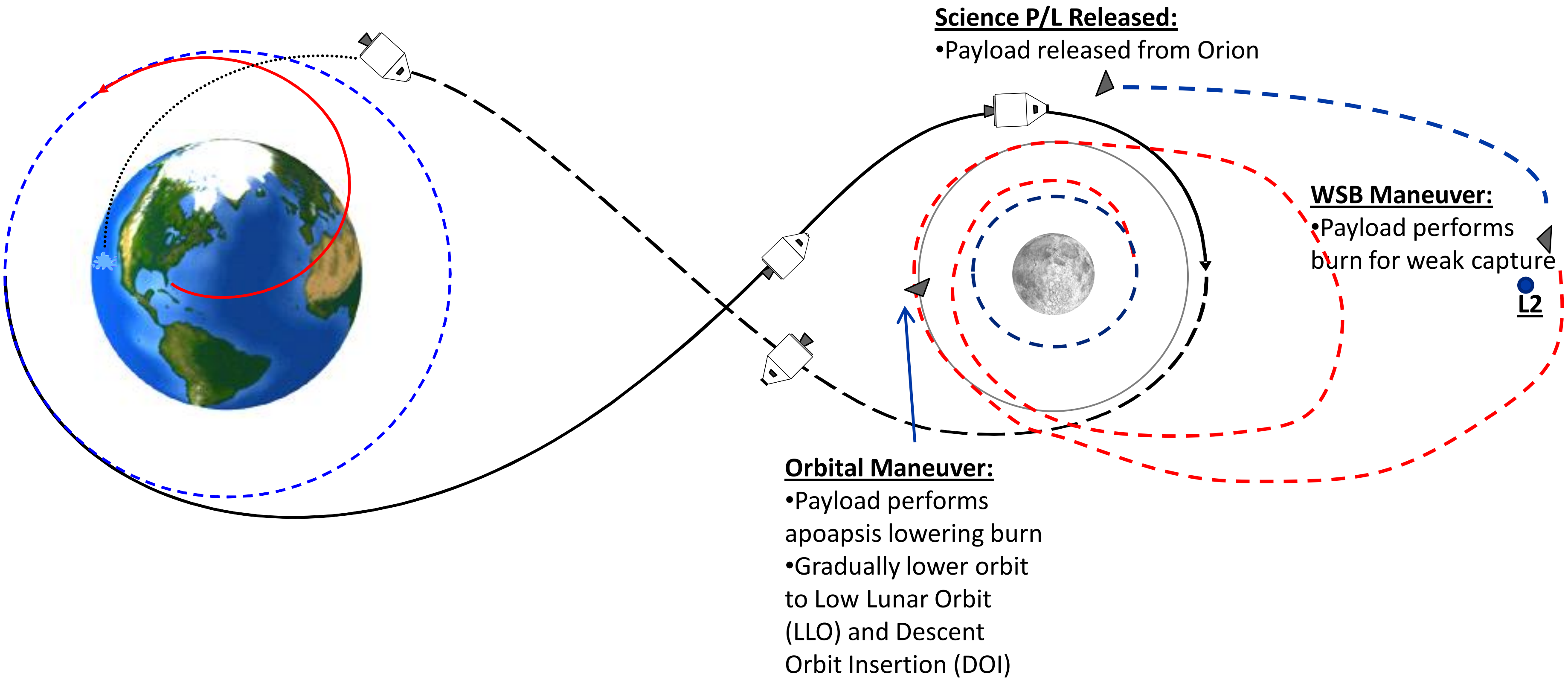


Aft Compartment Detail



Forward Compartment Detail

Science Payload Release & Lunar Capture



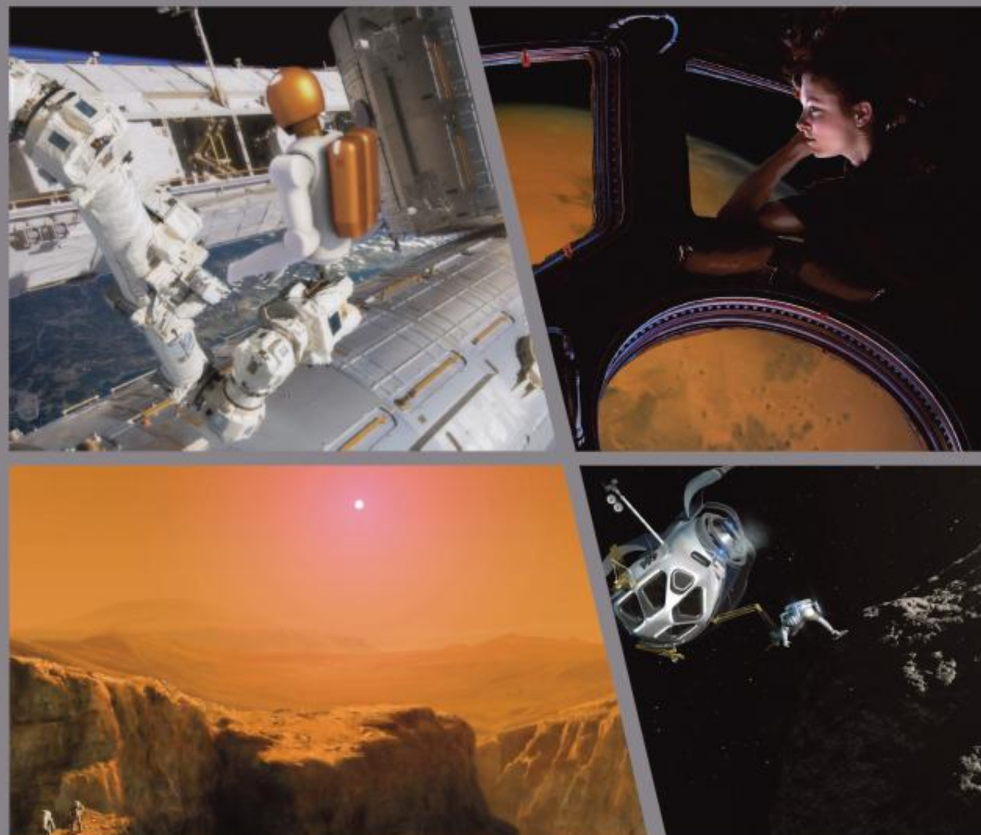
Selected Breakout Session Findings: Science
[From Teleoperations Symposium outbrief - 2012]

- **<u>Examples</u> of problems where low-latency telepresence *may* be enabling can be described further and quantitatively assessed:**
  - *Volatiles on the Moon (and their access, encapsulation) particularly within Permanently Shadowed Regions*
  - *Lunar farside astrophysical observatory (meter-wave radio) and surface geophysical/interior network*
  - *Mars surface biogeochemical sampling (and related issues) as part of the search for signs of ancient life*
  - *and many others, including those on outer planet satellites, Venus, small bodies*
- **New science can be enabled via telepresence at places that are**
  - *Distant (e.g., Mars, Titan)*
  - *Hostile to any reasonable form of human presence (25 K lunar polar regions , surface of Venus at 450 C, surface of Titan, surface of Mercury, meters underground on Mars or Europa, etc.)*
- **Scientists must be engaged in technology development of required capabilities (*i.e., science pull*)**
  - *The more science is involved <u>early</u> the better the tools for science will be integrated into useful capabilities*
  - *Related to <u>field science as an immersive process</u> here on Earth (where there is a large experience base)*
- **Learn from MER and MSL surface-rover experience what increased telepresence is germane to in high-priority planetary field science**
  - *Take advance of lessons learned from high-latency telepresence (MER, MSL)*
- **Contemporary commercial and defense telepresence activities are highly instructive, and even learning from Lunokhod may be of value.**
- **As latency is reduced is there a natural breakpoint where increase in complexity of tasks gives clear increase in value of science?**
  - *For Moon: if it is seconds, do from Earth;*
    but if fractional seconds, do from orbit or Earth-Moon L2?

National Aeronautics and Space Administration

Voyages

Charting the Course for Sustainable Human Space Exploration

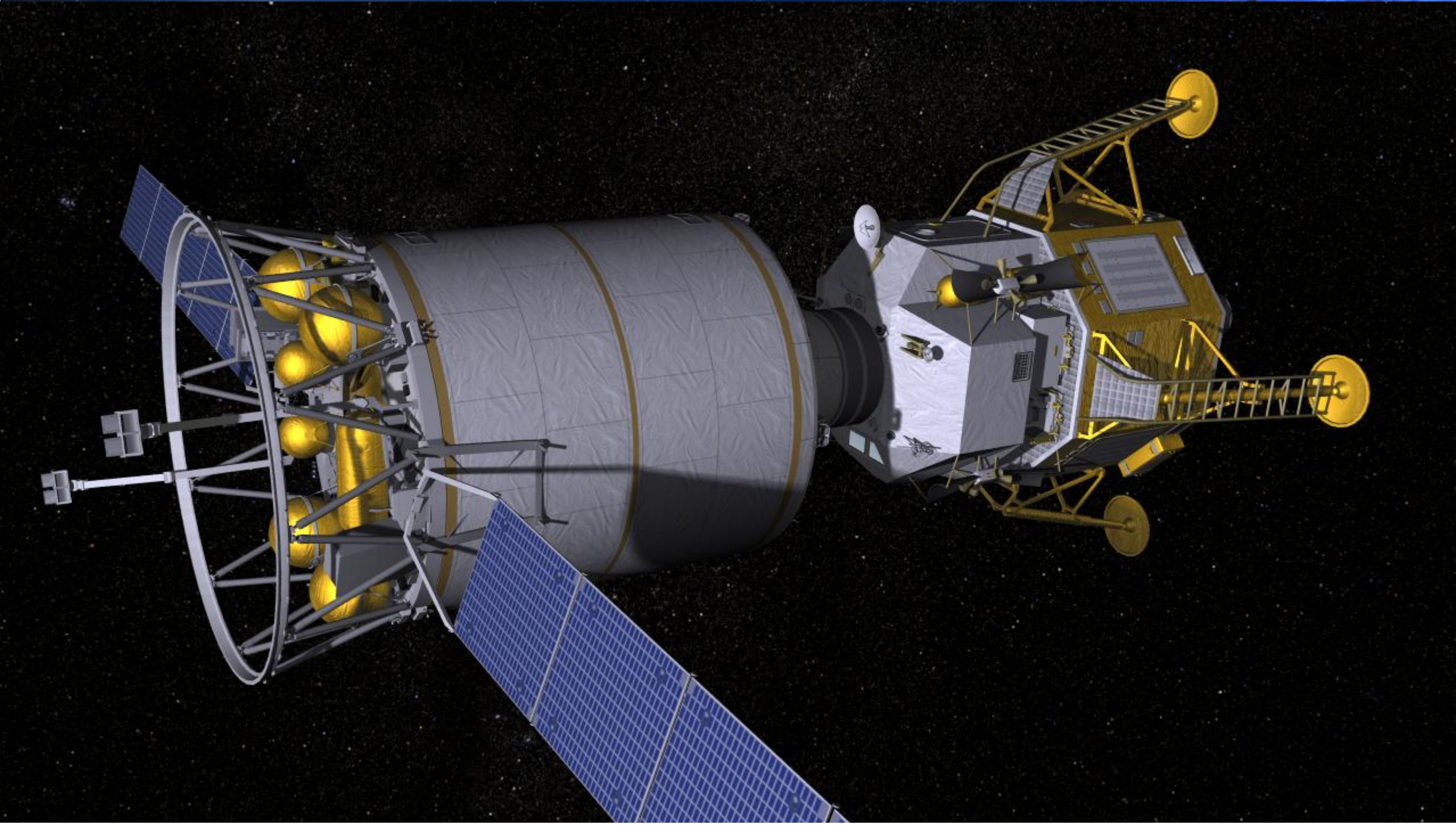


http://www.nasa.gov/exploration/whyweexplore/voyages-report.html

From NASA’s Voyages

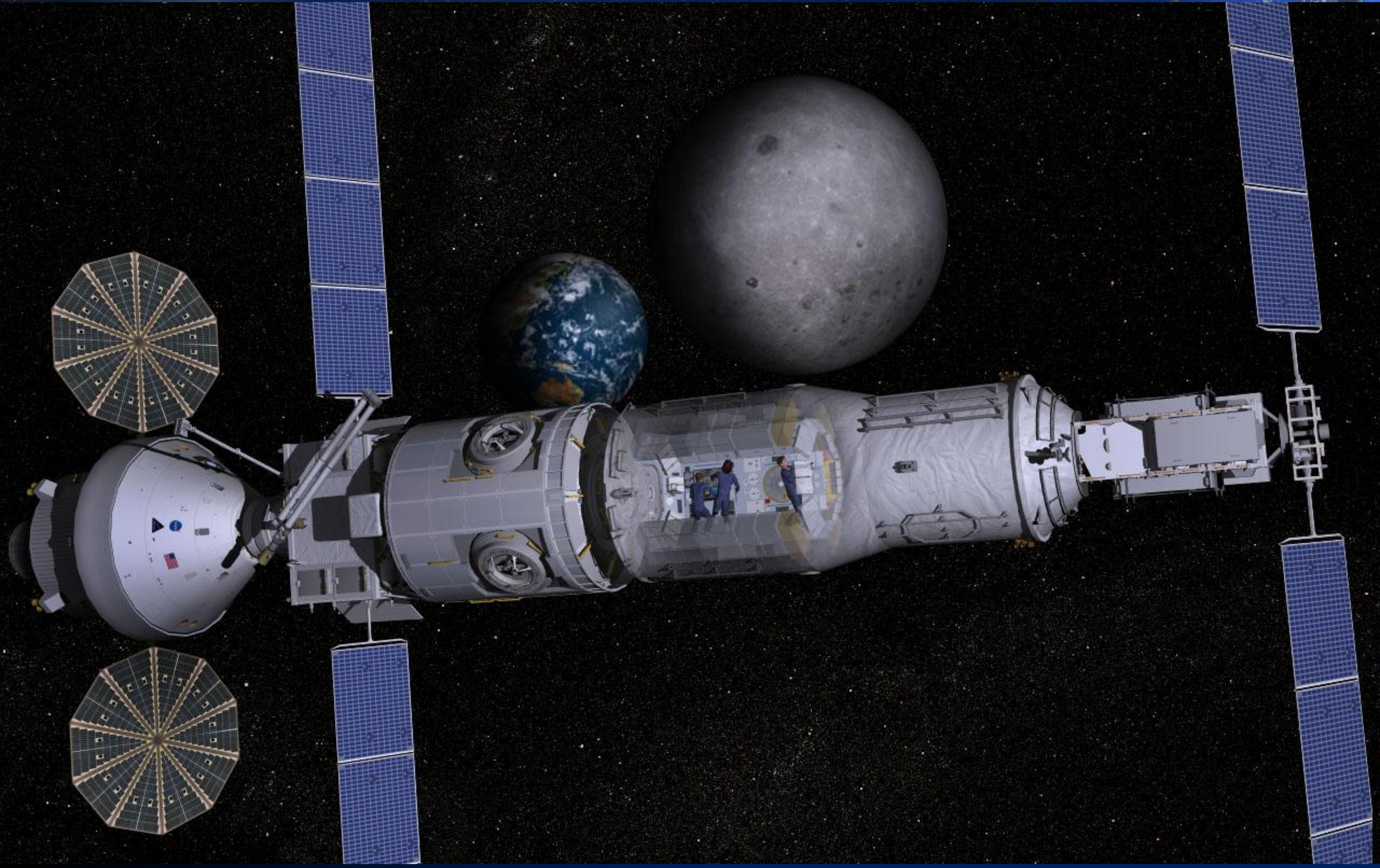
- **Capability driven approach**
  – Core evolving capabilities
  – Leveraged and reused instead of specialized, destination specific
- **Cislunar space will teach us about how humans live and work in space**
  – Build capabilities for future in-space activities and deep space exploration
  – Economic growth
  – Pave the way for future expeditions
  – Commercial and International collaboration
- **Precursor robotics**
- **Human-robotic interfaces**
  - Risk mitigation through telerobotics
- **Destination systems**
  – ISRU
    - Sustain human life off Earth with in-situ resources
  – Sustained presence
  – Long duration habitats

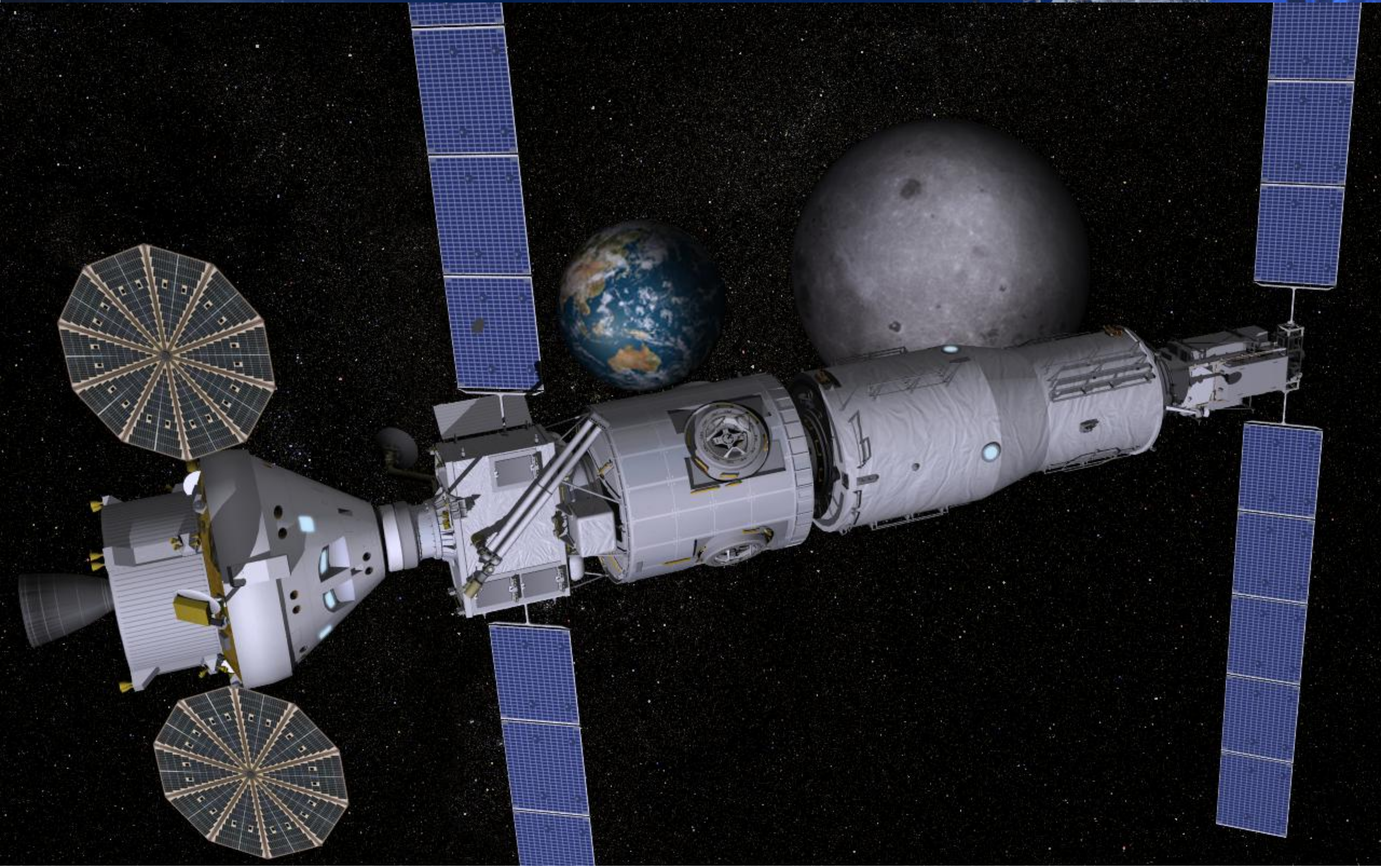
Refueling Tanker

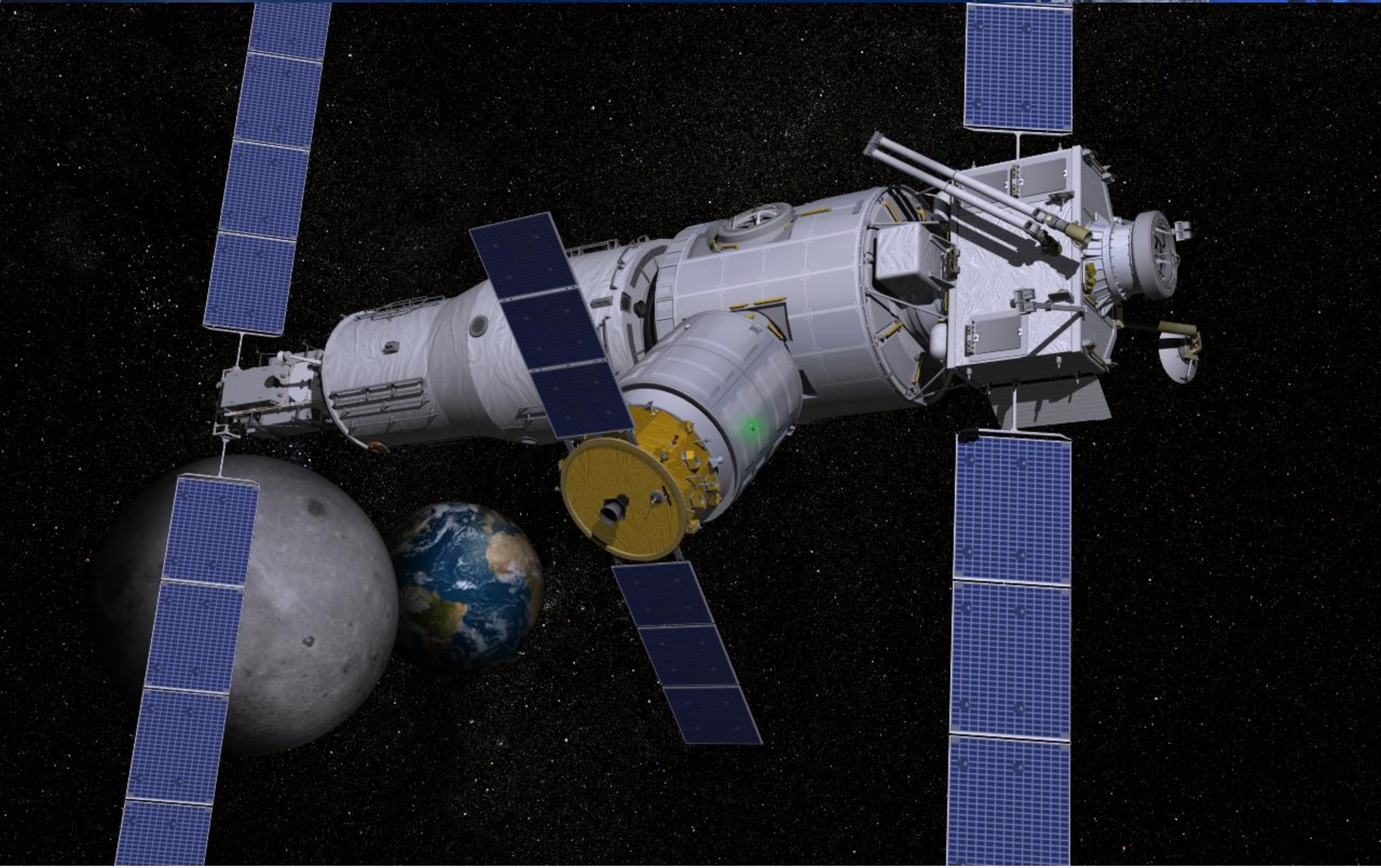


Summary

- Cislunar Next provides best opportunities for a sustainable Space Exploration Architecture
- 2017 offers us an opportunity
    - Similar to LRO – Science Mission Directorate (SMD)/Human Exploration and Operations Mission Directorate (HEOMD) Joint Mission
- Exploration Platform provides flexibility for many different types of missions
- ISS not just a spacecraft but the expression of what great nations can accomplish working together








BACKUP RELAY SERVICE
CONTROL ACCESS

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