National Aeronautics and Space Administration

# HEOMD NASA Advisory Council Public Session

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# What Were HEO's Biggest Accomplishments In 2013?

- Safe and successful operation of the ISS;
- ISS utilization: increase crew hours, benefits to humanity, new capabilities like rodent research on SpaceX 4
- Successful accomplishment of the Commercial Cargo Program, resulting in two providers of ISS cargo transportation services
- Received and evaluated the initial Certification Products Contracts Phase I products
- Successful accomplishment of the CCiCAP partners' milestones
- SLS preliminary design review
- Installation of SLS manufacturing tooling at Michoud Assembly Facility
- Delivery of Orion heatshield
- Orion power on
- Successful launches of TDRS-L, Landsat 8, and MaVEN
- Successful Lunar Laser Comm Demonstration from LADEE spacecraft in lunar orbit
- Initial definition of the Asteroid Redirect Mission

# What Are HEO's Biggest Challenges In 2014?

- Extending ISS beyond 2020 enables the nation's goals in space – commercialization, extending humans beyond low Earth orbit, returning benefits & humanity, and leading a global exploration partnership
- Continue safe, innovative and productive use of ISS, including achieving a regular cadence of commercial cargo flights. Most important thing is to use this unique facility to expose others to the benefits of space based research
- Receive, evaluate, and select CCtCAP provider(s)
- Deliver the Orion test article and fly EFT-1
- Guide SLS through Agency approval for final design and fabrication, and continue hardware development as the overall design matures to critical design review
- Establish the pathway for SLS upper stage development including international partner roles
- Keep Orion and the ESA service module on track
- Take ARM Mission into formulation
- Launch TDRS-L successfully and implement Space Network Ground Segment Sustainment


Asteroid Redirect Mission and
The Future of Human Spaceflight

# Leveraging Capabilities for an Asteroid Mission

- **NASA is leveraging key on-going activities in Science, Space Technology, and Human Exploration and Operations Mission Directorates**
  - Asteroid identification and characterization efforts
  - High power solar electric propulsion
  - Autonomous guidance and control
  - Orion and Space Launch System vehicles
  - Technologies for astronaut extra-vehicular activities

- **Each individual activity provides an important capability in its own right for human and robotic exploration**

- **We are working to utilize all of these activities to**
  - Identify and redirect a small asteroid to a stable orbit in the lunar vicinity; and
  - Investigate and return samples with our astronauts.

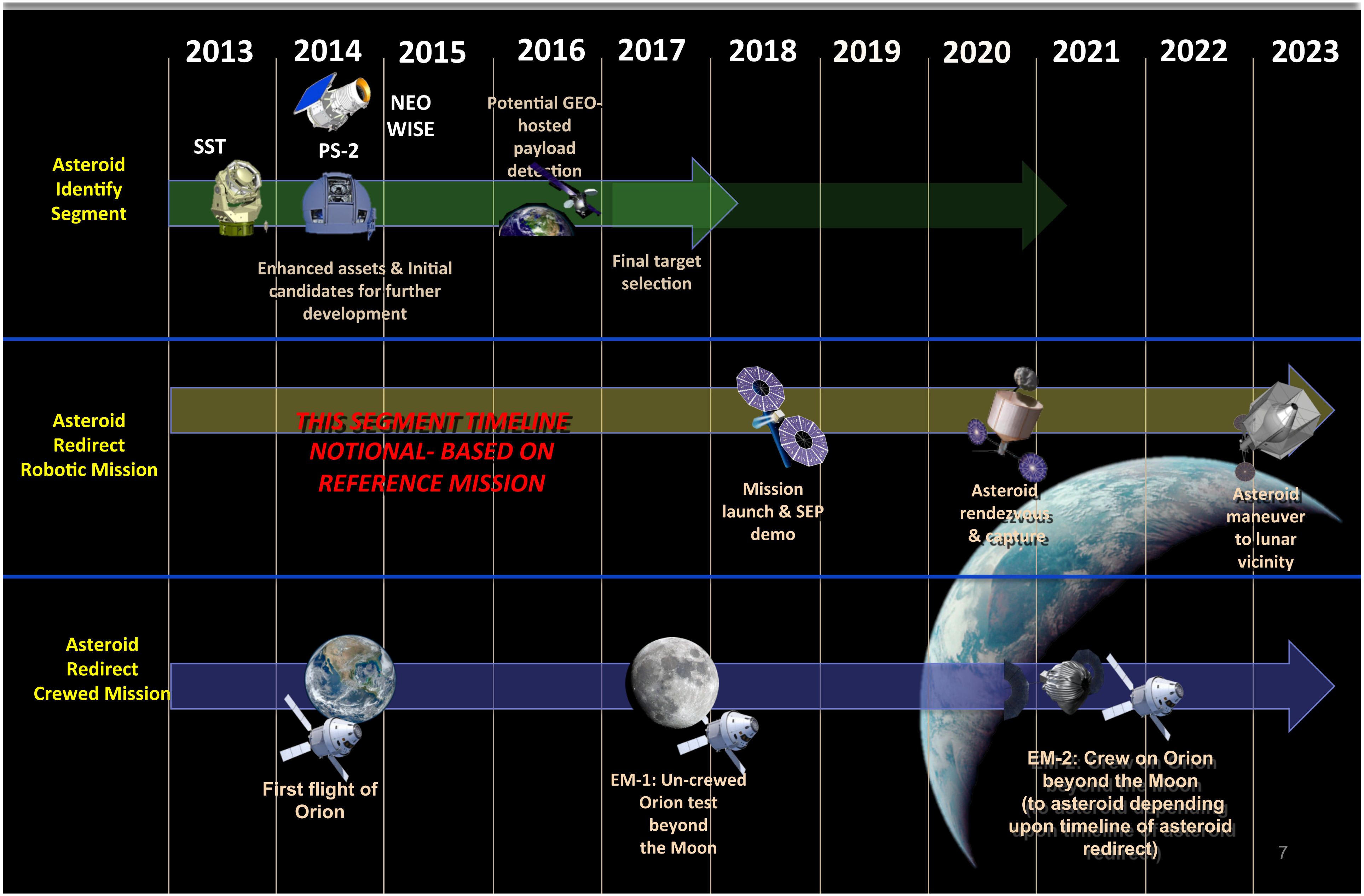
- **The FY14 budget supports continued advancement of the important individual elements and furthers the definition of the overall potential mission.**

# Asteroid Redirect Mission

| Identify | Redirect | Explore |
| --- | --- | --- |
|  |  |  |
| **Asteroid Identification:**<br><br>Ground and space based near Earth asteroid (NEA) target detection, characterization and selection | **Asteroid Redirect Robotic Mission:**<br><br>High power solar electric propulsion (SEP) based robotic asteroid redirect to lunar distant retrograde orbit | **Asteroid Redirect Crewed Mission:**<br><br>Orion and Space Launch System based crewed rendezvous and sampling mission to the relocated asteroid |

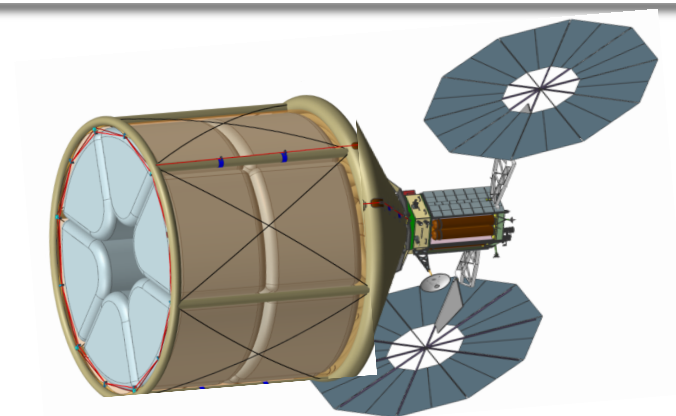
**Leveraging On-Going Activities**
**Each Provides Important Individual Capability**

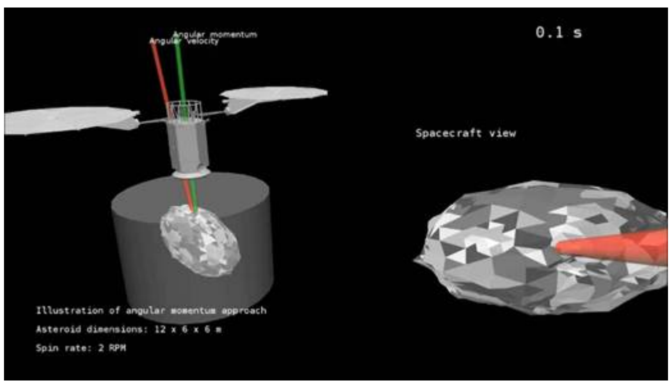
# Alignment Strategy for a Mission



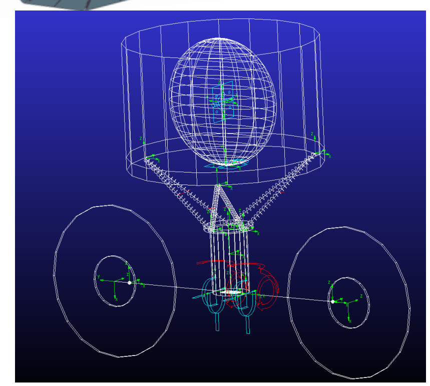
# Capture Mechanism Placeholder

- Capture bag designed to capture worst case rubble pile, using inflatable exoskeleton forming a cylindrical barrel section and conical section, actual size will depend on target






- Performing various dynamic analyses to assure robust system for capture at slow and fast rotation states while limiting forces on S/C

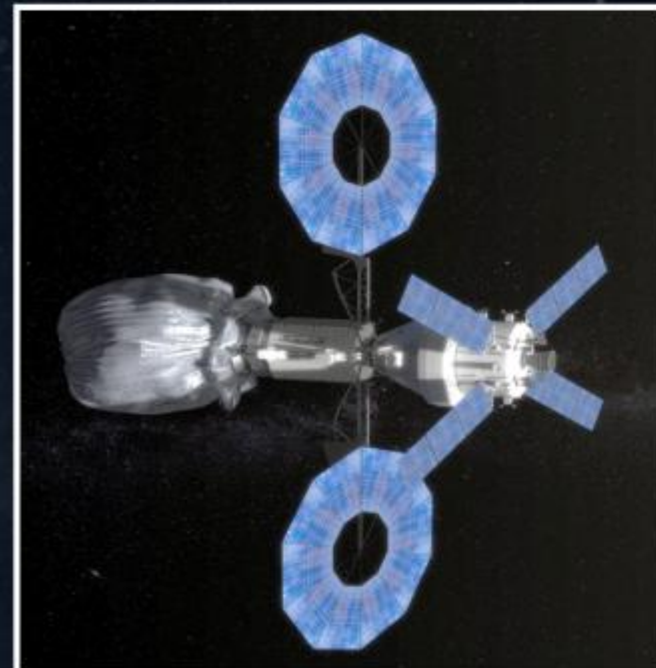


- Built 1/5 scale testbed
  - To help characterize stiffness and damping, forces on the bag, and general control of the bag and fabric
  - Upgrades to system to include pie-shaped inner bags for fast rotation capture planned for spring 2014.

# Asteroid Redirect Crewed Mission Overview

Deliver crew on SLS/Orion

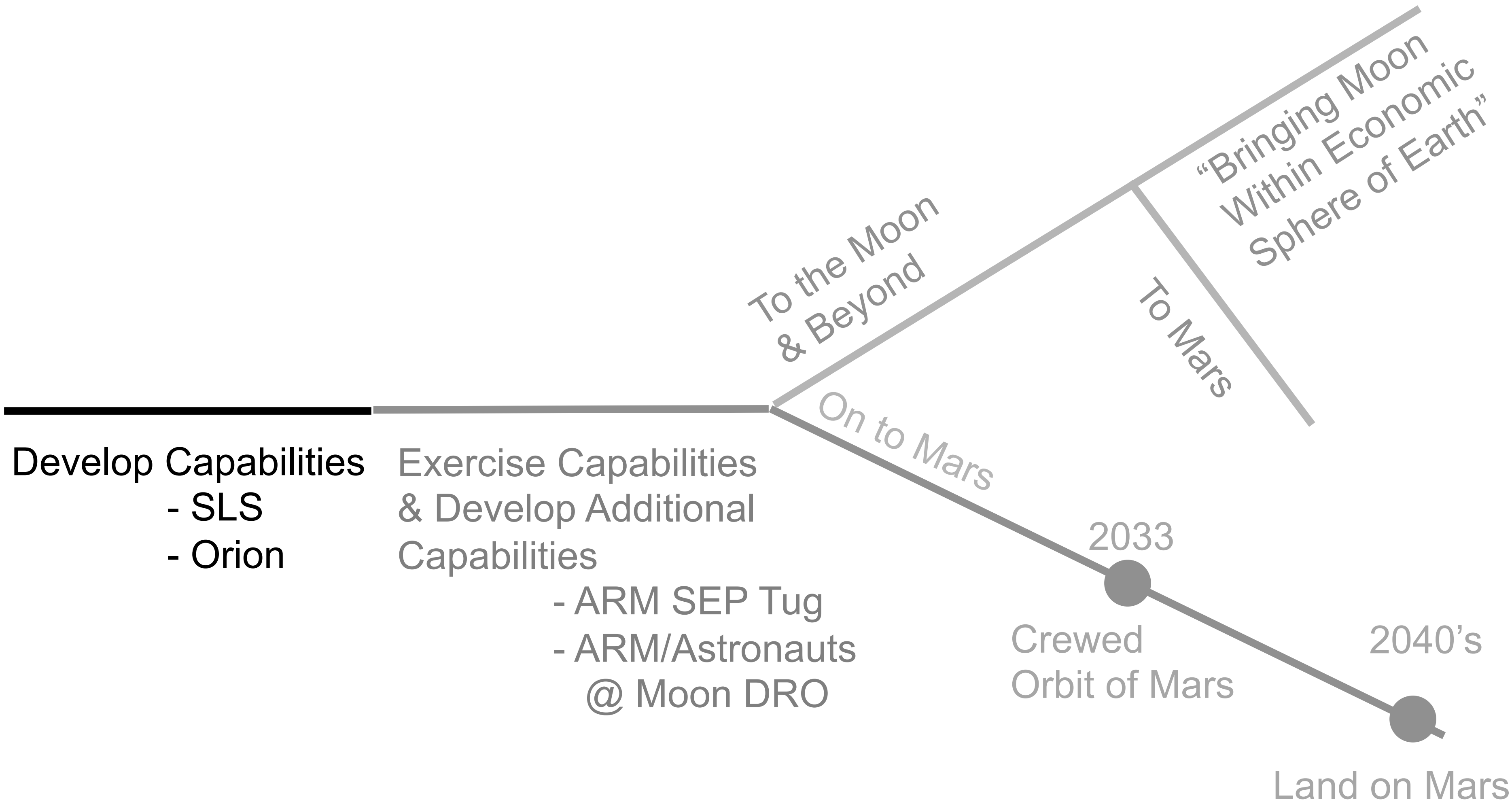
Attached Orion to robotic spacecraft



Perform extra-vehicular activity (EVA) to retrieve asteroid samples

Return crew safely to Earth with asteroid samples in Orion

# Example Human Exploration Pathways



# FY13 Modified ACES Testing Progress

**Winter 2012**

MACES EVAs are demonstrated as feasible and neutrally buoyant testing is warranted

**June 28th – Test #3 (2hr)**

Improvements in suit fit procedures needed

**July 22nd – Test #5 (2hr)**

Great capability improvements observed in subsequent runs indicating that training on the suit is vital.

**Sept. 25th – Test #8 (4hr)**

Best demonstration of suit capabil ity, attributed to good suit fit that allowed the subject easier access to standard work envelope.

May | June | July | August | September

**May 5th – Test #1 (2hr)**

Established baseline weigh out and ECS interface (both to be improved)

**June 7th – Test #2 (2hr)**

Established need for robust EVA gloves (EMU PhaseVI)

**July 12th – Test #4 (2hr)**

Two-handed task difficulties established need for suit shoulder biasing and better worksite stabilization

**Sept. 6th – Test #6 (3hr)**

Suit fit specific to EVA operations continues to be a significant performance factor

**Sept. 16th – Test #7 (4hr)**

Suit system demonstrated feasibility of 4 hour EVAs.

**Hardware and Procedure Improvements**

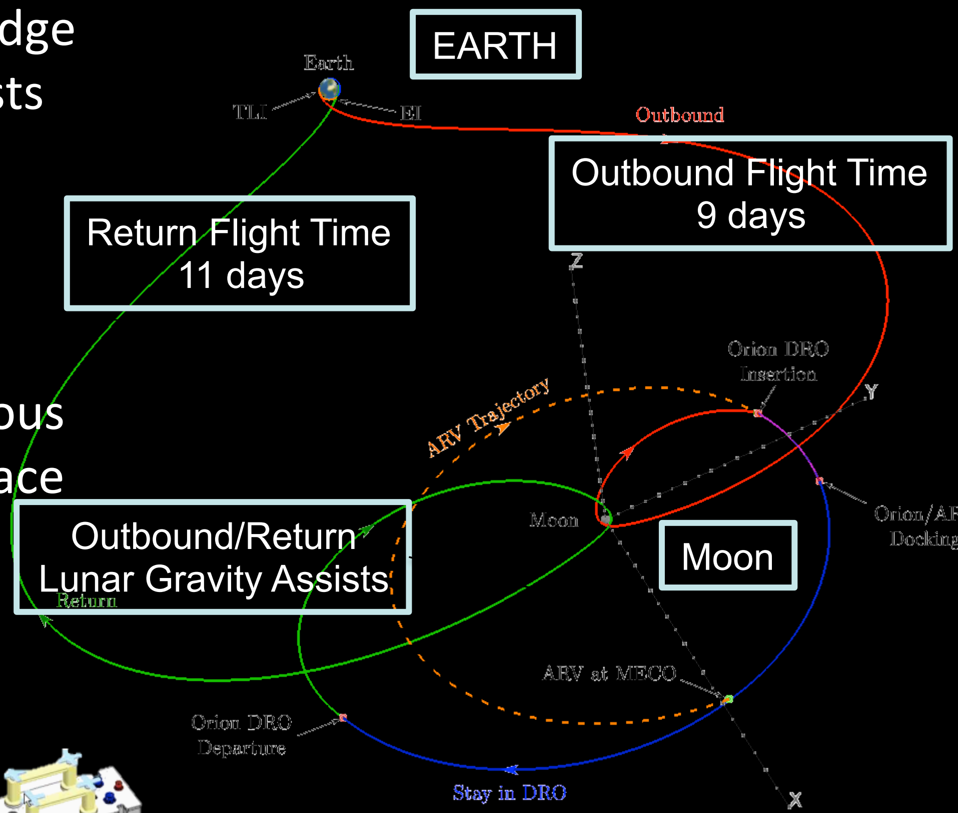
- Improved weights
- Phase IV Gloves
- Added tool harness
- Cooling System modifications
- Drink bag included
- Improved Poolside Procedure
- New liquid cooling garment

# EVA Technique Development

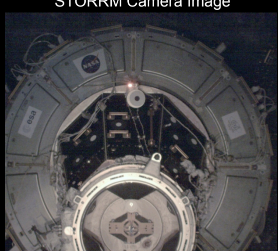
Asteroid Mission NBL Testing

# Leveraging Trajectory and Rendezvous

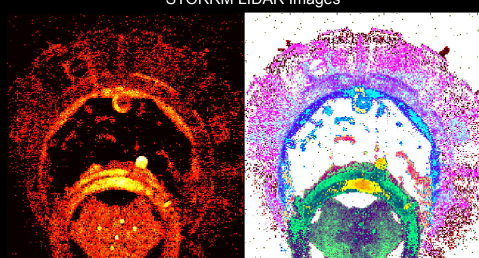
- Common sensors derived from knowledge gained from Space Shuttle Detailed Tests
- Synergy between crewed and robotic mission sensors
- Trajectory launch constraints, rendezvous techniques, navigation enable deep space

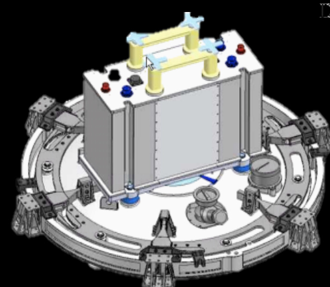



STORRM Camera Image



STORRM LIDAR Images





Notional Relative Navigation Sensor Kit

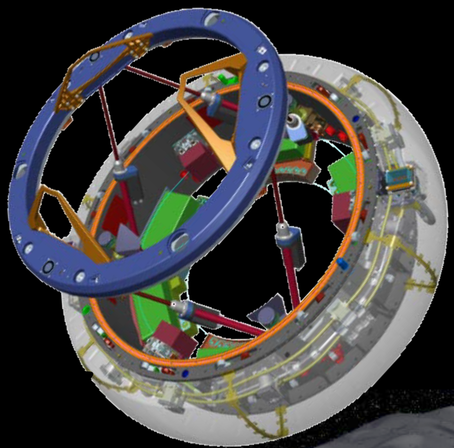
Outbound Flight Time: 8 days, 9 hrs
Return Flight Time: 11 days, 6 hrs
Rendezvous Time: 1 day
DRO Stay Time: 5 days

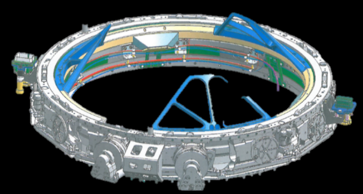
# Docking System

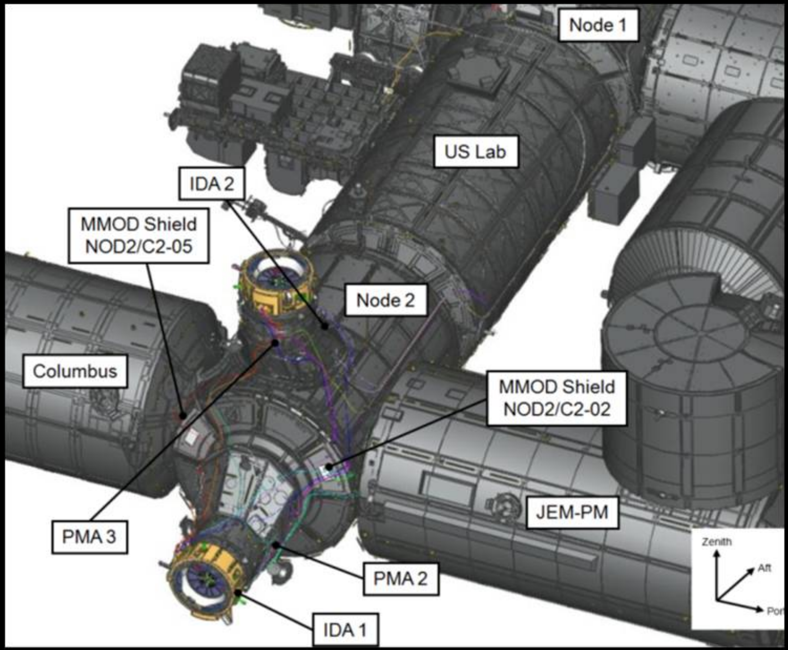
- **Docking System for Orion and Robotic Spacecraft leverages development of International Docking System Standard**

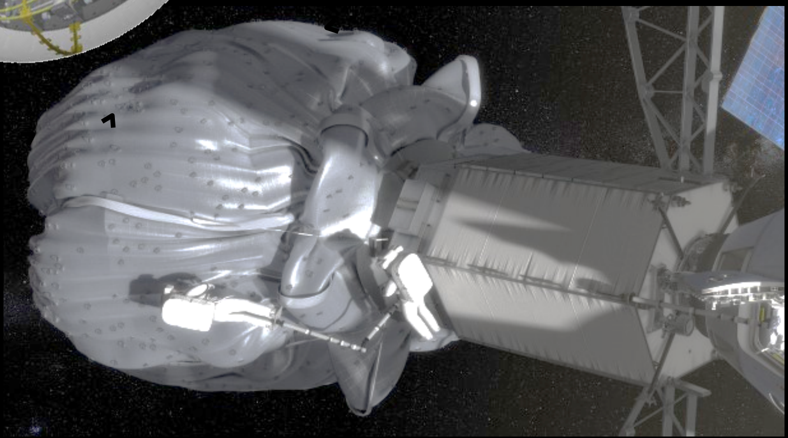
Orion Active Docking Mechanism (extended)

Robotic Spacecraft Passive Docking Mechanism







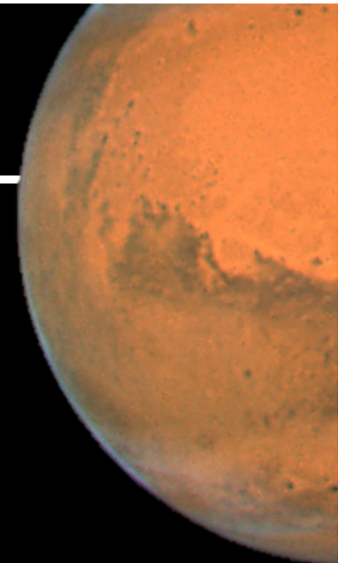



- International Docking Adapter will create a docking port on ISS
- Compatible with new International Standard
- Provides Power and data utility connections to visiting vehicles
- Delivered to ISS in trunk of Space –X Dragon Cargo Vehicle

# ARM Provides First Steps to Mars/Other Destinations

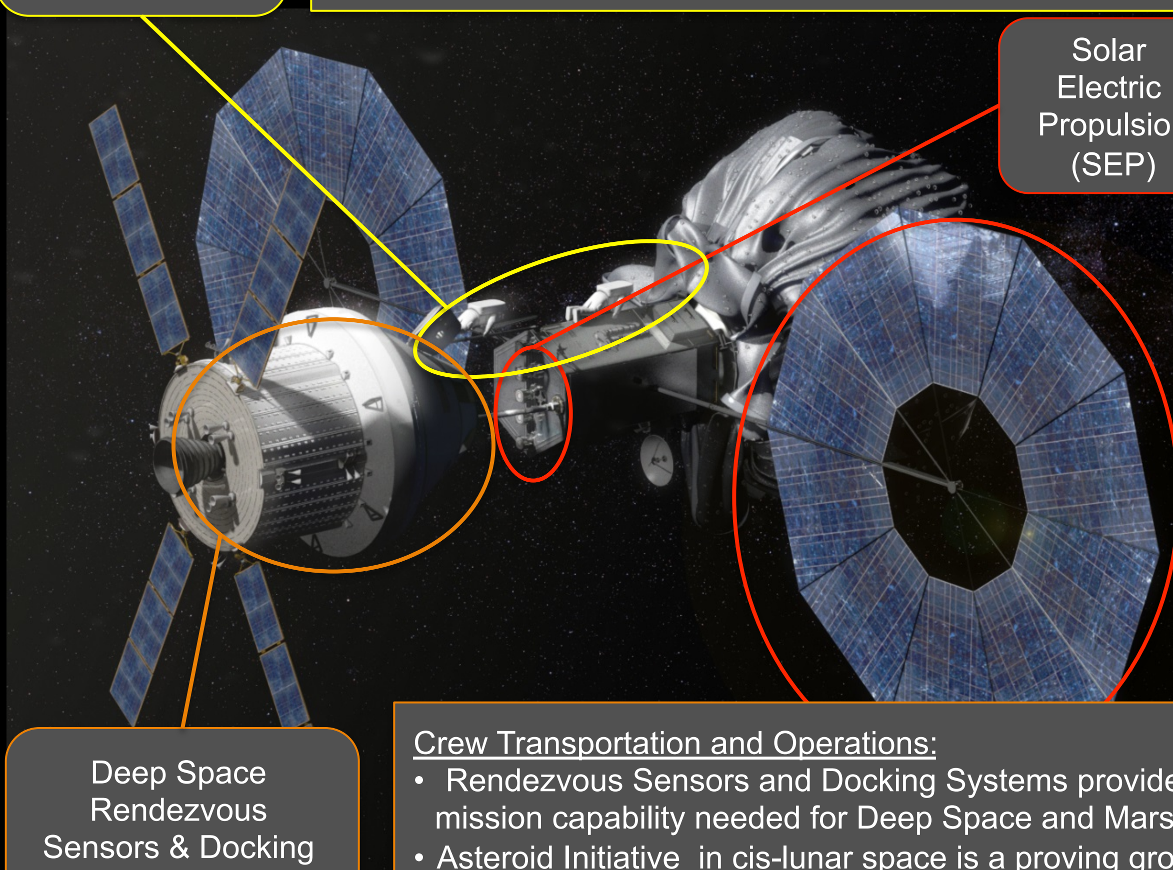
| | Mission / Sequence | Current ISS Mission | Asteroid Redirect Mission | Long Stay In Deep Space | Mars Orbit | Mars Surface, Short Stay | Mars Surface, Long Stay |
|---|---|---|---|---|---|---|---|
| Mars Destination Capabilities | In Situ Resource Utilization & Surface Power | | | | | | X |
| | Surface Habitat | | | | | | X |
| | Entry Descent Landing, Human Lander | | | | | X | X |
| | Advanced Cryogenic Upper Stage | | | | X | X | X |
| Initial Exploration Capabilities | Solar Electric Propulsion for Cargo | | X | X | X | X | X |
| | Exploration EVA | | X | X | X | X | X |
| | Crew Operations beyond LEO (Orion) | | X | X | X | X | X |
| | Deep Space Guidance Navigation and Control/Automated Rendezvous | | X | X | X | X | X |
| | Crew Return from Beyond LEO – High Speed Entry (Orion) | | X | X | X | X | X |
| | Heavy Lift Beyond LEO (SLS) | | X | X | X | X | X |
| ISS Derived Capabilities | Deep Space Habitat | * | → | X | X | X | X |
| | High Reliability Life Support | * | → | X | X | X | X |
| | Autonomous Assembly | * | → | X | X | X | X |

# Asteroid Initiative Extensibility for future Deep Space/Mars Missions



EVA:
- EVA kits build capability for future exploration:
  - MACES
  - PLSS (Design accommodates Mars)
- Follow-on Asteroid Utilization mission can provide more capable micro-g exploration suit
- Technologies allow NASA to develop the next generation surface suit and PLSS.

Exploration EVA Capabilities



Solar Electric Propulsion (SEP)

In-space Power and Propulsion :
- High Efficiency Solar Arrays and SEP advance state of art toward capability required for Mars
- Robotic ARM mission 50kW vehicle components prepare for Mars cargo delivery architectures
- Power enhancements feed forward to Deep Space Habitats and Transit Vehicles

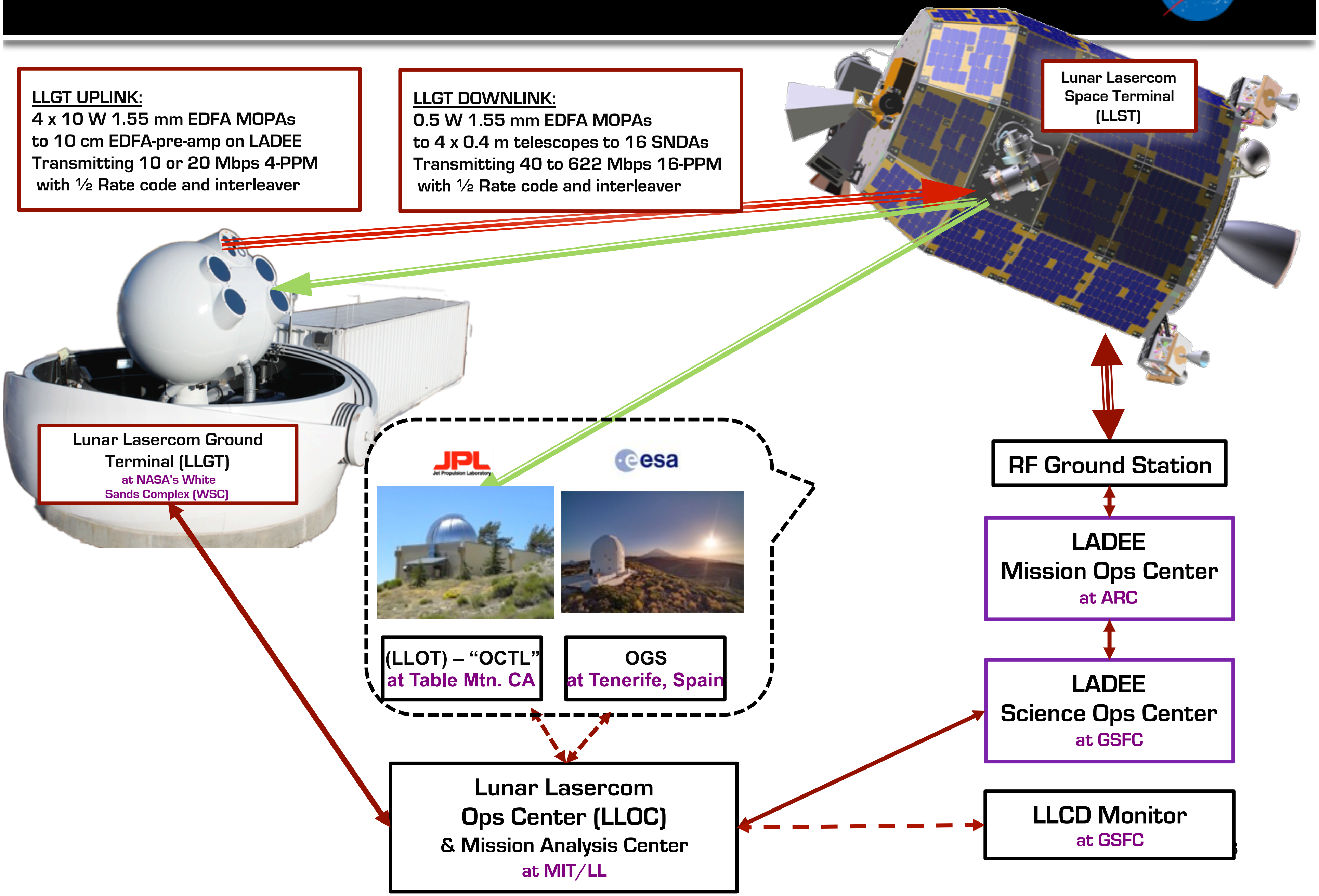
High Efficiency Large Solar Arrays

Deep Space Rendezvous Sensors & Docking Capabilities

Crew Transportation and Operations:
- Rendezvous Sensors and Docking Systems provide a multi-mission capability needed for Deep Space and Mars
- Asteroid Initiative in cis-lunar space is a proving ground for Deep Space operations, trajectory, and navigation.


Space Communications
and Navigation Update

# LLCD Mission Architecture



# Project Accomplishments – LLST to the Lunar Lasercomm Ground Terminal (LLGT)

**Performance to Date:**

- ✓ Regular, instantaneous (seconds!) all-optical acquisition and tracking between LLST and LLGT
- ✓ Error-free D/L to LLGT at 40, 80, 155, 311 Mbps
- ✓ 622 Mbps D/L regularly achieved with a code word error rate (CER) < $1x10^{-5}$ (Req. < $1x10^{-4}$)
- ✓ Error-free U/L from LLGT at 10, 20 Mbps
- ✓ Initial TOF measurements collected and being processed to allow centimeter-class ranging
- ✓ Error-free operation at low Moon elevation angles (< 4 degrees at White Sands/LLGT!)
- ✓ Operation to within 3 degrees of the Sun at up to 622 Mbps with no degradation at the LLGT!


**Operational Achievements to Date:**

- ✓ LLST U/L commanding sent and LLST telemetry received over optical link
- ✓ LADEE spacecraft data downlinked through high-speed data interface to LLST Modem; entire 1 GB LADEE buffer downlinked in < 5 min @ 40 Mbps (LADEE C&DH limit)
- ✓ Multiple streaming HD videos transmitted to the Moon and looped back to LLGT at 20 Mbps (limited by U/L rate)
- ✓ All-optical (no RF!) Comm passes using automated scripts to awaken and point LLST on schedule

# Project Accomplishments –
# JPL OCTL and ESA OGS Ground Terminals

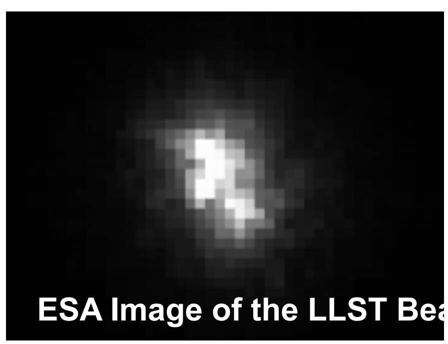
**<u>JPL's LLOT Ground Terminal (OCTL)</u>**

- ✓ Regular, instantaneous (seconds!) all-optical acquisition and tracking between LLST and OCTL
- ✓ Properly-framed, error-free D/L to JPL's OCTL at 40, 80 Mbps
- ✓ Operation at low elevation angles of the Moon ( degrees at JPL's Table Mountain/LLOT)
- ✓ **"Hand-off" from WSC to JPL during pass in < 2 min!**

JPL's OCTL Facility in Southern CA

**<u>ESA's LL-OGS Ground Terminal</u>**

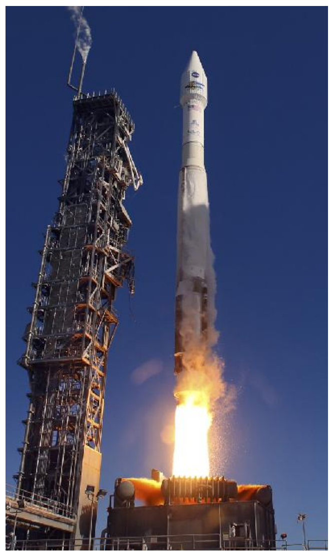
- ✓ Received communication D/L to ESA's OGS at 40 Mbps (new station)
- o Fine-tracking on U/L sometimes achieved at LLST, but signal level is still 5 dB too low to permit U/L comm
- o Final week of passes will try to exercise improved OGS U/L beam pointing

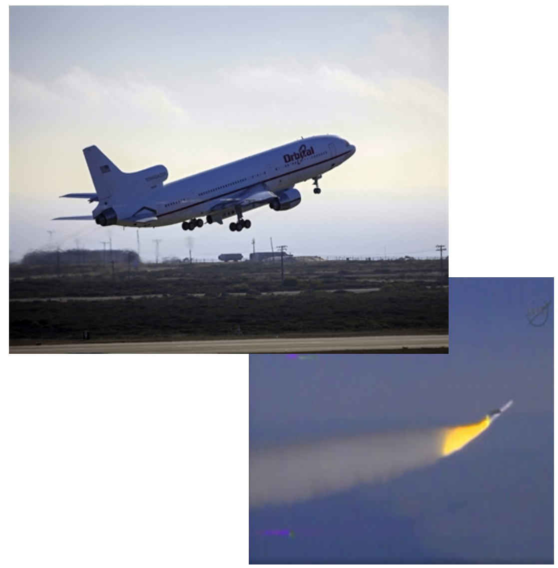


ESA Image of the LLST Bea

ESA's LL-OGS on Tenerife, Spain

# Launch Services Program -- CY13 Launch Highlights





**January 30, 2013**

TDRS-K

**February 11, 2013**


**June 27, 2013**

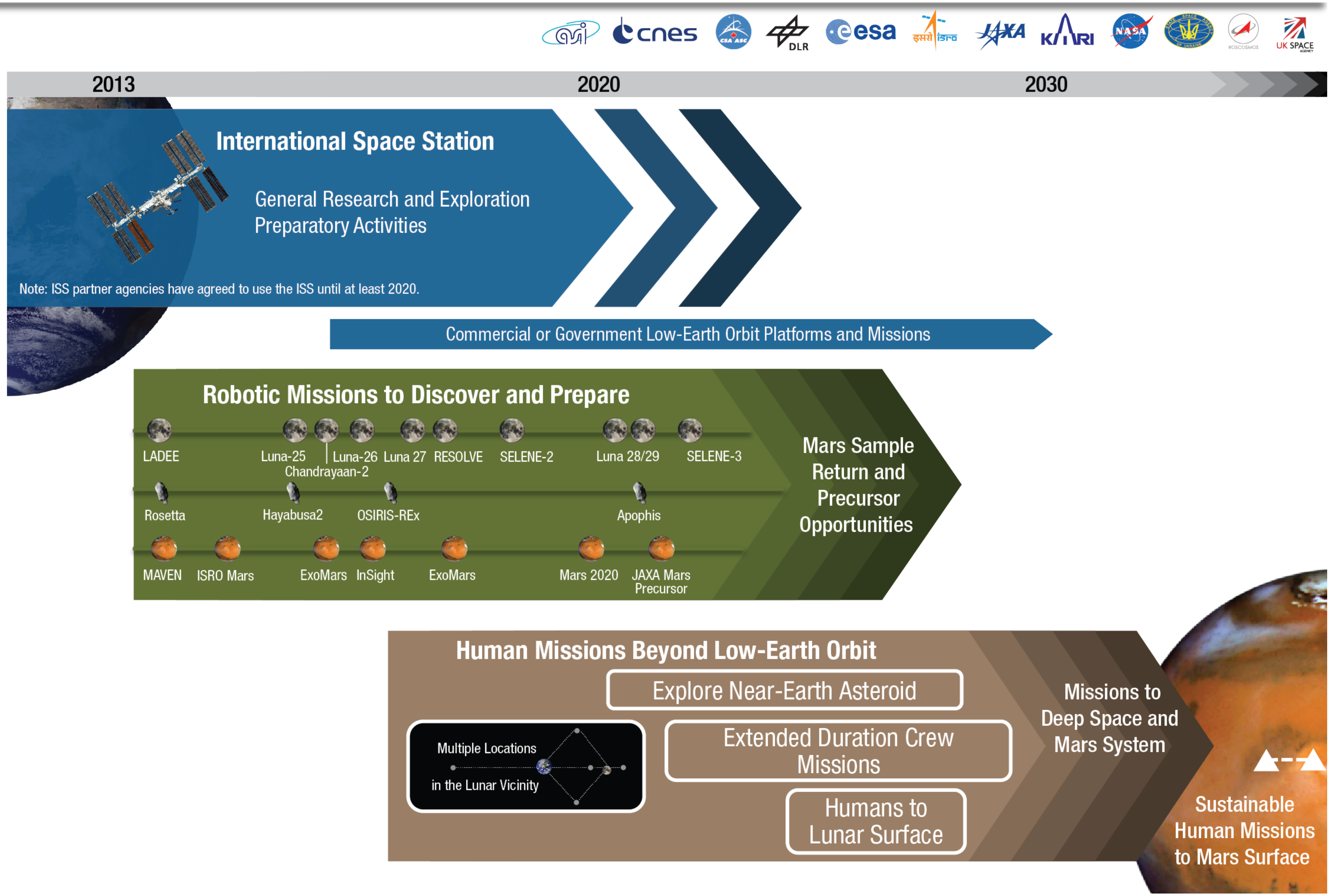
IRIS

**November 18, 2013**

MAVEN

CU/LASP • GSFC • UCB/SSL • LM • JPL

# Global Exploration Roadmap



www.nasa.gov