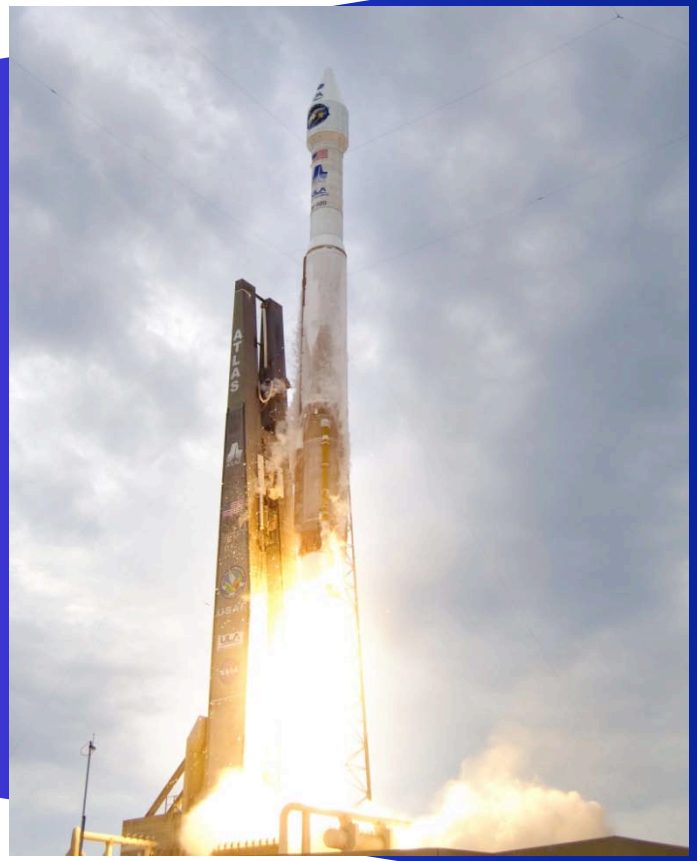
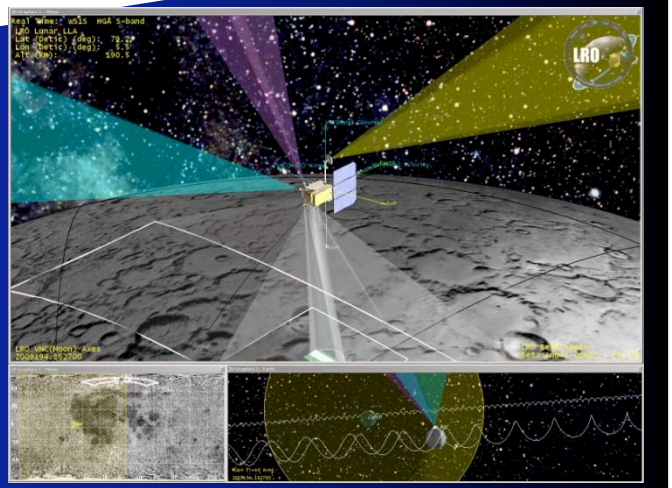
The Lunar Reconnaissance Orbiter: Observations for Lunar Exploration and Lunar Science





Rich Vondrak, NASA GSFC
NLSI Forum, July 21, 2010

LRO: The ESMD Mission

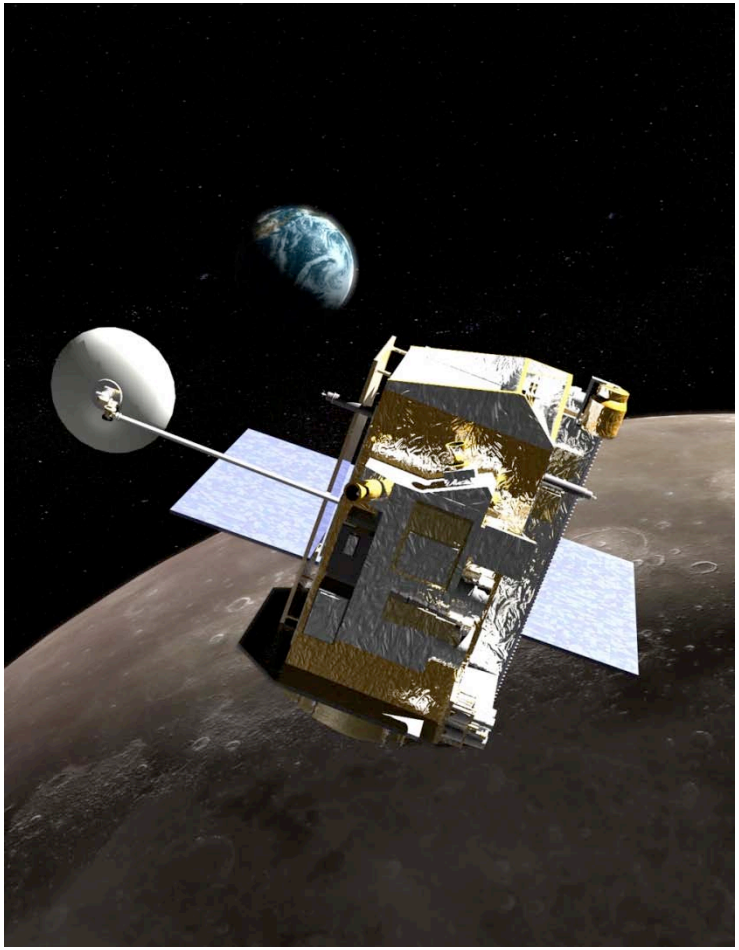
Goals: Locate resources
Identify safe landing sites
Measure the space environment

Seven instrument payload

Cosmic Ray Telescope for the Effects of Radiation (CRaTER)
Lunar Orbiter Laser Altimeter (LOLA)
LRO Camera (LROC)
Lyman-alpha Mapping Project (LAMP)
Diviner Lunar Radiometer Experiment (DLRE)
Lunar Exploration Neutron Detector (LEND)
Miniature Radio Frequency Technology Demonstration (Mini-RF)

LRO will return

- Global day/night temperature maps (DLRE)
- Global high accuracy geodetic grid (LOLA)
- High resolution black and white imaging (LROC)
- High resolution local topography (LOLA, LROC)
- Global ultraviolet 'albedo' map of the Moon (LAMP)
- Polar observations both in shadowed and illuminated areas (LEND, LROC, LOLA, DLRE, Mini-RF, LAMP)
- Ionizing radiation measurements in the form of energetic charged particles and neutrons (CRaTER, LEND)



LRO Launched June 18, and entered mapping orbit September 15, 2009

LRO Instruments and Investigations

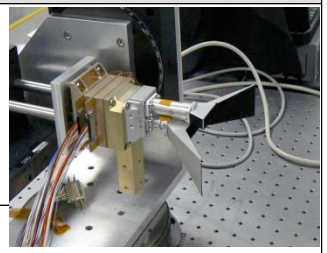
LOLA: Lunar Orbiter Laser Altimeter

- Topography
- Slopes
- Roughness

Deliverables:
~50m scale topography at <1m vertical, roughness

LROC/WAC: Wide-Angle Camera

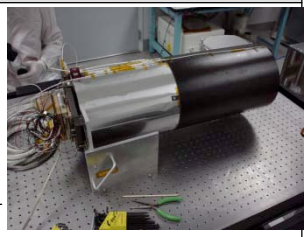
- Global Imagery
- Lighting
- Resources



Deliverables :
Entire Moon at 100m in UV, Visible (time series)

LROC/NACs: Narrow Angle Cameras

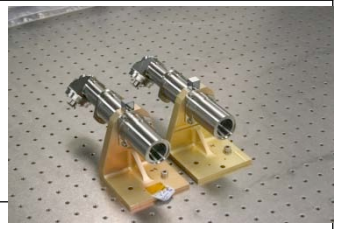
- Targeted Imagery
- Hazards
- Topography



Deliverables :
1000's of 50 cm/pixel images (125 km^2)

LR: Laser Ranging

- Topography
- Gravity



Deliverables:
Prescision orbit determination

DLRE: Diviner Lunar Radiometer Exp.

- Temperature
- Lighting
- Hazards
- Resources

Deliverables:
~300m scale maps of temperature, cold traps, and rocks

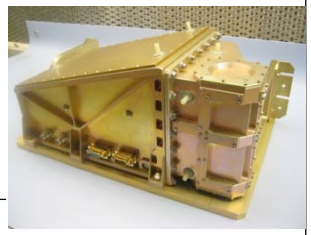
Mini-RF: Synthetic Aperature Radar

- Tech Demonstration
- Resources
- Topography

Deliverables:
Stokes parameter SAR images

CRaTER: Cosmic Ray Telescope…

- Radiation Spectra
- Tissue Effects



Deliverables:
Linear Energy Transport Spectra

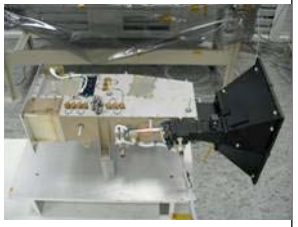
LEND: Lunar Expl. Neutron Detector

- Neutron Albedo
- Hydrogen Maps

Deliverables:
Maps of polar hydrogen in upper m of Moon at ~10km

LAMP: Lyman-Alpha Mapping Project

- Water-Frost
- PSR Maps

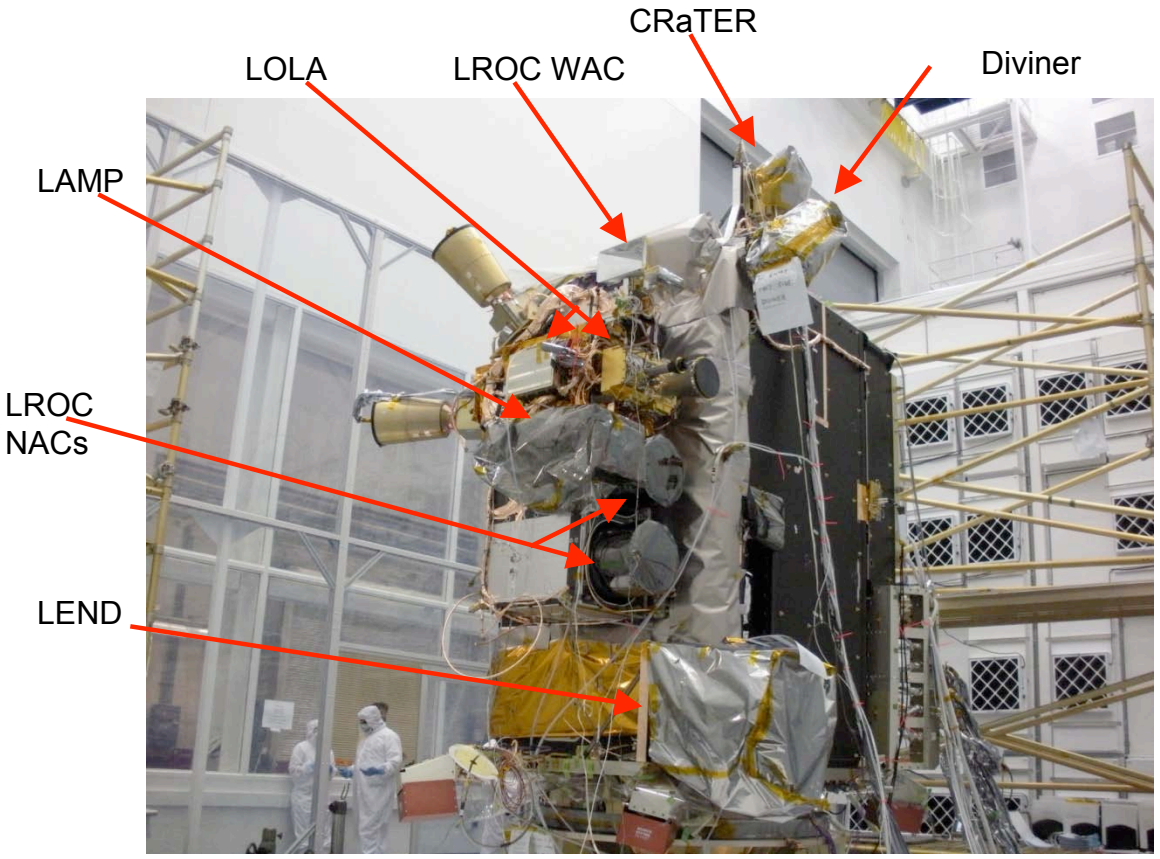


Deliverables:
Maps of frosts in permanently shadowed areas, etc.

LRO has robust and resilient capabilities

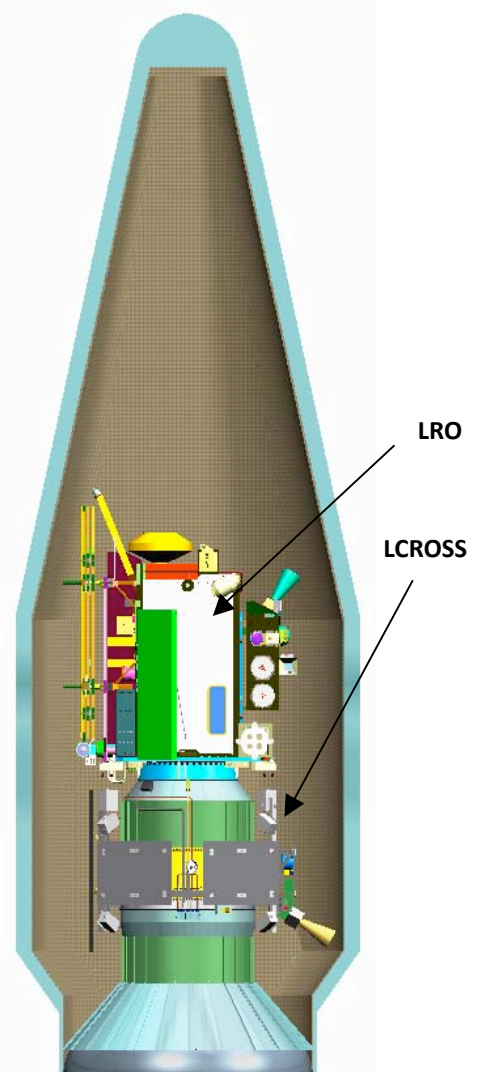
	Objectives	LRO Requirements	Contributing Instruments
1	Find Safe Landing Sites	M30 M40 – Global geodetic grid 10 cm vertical, and at the poles, 50 m horizontal resolution	LOLA, LROC
		M80 – Identify surface features & hazards	LROC, LOLA, DLRE
2	Locate Potential Resources	M50 – Provide lunar temperature map from 40 - 300K, 5 K precision over full diurnal cycle.	DLRE
		M60 – Image the permanently shadowed regions.	LAMP, LOLA
		M70 - Identify putative deposits of water-ice	LAMP,LEND, LOLA
		M90 – Characterize the polar region illumination environment	LROC, LOLA, DLRE
		M100 - Characterize lunar mineralogy	LROC, DLRE
		M110 - Hydrogen mapping	LEND
3	Life in the Space Environment	M10 - Characterize the deep space radiation environment at energies in excess of 10 MeV	CRaTER, LEND
		M20 - measure the deposition of deep space radiation on human equivalent tissue.	CRaTER
4	New Technology	P160 - Technology demo	Mini-RF

LRO Spacecraft and Instruments



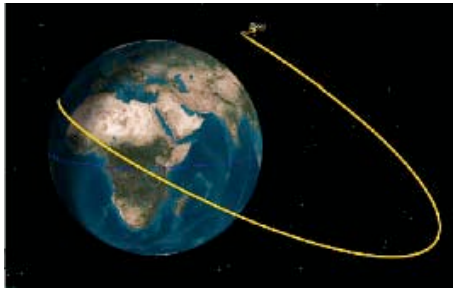
LRO Mission Overview

- Launched on an Atlas V into a direct insertion trajectory to the Moon. Co-manifested with LCROSS lunar impactor mission.
- On-board propulsion system used to capture at the Moon, insert into and maintain 50 km mean altitude circular polar orbit.
- 1 year exploration mission followed by handover to NASA Science Mission Directorate.
- Orbiter is 3-axis stabilized, nadir pointed, operates continuously during the primary mission.
- Data products delivered to Planetary Data Systems (PDS).
- Launched on June 18, 2009.
- Began Exploration orbit on September 15.

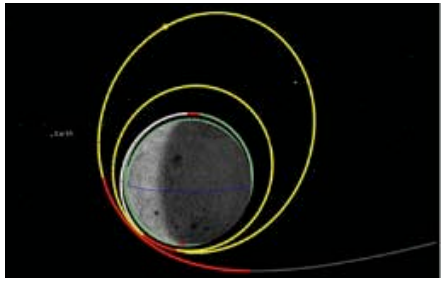


ESMD Operational Phase

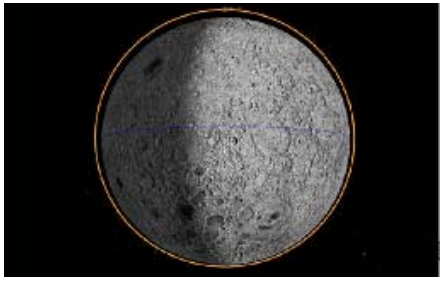
- **Four day cruise to Lunar Orbit Insertion**
- **Three month commissioning phase**
  - Spacecraft and instrument check out
  - Low energy elliptical orbit 30 x 216 km orbit, periapsis at south pole
- **Twelve month nominal phase (i.e., the EM)**
  - Near-circular 50 x 50 km orbit
  - Decays to 35 x 65 km in one month
  - Re-initialized every month (11 m/sec ΔV)



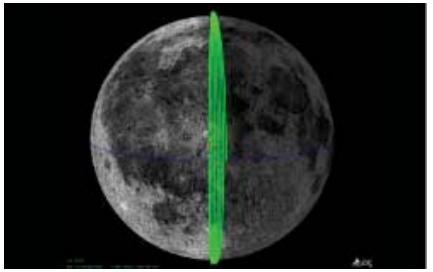
Minimum Energy Lunar Transfer ~ 4 Days



Lunar Orbit Insertion Sequence, 4-6 Days



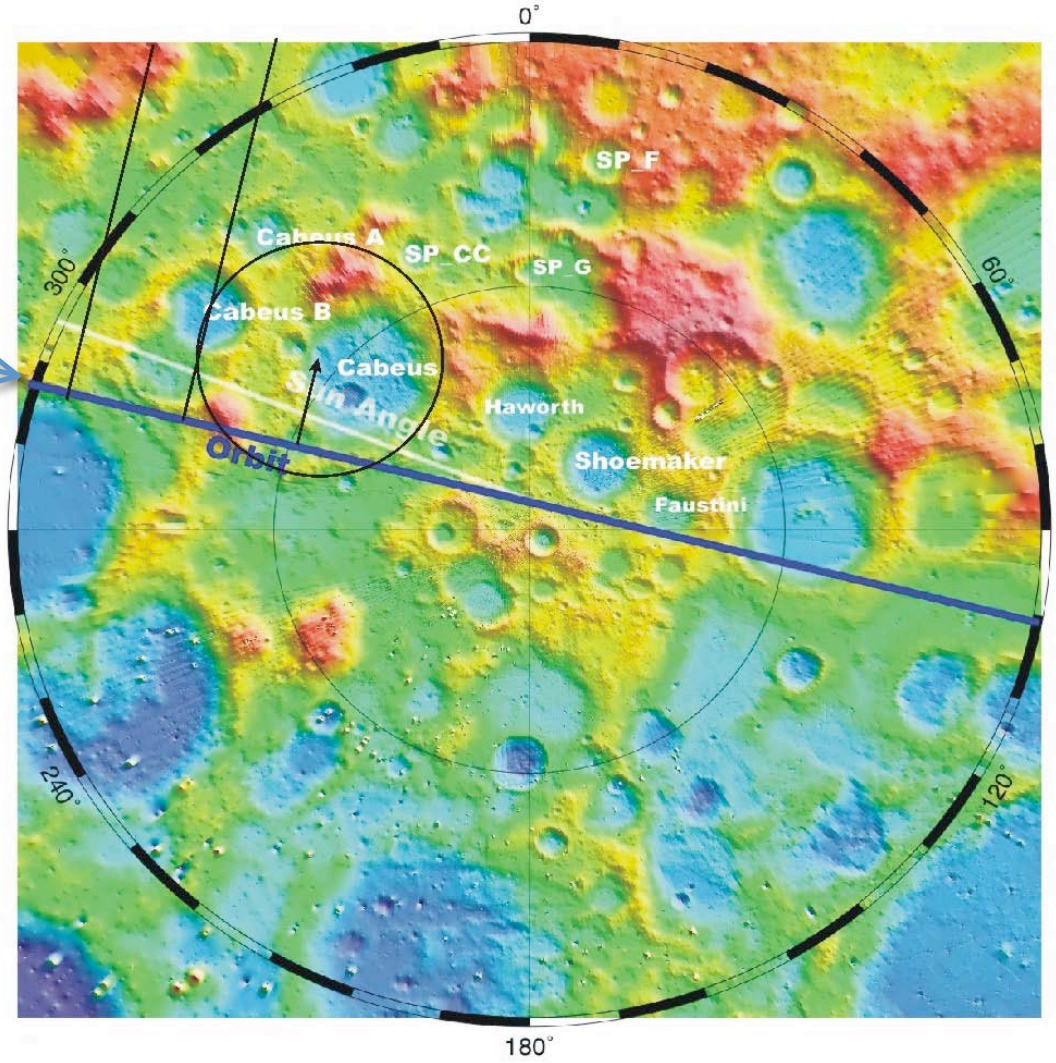
Commissioning Phase, 30 x 216 km Altitude Quasi-Frozen Orbit, Up to 60 Days



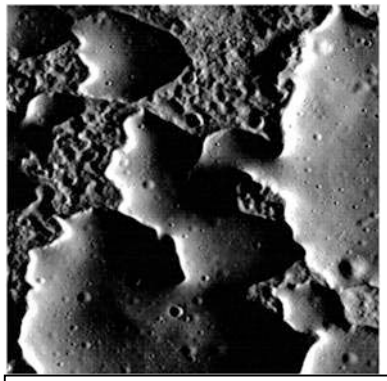
Polar Mapping Phase, 50 km Altitude Circular Orbit, At least 1 Year

LCROSS Impact on October 9, 2009

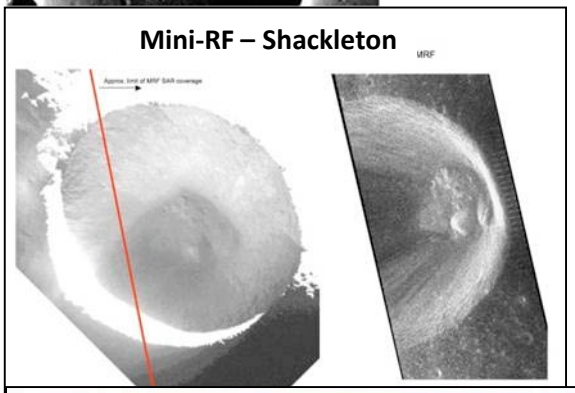
LRO ground track

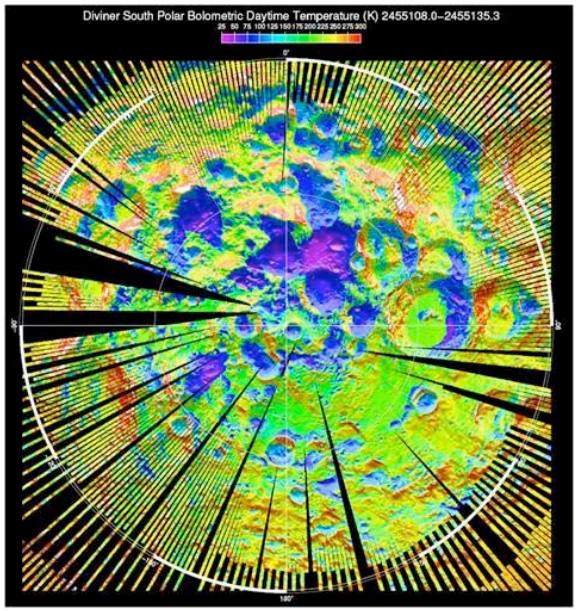


We are Witnessing a *New Moon* from LRO

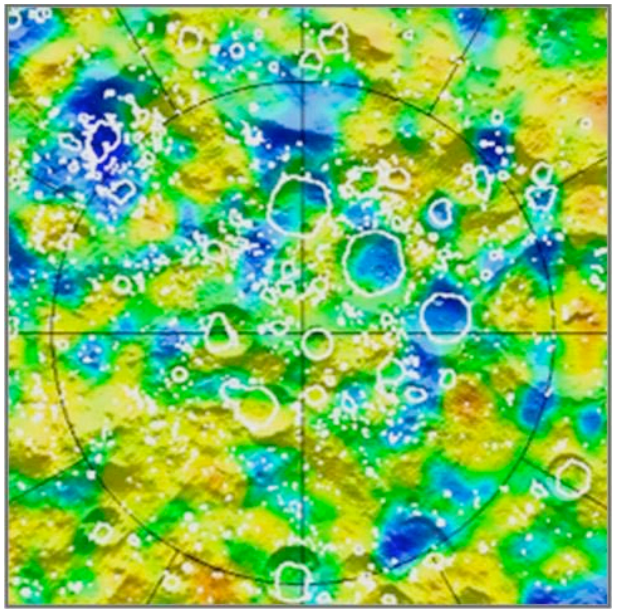


LROC (Ina)

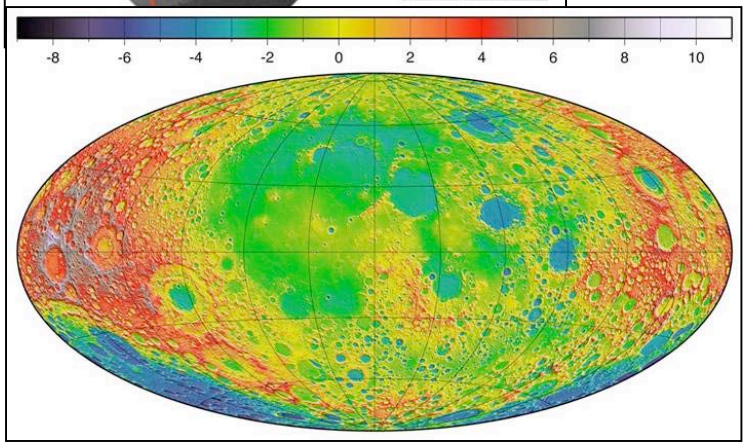




DLRE – South Pole Temp.

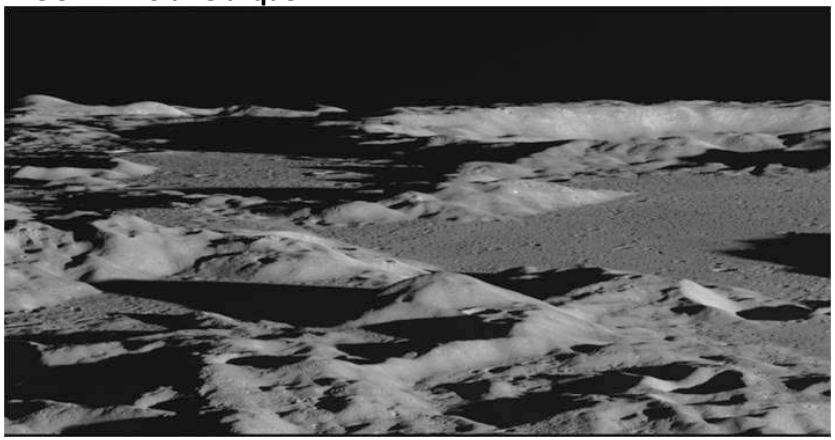


LEND – South Pole suppressed neutrons

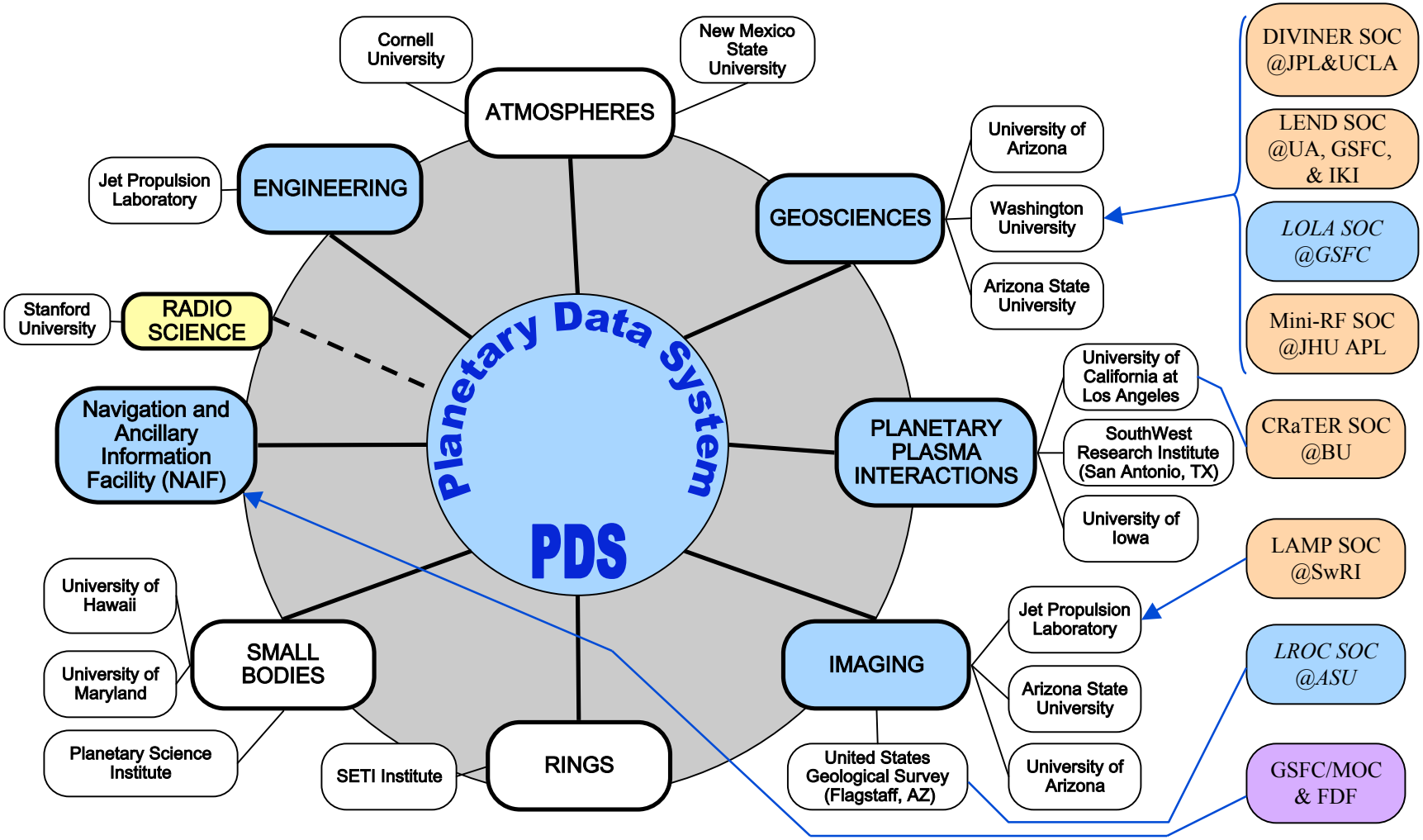


LOLA DEM

LROC – N. Polar Oblique

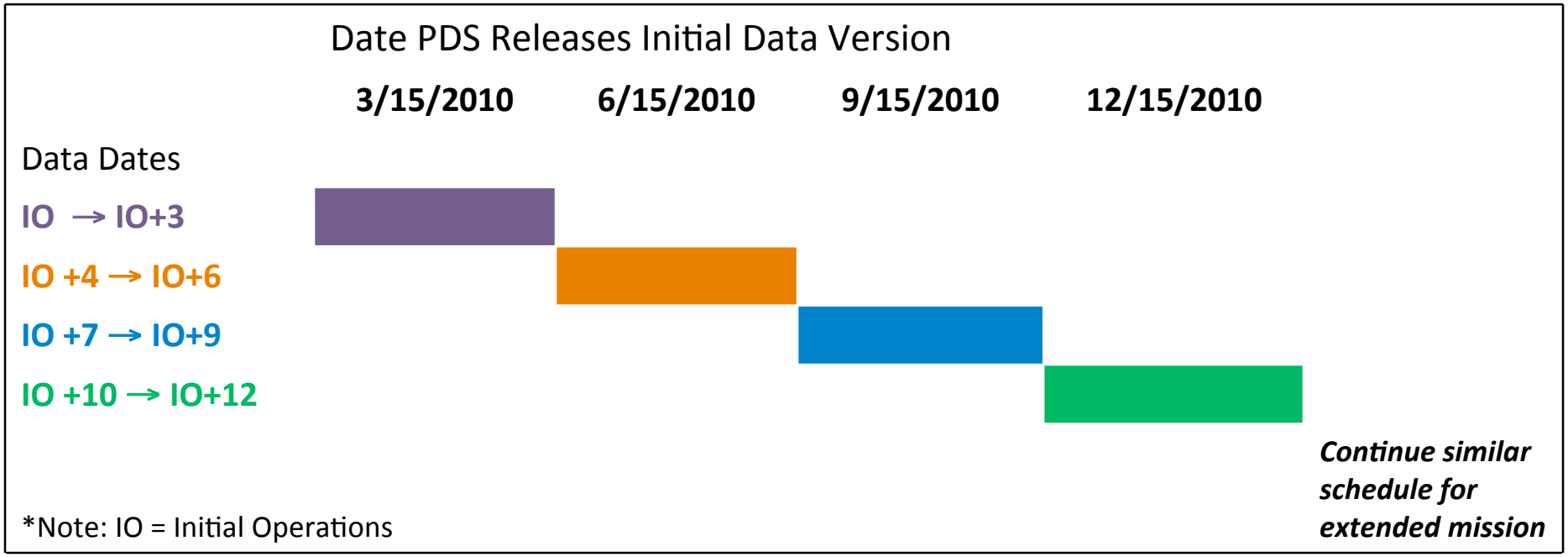


LRO SOCs & PDS Nodes/Subnodes/*Data Nodes*



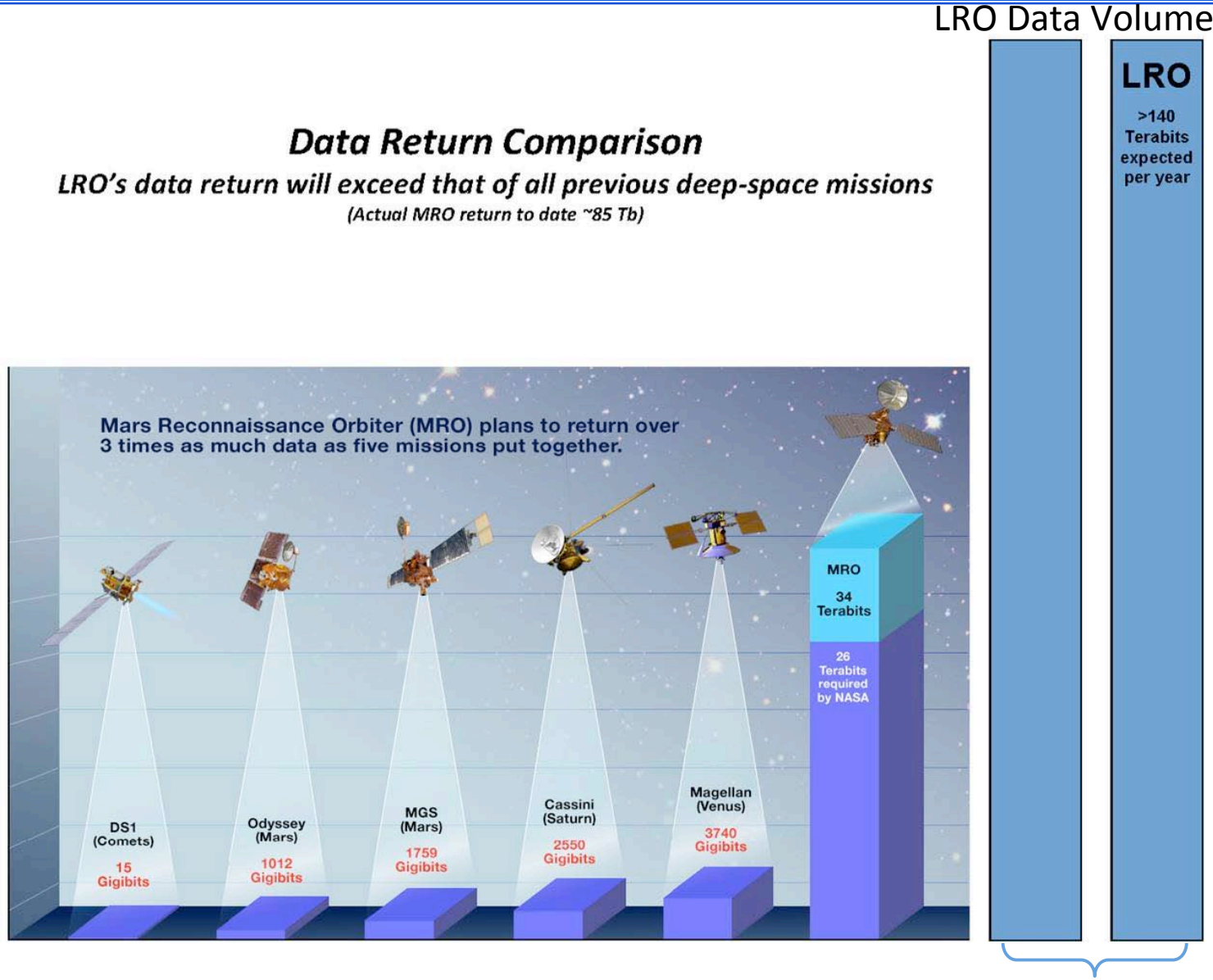
LRO Data Delivery Schedule

SOCs deliver 3-6 month old, validated, initial version of LRO data to PDS every 3 months, starting 6 months after Initial Operations on 9/15/09.



3/15/10 Release = 47.8 Terabits
6/15/10 Release = 30.2 Terabits

LRO Data Volume



After 1 year of operation to accomplish Exploration objectives, LRO will be operated by NASA's Science Mission Directorate

- LRO instrument suite has strong planetary science heritage
- Measurement capabilities align with lunar science goals that were identified by the NRC Decadal Survey and SCEM reports

- At SMD request, in January the LRO Science Team submittal a proposal for a two-year Science Mission to SMD
- That proposal was favorably assessed by a Senior Review Panel
- SMD has identified funding within the Lunar Quest Program for two years of LRO Science Mission operations, followed by six months of data analysis

Objectives of the LRO Science Mission

1. Investigate the bombardment history of the Moon, including basin-forming events and modern impact processes

2. Investigate lunar geologic processes and their role in the evolution of the lunar crust and shallow lithosphere

3. Investigate the processes that have shaped the global lunar regolith

4. Investigate and quantify the types, sources, sinks, and transfer mechanisms associated with volatiles on the Moon with emphasis on the polar regions

5. Investigate how the space environment interacts with the lunar surface on diurnal, seasonal, and yearly time scales

LRO Science Mission Operations

- LRO will stay in the 50-km orbit for several months

- LRO might then move to a transition orbit for 350 days
  - mean altitude of 110 km
  - initially 20x220 km with periselene at 40 degrees south
  - line of apsides moves northwards until 90x150 at pole
  - returns to 20x220 km at 40 degrees south

- Eventually LRO will be placed in a more stable orbit (30 x 216 km) for prolonged operations

- Spacecraft operations might differ from ESMD mission (e.g. more limb views)

- All LRO data products will be delivered to the Planetary Data System within six months for use by the scientific community

More information

- About LRO:

  http://www.nasa.gov/lro

- To contact the LRO Project Scientist:

  richard.vondrak@nasa.gov