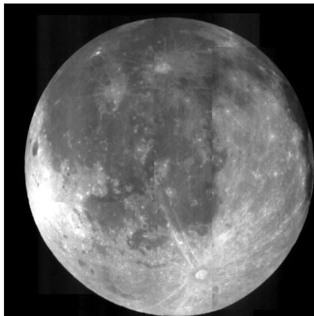
MOBLAS-6 participation in NASA LRO Mission
or
Back to the Moon

Ludwig Combrinck
HartRAO

2nd Space Geodesy Workshop
12-15 November 2007
Matjiesfontein



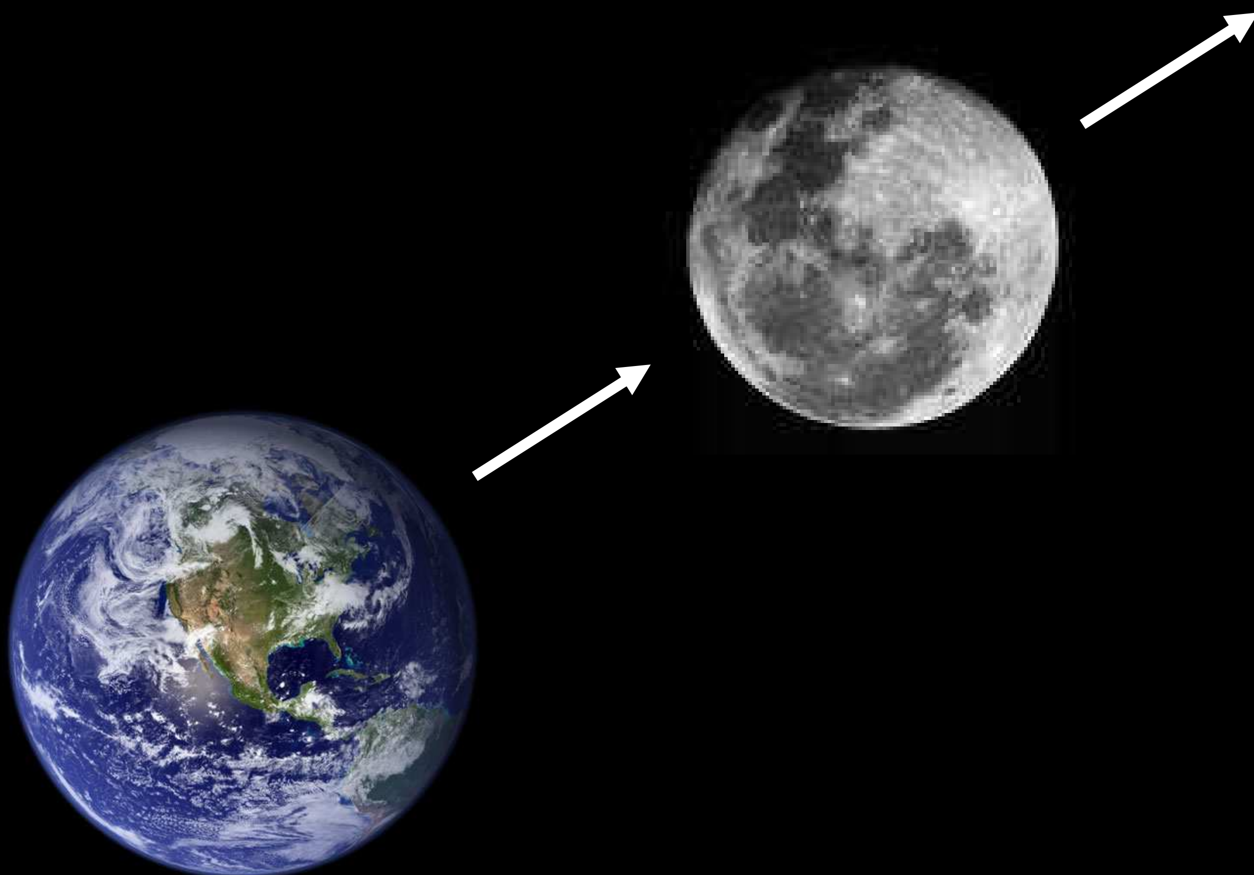
A Bold Vision for Space Exploration, Authorized by Congress

- Complete the International Space Station
- Safely fly the Space Shuttle until 2010
- Develop and fly the Crew Exploration Vehicle no later than 2014 (goal of 2012)
- Return to the Moon no later than 2020
- Extend human presence across the solar system and beyond
- Implement a sustained and affordable human and robotic program
- Develop supporting innovative technologies, knowledge, and infrastructures
- Promote international and commercial participation in exploration

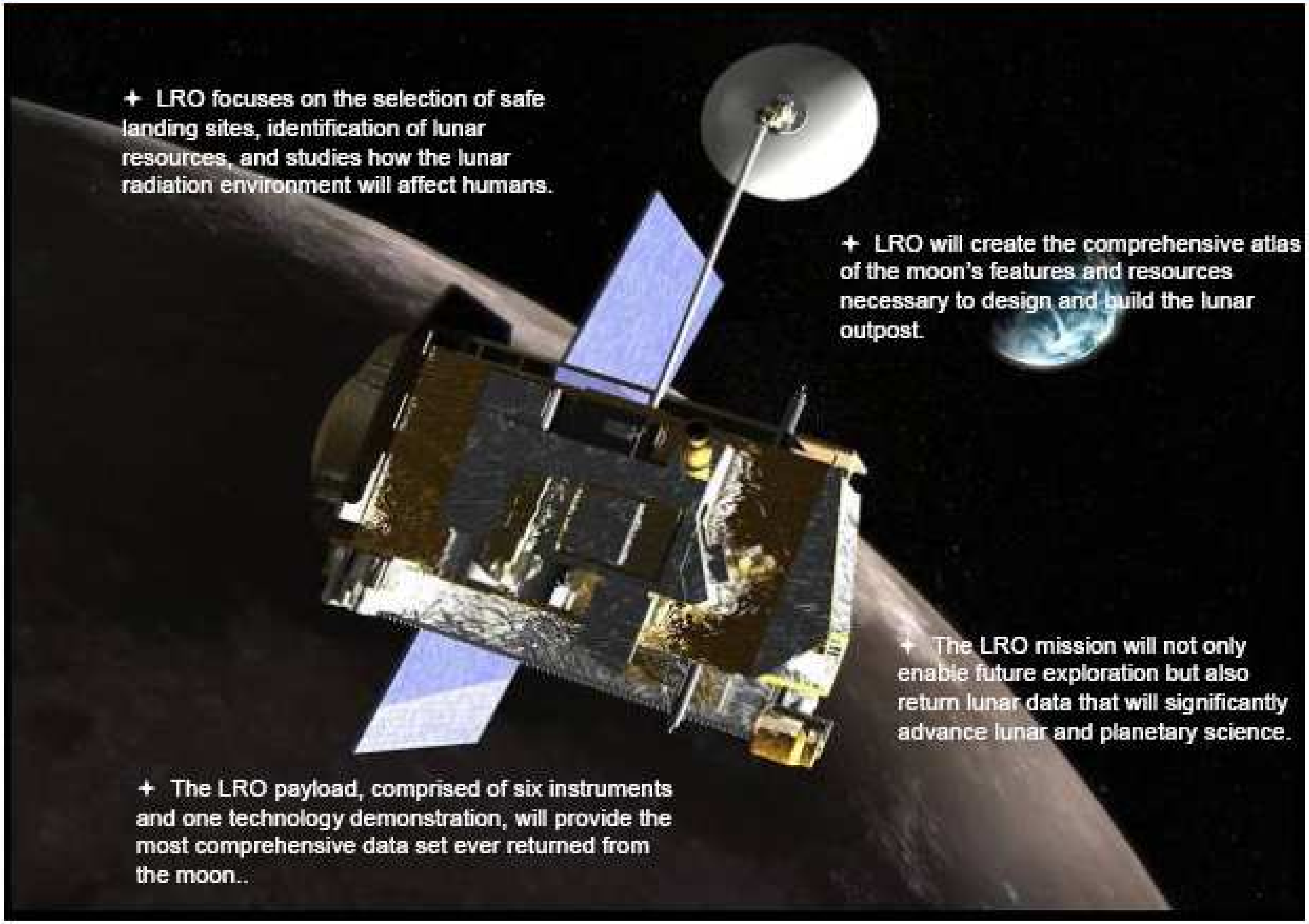
NASA Authorization Act of 2005

The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.

Human Exploration of the Moon and Mars



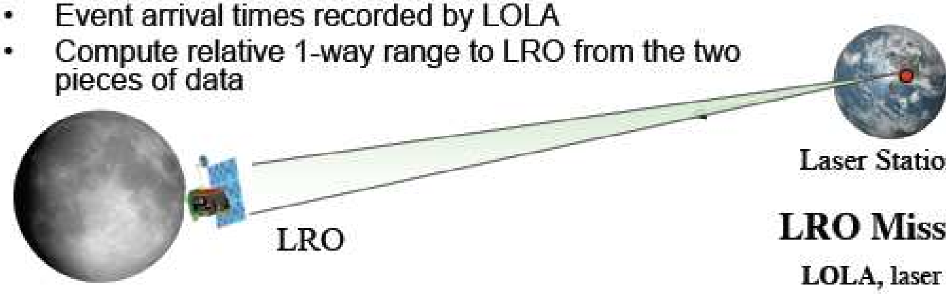
The Lunar Reconnaissance Orbiter (LRO) is NASA's first step in returning humans to the moon.

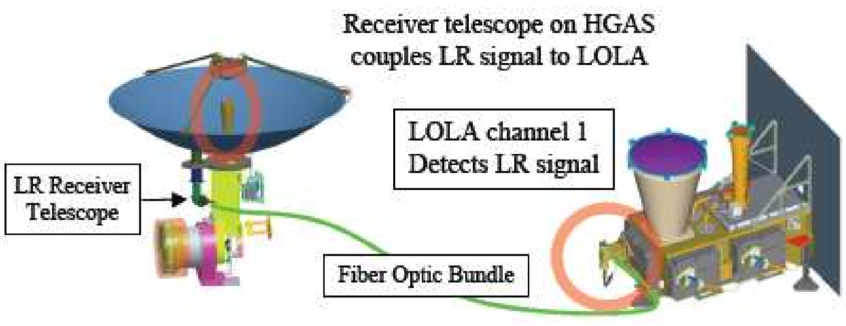


Lunar Reconnaissance Orbiter (LRO) – Laser Ranging (LR) Overview

LRO is requesting ILRS support for one-way laser ranging

- Transmit 532 nm laser pulses at =< 28Hz to LRO
- Time stamp departure times at ground station
- Event arrival times recorded by LOLA
- Compute relative 1-way range to LRO from the two pieces of data





LRO Mission Includes:

LOLA, laser altimeter

LROC, camera

LAMP, Lyman alpha telescope

LEND, neutron detector

DIVINER, thermal radiometer

CRATER, cosmic ray detector

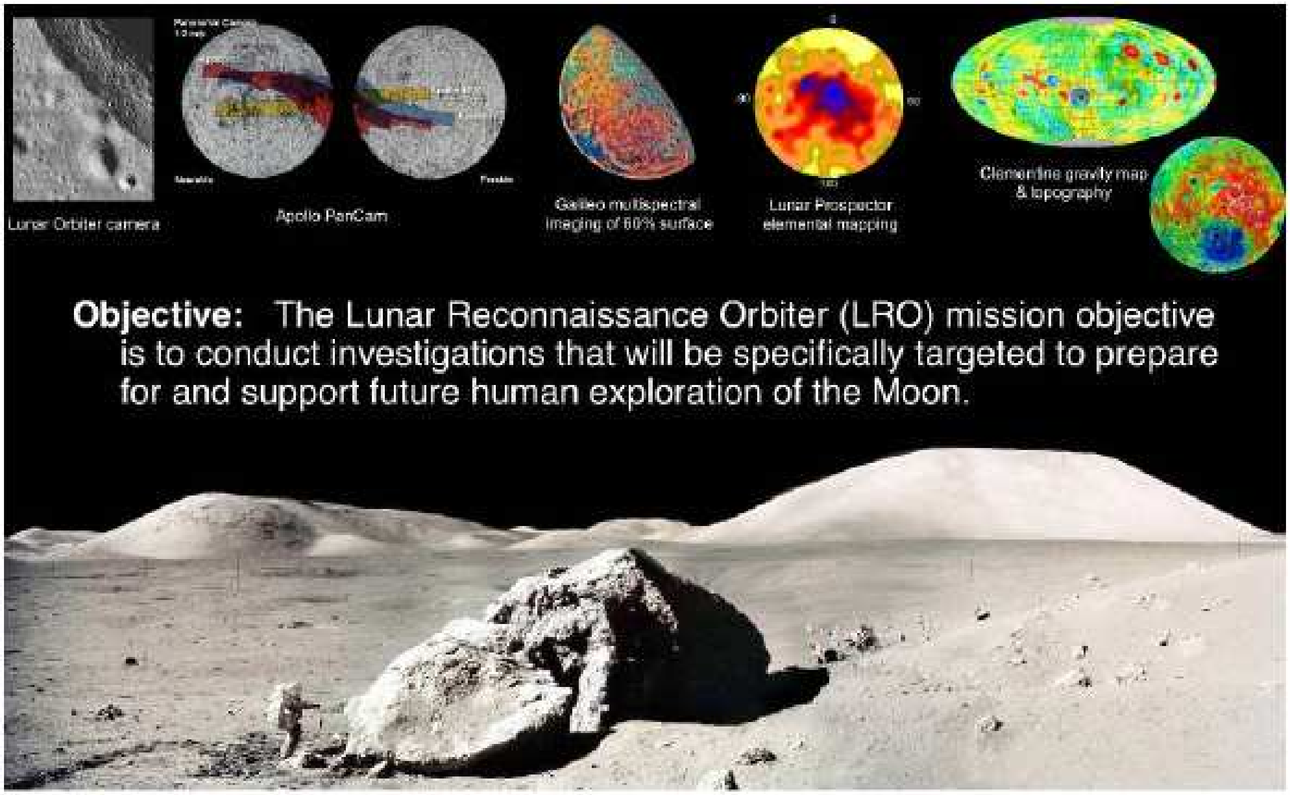
mini-RF, radar tech demo

Laser Ranging Overview

- LR will support the precision orbit determination process that will, in conjunction with S-band tracking and LOLA altimetry, enable improved positioning of LRO and improvements to the lunar gravity field model.
  - 25 to 50 meter positioning of LRO in horizontal position over both lunar near and far side
  - Improve instrument targeting

- LR will provide 1-way range measurements between earth station(s) and LRO to better than 10cm precision.
  - SLR2000 transmits laser pulses at 532.2 nm synchronized to the LOLA instrument operating cycle of 28 Hz.
  - Participating ILRS stations transmit asynchronously (eg MLRS at 10 Hz).
  - LOLA detects the LR signals and transmits this information and receive energies in the LOLA telemetry packet for "real-time" feedback to stations.
  - LOLA SOC generates range data from ground station fire times and LOLA receive events.

Lunar Reconnaissance Orbiter
Mission Objectives



Locate Potential Resources
Hydrogen/water at the lunar poles
Continuous solar energy
Mineralogy

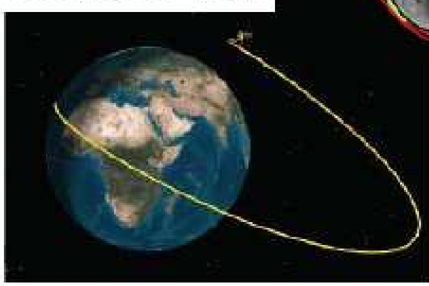
Safe Landing Sites
High resolution imagery
Global geodetic grid
Topography
Rock abundances

Space Environment
Energetic particles
Neutrons

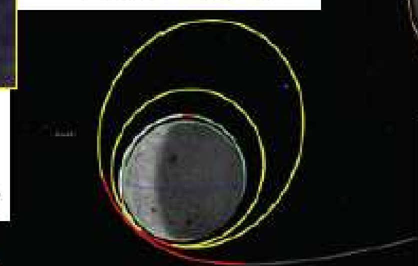
LRO Mission Overview

Launch: October 28, 2008

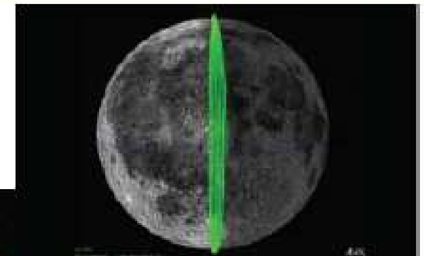
Minimum Energy
Lunar Transfer ~ 4 Days



Lunar Orbit Insertion
Sequence, 4-6 Days



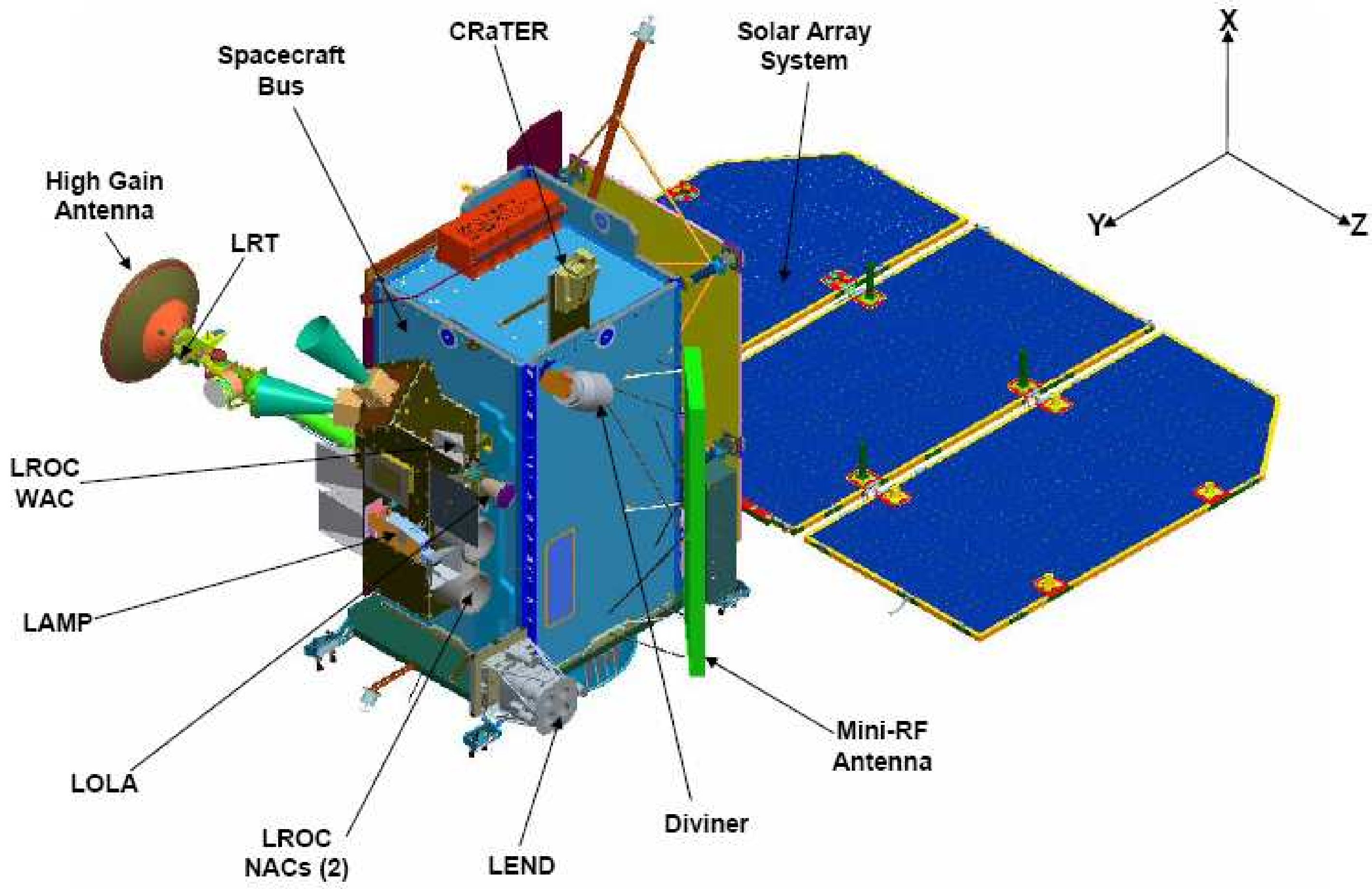
Commissioning Phase,
30 x 216 km Altitude
Quasi-Frozen Orbit,
Up to 60 Days



Polar Mapping Phase,
50 km Altitude Circular Orbit,
At least 1 Year

Nominal End of Mission: February 2010

LRO Spacecraft



Orbiter Instrumentation

LROC/WAC: Wide-Angle Camera

- Global Imagery
- Lighting
- Resources

Day Side
Autonomous

LROC/NACs: Narrow-Angle Cameras

- Targeted Imagery
- Hazards
- Topography

Day Side
Timeline Driven

LOLA: Lunar Orbiter Laser Altimeter

- Topography
- Slopes
- Roughness

Full Orbit
Autonomous

DLRE: Diviner Lunar Radiometer Exp.

- Temperature
- Hazards
- Resources

Full Orbit
Autonomous

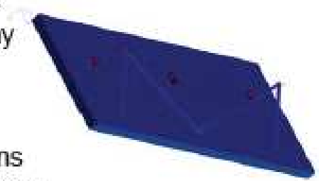
LAMP: Lyman-Alpha Mapping Project

- Water-Frost
- PSR Maps

Night Side
Autonomous

Mini-RF: Synthetic Aperture Radar

- Tech Demonstration
- Resources
- Topography



Polar Regions
Timeline Driven

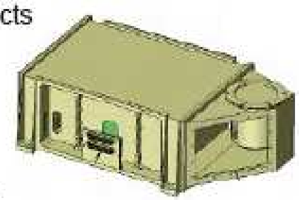
LEND: Lunar Explr. Neutron Detector

- Neutron Albedo
- Hydrogen Maps

Full Orbit
Autonomous

CRaTER: Cosmic Ray Telescope…

- Radiation Spectra
- Tissue Effects



Full Orbit
Autonomous

LRT: Laser Ranging Telescope

- Topography
- Gravity

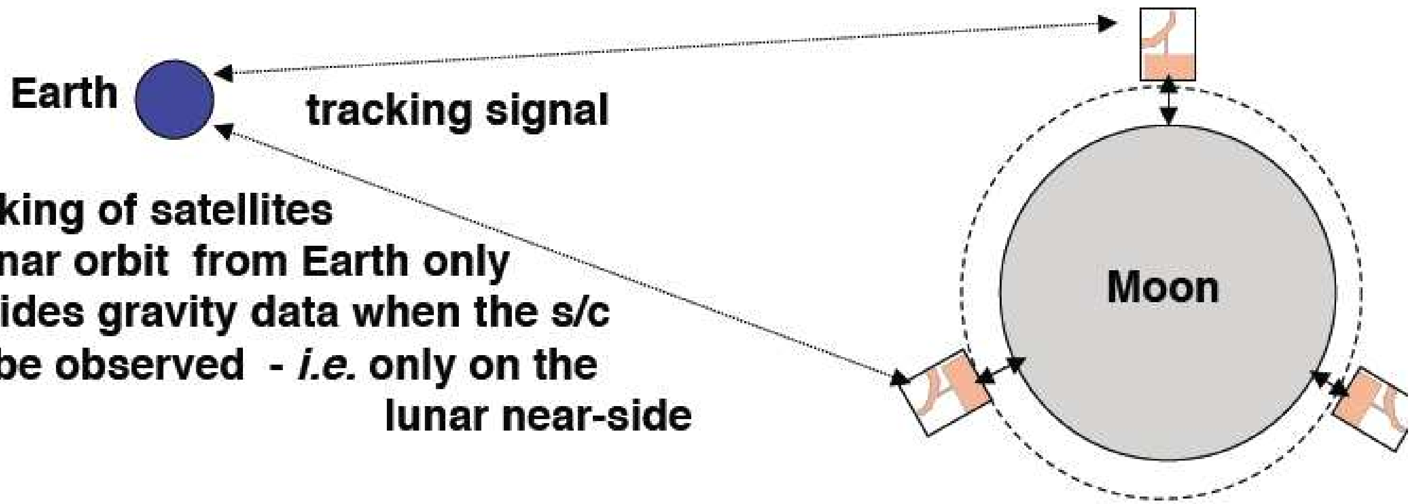
LRGS LOS
Autonomous

Required Science Measurements by LR

LR measurements will:

- Provide relative range measurements to LRO spacecraft at <10-cm precision, at 1 Hz.
- Maintain range stability to ±1 m over 1 hour.
- in conjunction with the S-band data and the LOLA altimeter data, allow the orbit of the LRO spacecraft to be determined within 50 m along track, 50 m across track, and 1 m radial.
- improve the targeting of LROC by improving the prediction of the LRO orbit.
- allow every LROC pixel coordinate to be known to 50 meters and all LRO data co-registered at the 50-m horizontal level.
- improved knowledge of the lunar gravity model to enable visiting a particular location to within ~50 m.

Improving the Lunar Gravity Field

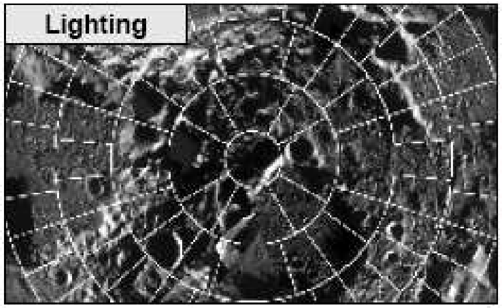


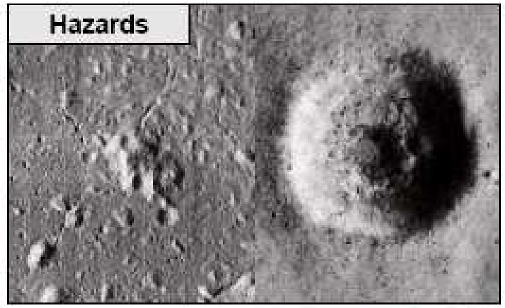
Tracking of satellites in lunar orbit from Earth only provides gravity data when the s/c can be observed - *i.e.* only on the lunar near-side

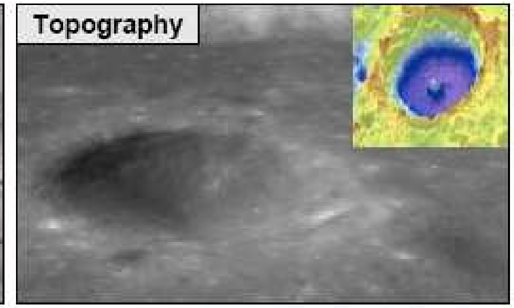
Altimetry and altimetric cross-overs on the far-side (and near-side) of the Moon will be included as a tracking data for gravity estimation

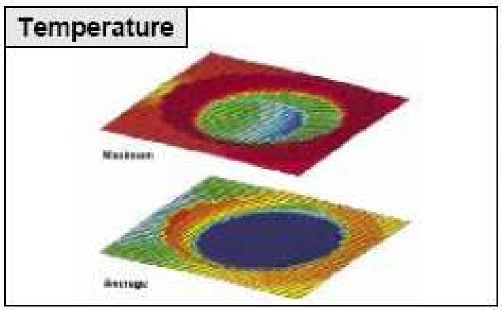
Cross-overs occur about every 1 to 2 km in longitude and 3 deg in latitude at equator

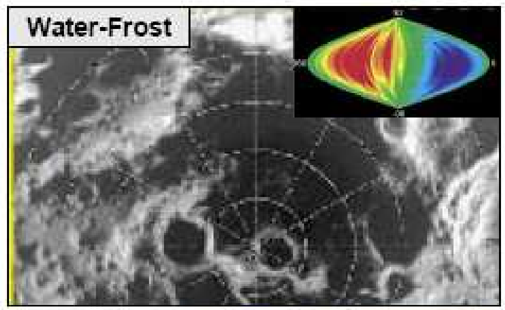
Orbiter Data Products

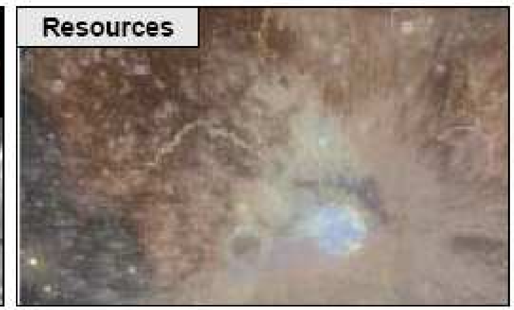


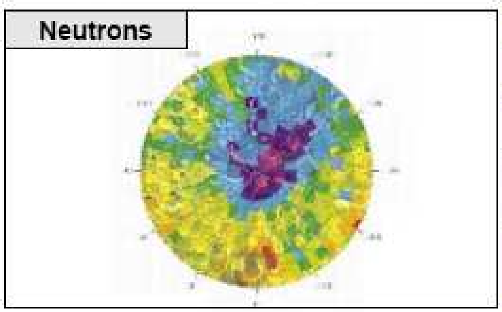


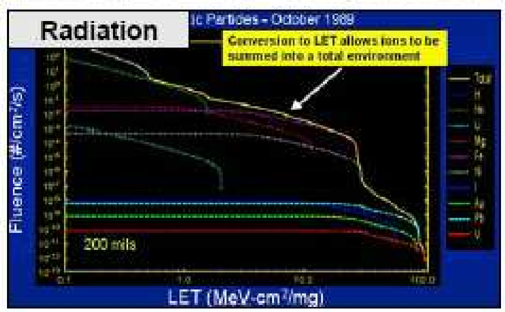


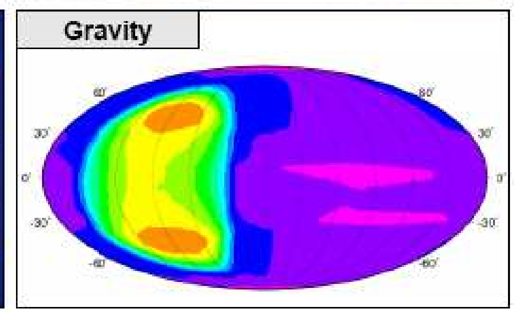












Configuration changes needed to Moblas-6

Picosecond event timer, to be integrated into sysytem

Ground System Requirements

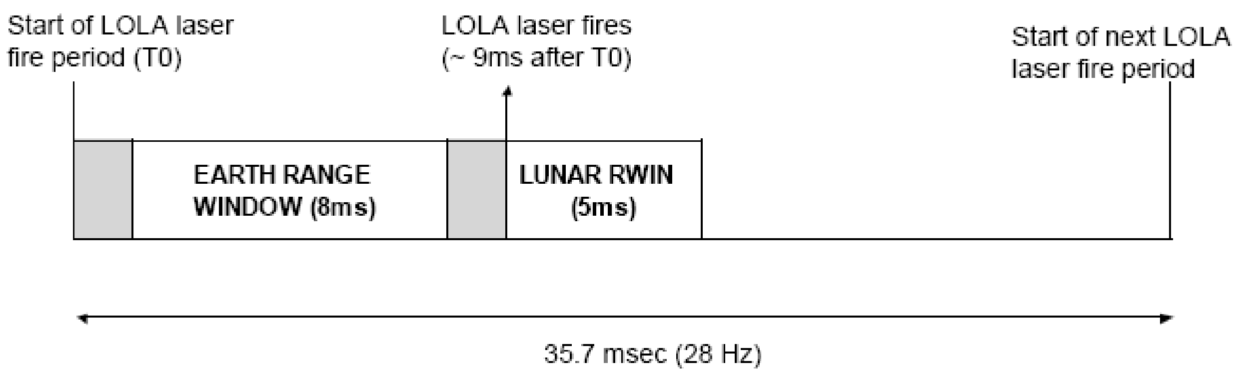
- Deliver between 1 and 10 femtoJoules per sq.cm of signal to the receiver aperture. For SLR2000 (55 microrad laser divergence) → 30mJ per pulse.
- Wavelength must be 532.2 +- 0.15 nm. LRO filter throughput will be 50% at 532.05 and 532.35 nm (many ILRS stations fall within this wavelength region).
- Laser pulsewidth =< 8ns (onboard system bandwidth is ~6ns).
- Maintain the transmitted pulse time stamp accuracy to within 100 ns of UTC.
- Measure the relative laser time of fire to better than 200 ps (1 sigma) shot-to-shot over a 10 sec period. Laser fire time must be recorded to <100 psec resolution.
- Deliver laser pulses into the LOLA earth window at least once per second. Laser fire rate cannot exceed 28 Hz because it will affect LOLA threshold!
- Shot to shot measurement of the output laser energy is desired.
- Data should be delivered to CDDIS in new CRD format daily (or faster).

One LOLA Detector does both earth and lunar

- Two range windows in one detector: fixed 8 msec earth and up to 5 msec lunar.

- Range to LRO changes ~ 5-10 ms over an hour's visibility.

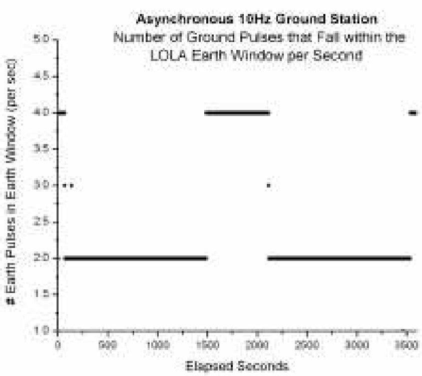
- Need to either synchronize the ground laser fires to LOLA to ensure pulses land in every Earth Window, or fire asynchronously to LOLA (eg 10Hz).



Getting Pulses into the LOLA Earth Window

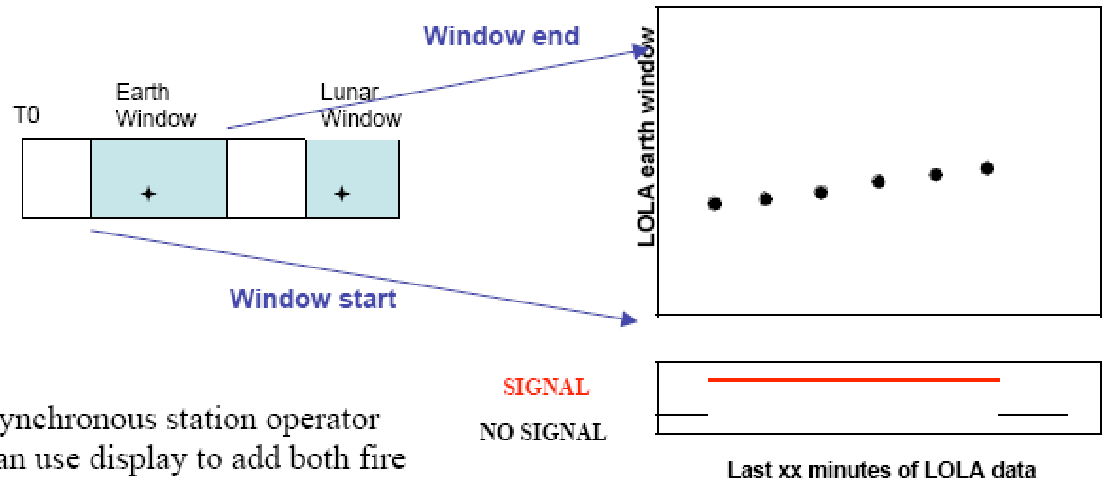
- **Method #1 (SLR2000): synchronize to LOLA**
  - -Must compensate for range changes (5-10 msec per hour).
  - -Knowledge of UTC to spacecraft MET will be good to < 3 msec.
  - -Start of LOLA fire interval (35.7 ms) is sychronized to MET.
  - -LOLA earth window opens 1.0 msec after start of fire interval.
  - -LOLA earth window is open for 8 msec.

- **Method #2: run asynchronous to LOLA but at a fire rate that ensures at least one pulse per second into the earth window.**
  - -Ground system fire rate of 10Hz ensures 2-4 pulses per second get into the earth window.
  - -No control of laser is needed.



Website Feedback from LOLA

- LOLA onboard algorithm determines if it sees earth pulses and if so it estimates the earth pulse event time.
- Each dot represents estimate over one second of time.
- If synchronous fire control is in the LOLA Earth Window the dots will form a straight line with small slope.
- Onboard algorithm will probably not be able to pick out asynchronous ground laser fires but LOLA SOC ground processing software can.
- Receive energies will also be sent down in real-time telemetry.



Synchronous station operator can use display to add both fire time bias to control laser fire.

Acknowledgements

LOLA investigation Team:

David E. Smith, PI

Maria T. Zuber, Dep PI

Co-I's: Oded Aharonson (Caltech); James W. Head (Brown);
Frank G. Lemoine (GSFC) Gregory A. Neumann (GSFC/MIT);
Mark Robinson (Northwestern)

LOLA Instrument Scientist

Xiaoli Sun (GSFC)

LOLA and LR Instrument Design:

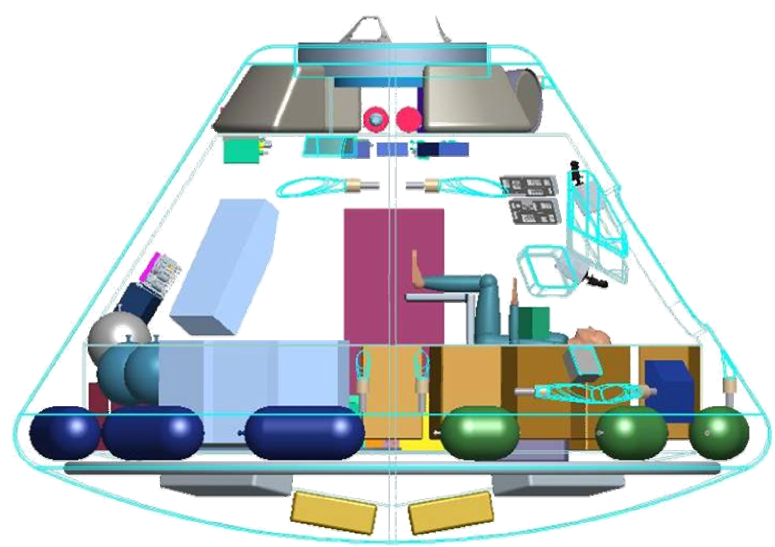
Jim Abshire, Xiaoli Sun, Jay Smith, John Cavanaugh, Luiz Ramos,
Danny Krebs, Jan McGarry, and many others

Slides from Mark Torrence, Jan McGarry presentation, ILRS workshop, Grasse 2007, Scott Greatorex,

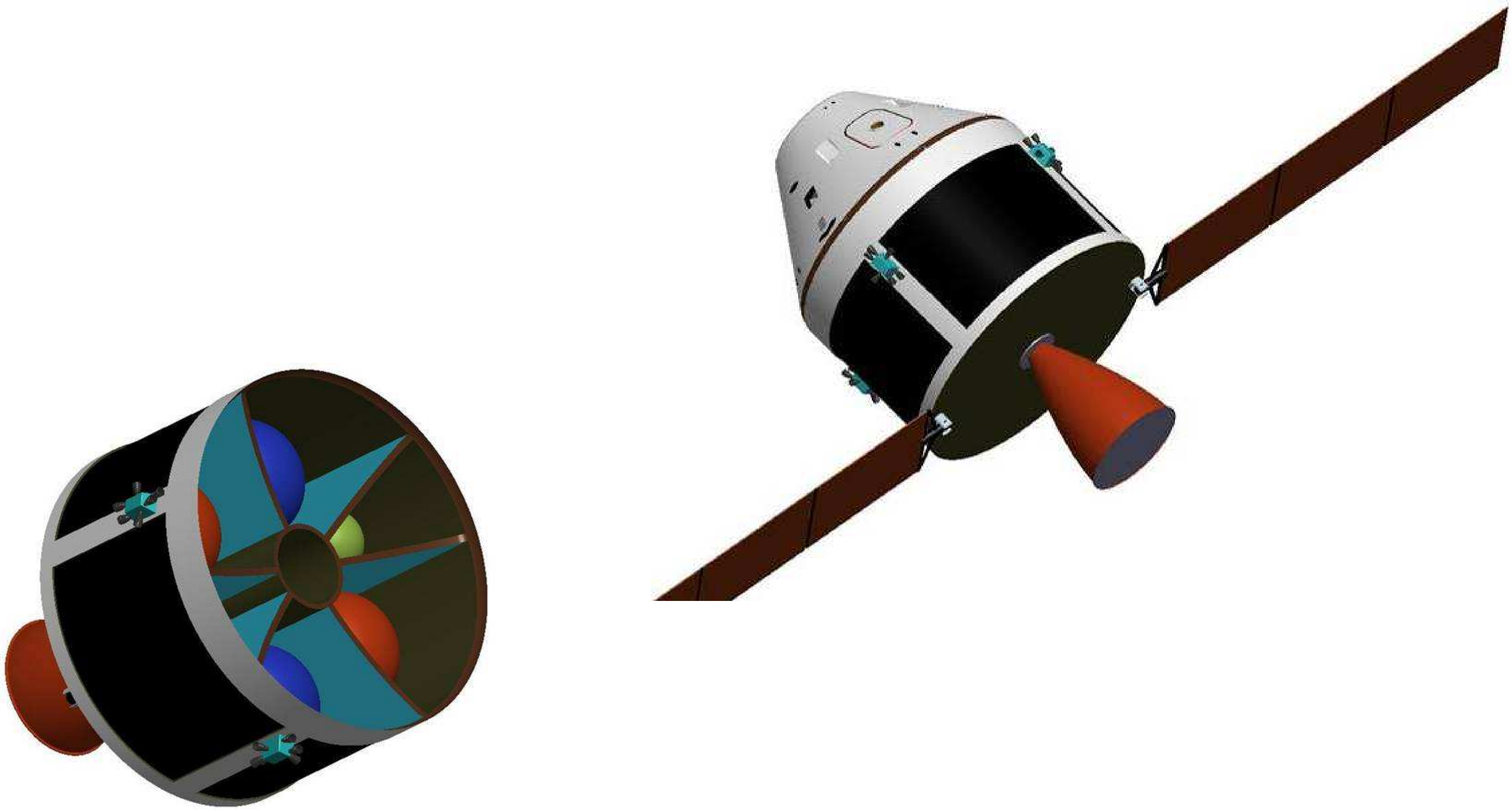
Launch configuration

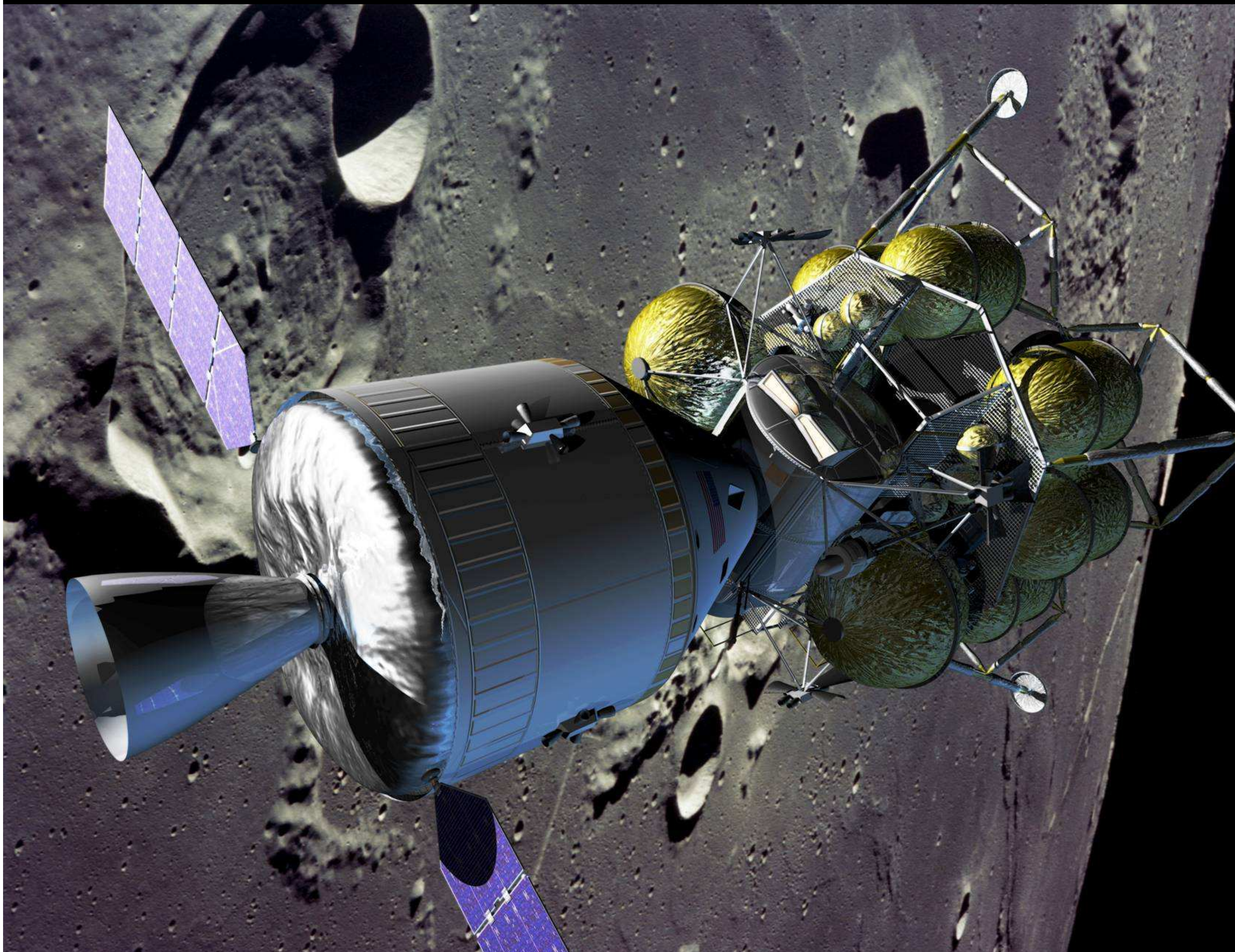

USA

Crew Exploration Vehicle

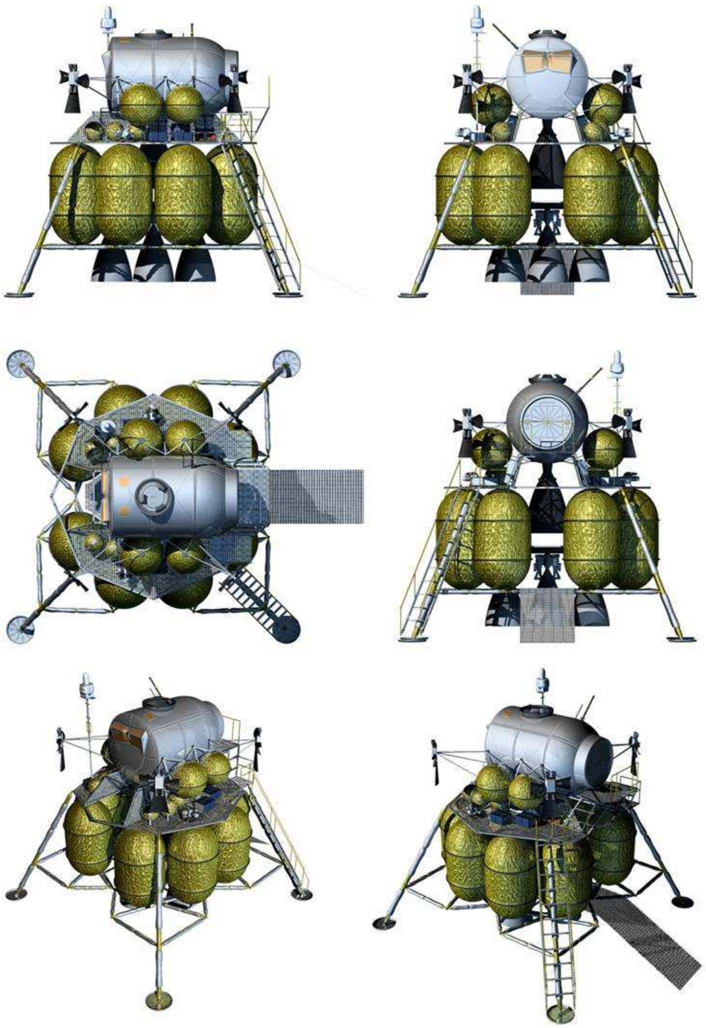


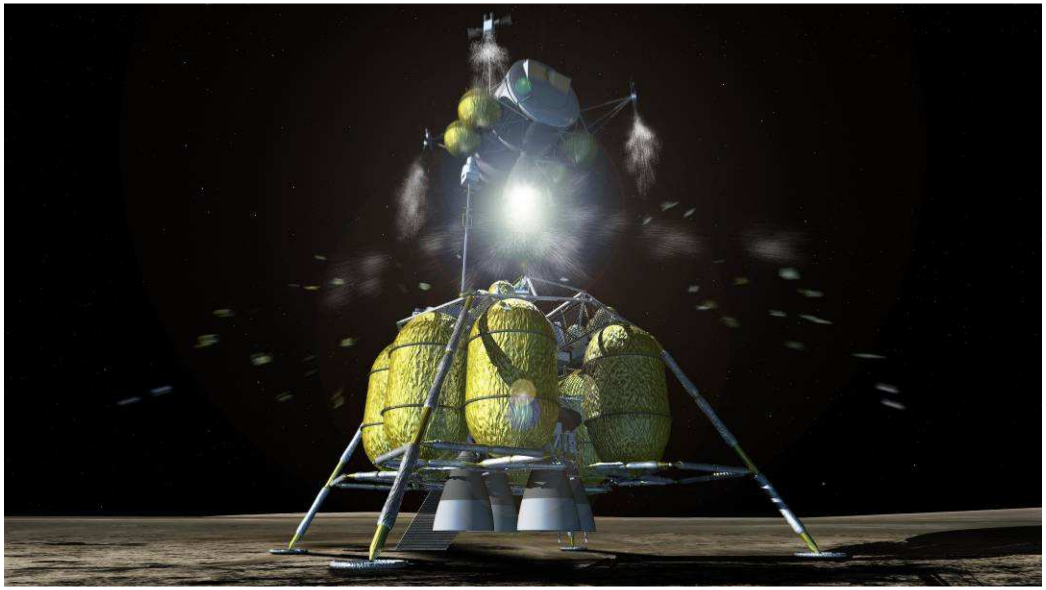
Service module carries the CEV to the Moon





Lunar Surface Module

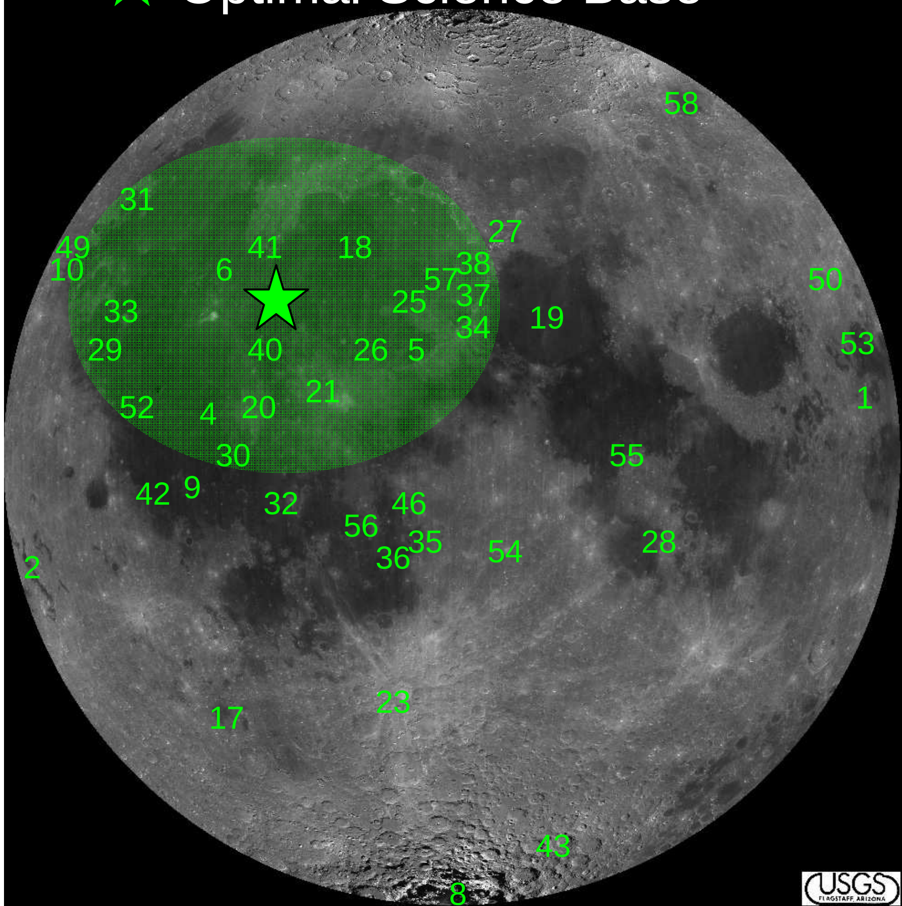




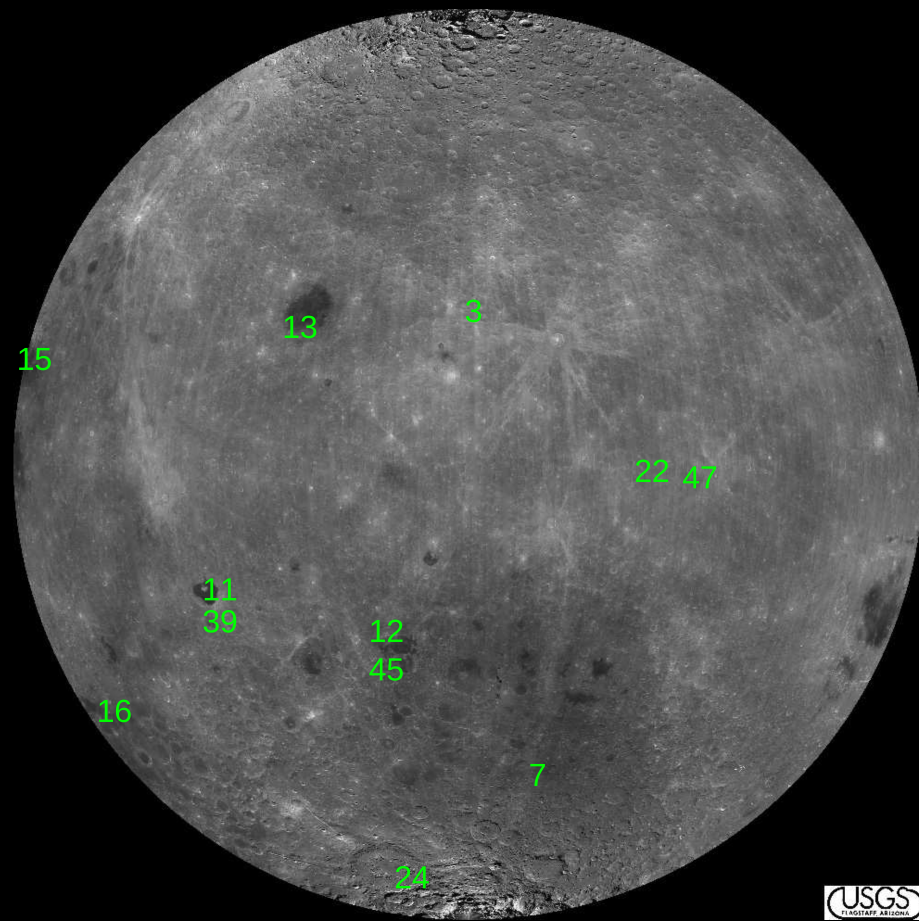
Site Selection for Moon

★ Optimal Science Base

* Numbers indicate sortie sites



Near-side



Far-side

Do it on the Moon first

- Partial gravity
- Radiation
- Planetary protection

Near-term missions

Using the martian soil and atmosphere for a plant growth module