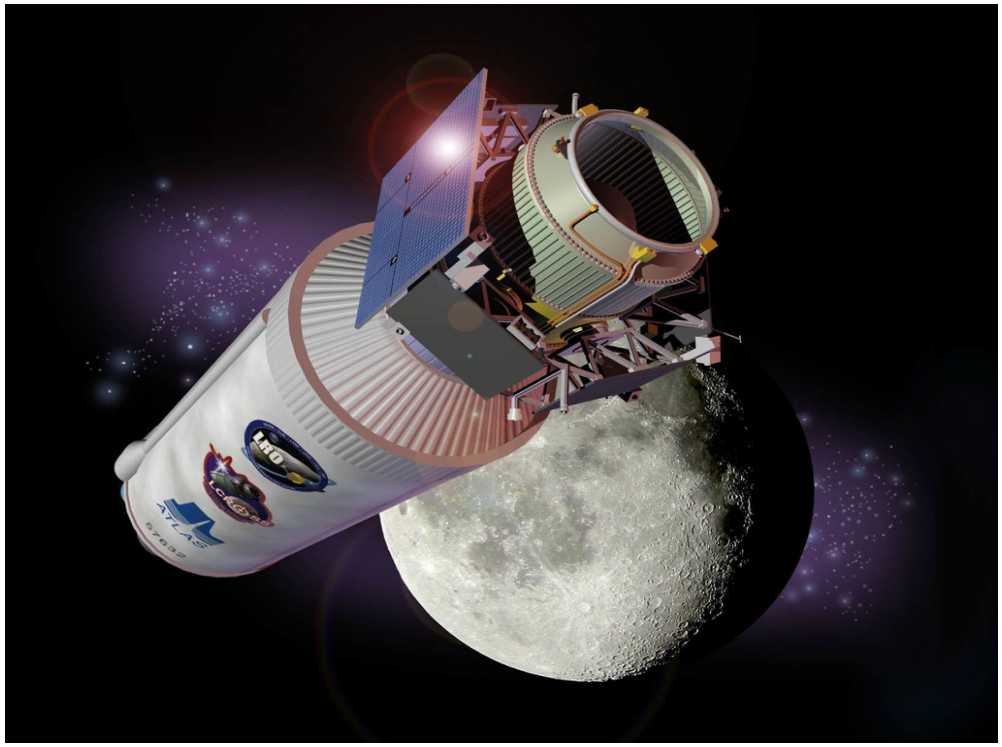
Lunar Reconnaissance Orbiter &
Lunar CRater Observation and Sensing Satellite Project

Commercial Development Summit
May 13, 2008



Benjamin Neumann
Exploration Systems Mission Directorate

Exploration Roadmap

05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Initial Orion (CEV) Capability

Lunar Robotic Missions

Lunar Outpost Buildup

Science Robotics Missions

Research and Technology Development on ISS

Commercial Crew/Cargo for ISS

Space Shuttle Operations

SSP Transition

Ares I and Orion Development

Operations Capability Development
(EVA, Ground Operations, Mission Operations)

Orion and Ares I Production and Operation

Altair Lunar Lander Development

Ares V & Earth Departure Stage

Surface Systems Development

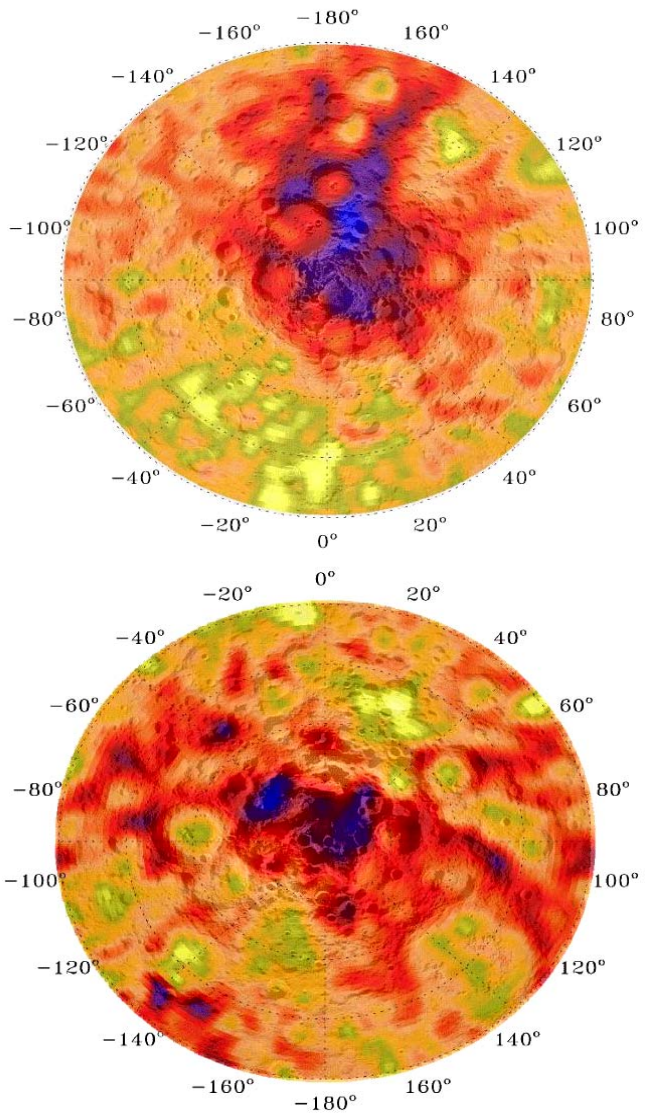
Lunar Reconnaissance Orbiter

- Provide early information for human missions to the Moon
  - **Focus on unknowns associated with the North and South Poles – likely destinations for a lunar outpost**
- Increase capability and sustainability through strategic priorities:
  - **Good quality topographical global map**
  - **Surface temperature and illumination characteristics**
  - **Resource distribution to overlay map**
  - **Radiation environment**
  - **Search for presence of water in permanently shadowed craters at lunar poles**

LRO Mission Overview

- **Launch in late 2008 on a Atlas V into a direct insertion trajectory to the moon. Co-manifested with LCROSS lunar impacter mission.**
- **On-board propulsion system used to capture at the moon, insert into and maintain 50 km mean altitude circular polar reconnaissance orbit.**
- **1 year mission with extended mission options.**
- **Orbiter is a 3-axis stabilized, nadir pointed spacecraft designed to operate continuously during the primary mission.**
- **Investigation data products delivered to Planetary Data Systems (PDS) within 6 months of primary mission completion.**

Interpretation: Polar Hydrogen Deposits on the Moon

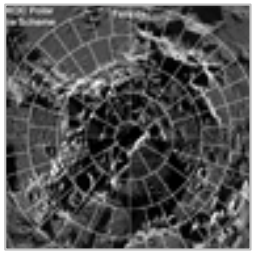


- The deposits at the north appear to be in the form of many small pockets which average about 100 ppm above the equatorial hydrogen content.
  - The spatial resolution of the spectrometer was on the order of 50 to 150 km, insufficient to resolve surface features associated with the hydrogen signature.
- The deposits in the permanently-shaded craters near the south are consistent with a thick soil containing an enhancement of 1670±890 ppm hydrogen.
  equivalent to 1.5 ± 0.8 wt.% H2O

Observations from Lunar Prospector Neutron Spectrometer

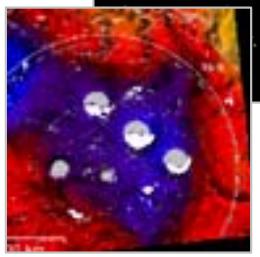
Lunar Reconnaissance Orbiter

Goddard Space Flight Center (GSFC)



LROC
Lunar Reconnaissance Orbiter Camera

Arizona State Univ

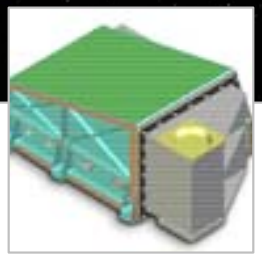


LEND
Lunar Exploration Neutron Detector

Russian Inst for Space Research

DLRE
Diviner Lunar Radiometer Experiment

UCLA/JPL



CRaTER
Cosmic Ray Telescope for the Effects of Radiation

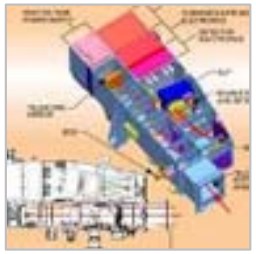
Boston U/MIT

MINI-RF
Synthetic Aperture Radar

Naval Air Warfare Center

LOLA
Lunar Orbiter Laser Altimeter

GSFC

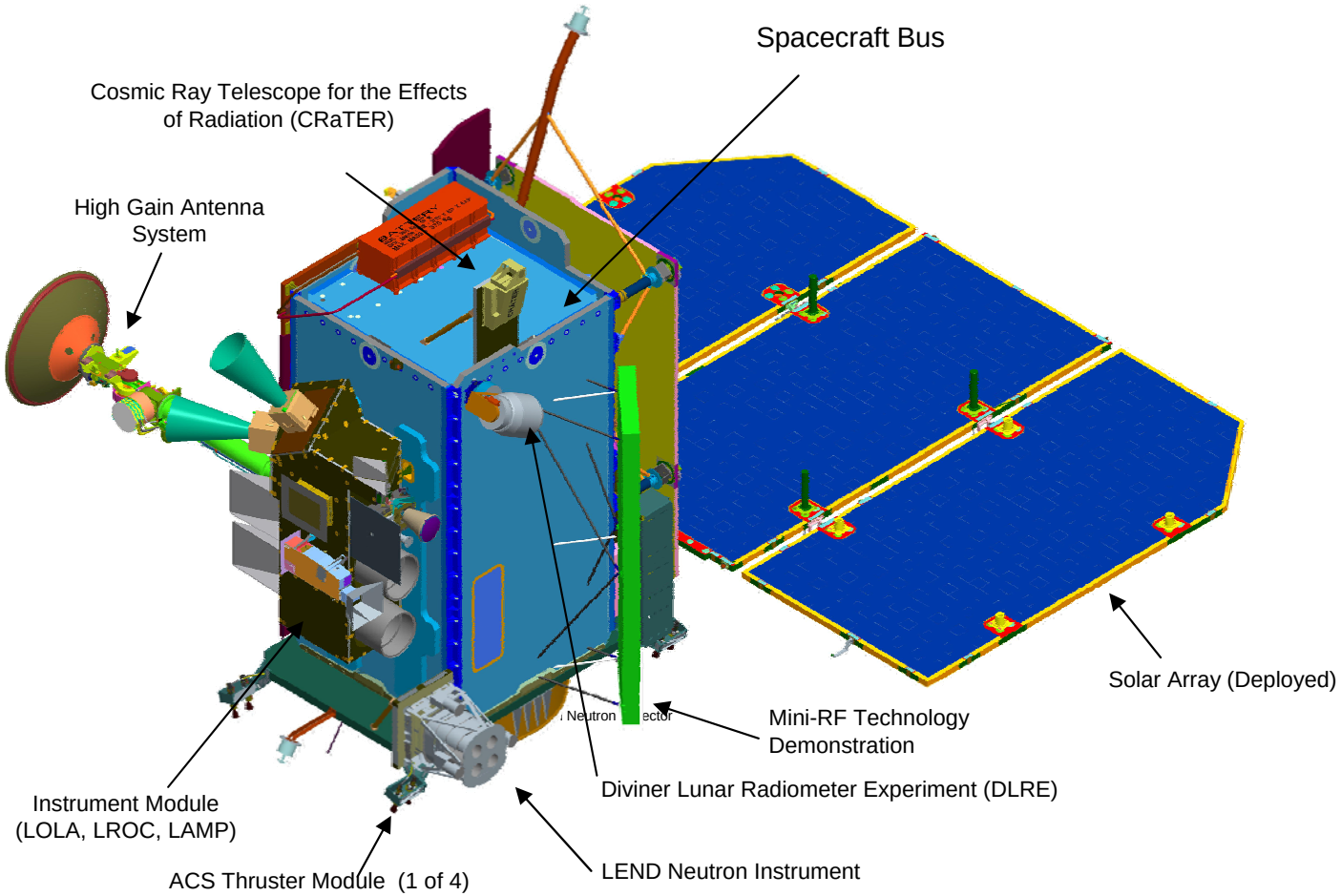


LAMP
Lyman Alpha Mapping Project

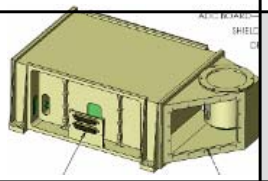
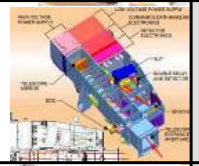
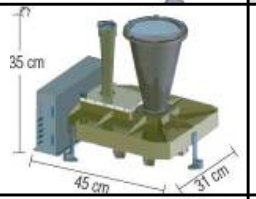
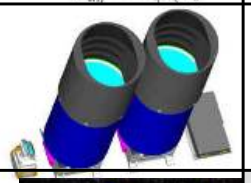
Southwest Research Inst

LRO Spacecraft

LRO Orbiter Characteristics		
Mass (CBE)	**1845 kg**	**Dry: 924 kg, Fuel: 898 kg (1263 m/sec)**
Orbit Average Bus Power	**681 W**	
Data Volume, Max Downlink rate	**461 Gb/day, 100Mb/sec**	
Pointing Accuracy, Knowledge	**60, 30 arc-sec**	

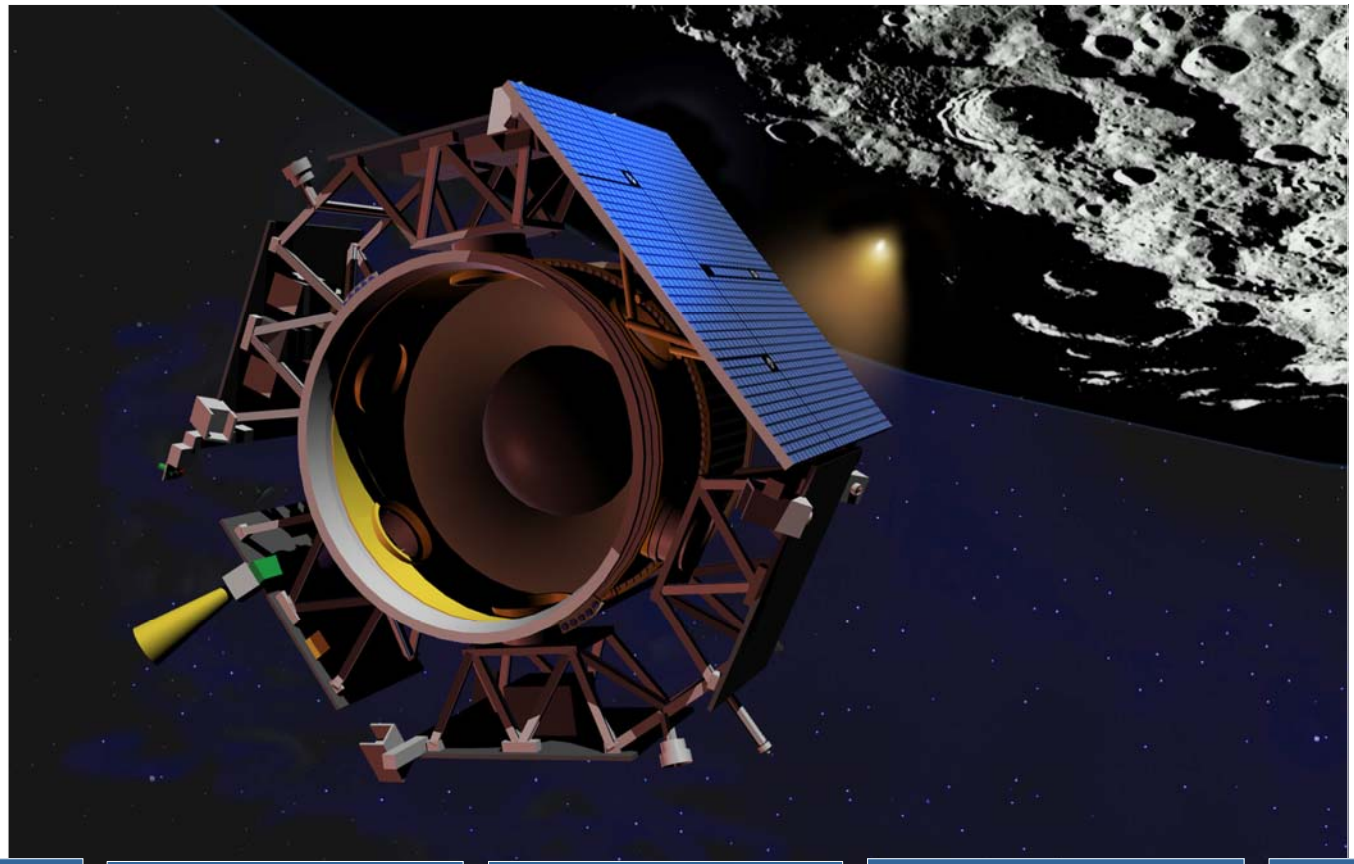


Instrument Suite has Detailed Traceability to Exploration Requirements

Instrument	Navigation/ Landing Site Safety	Locate Resources	Life in Space Environment	New Technology
CRaTER Cosmic Ray Telescope for the Effects of Radiation 			• High Energy Radiation • Radiation effects on human tissue	
DLRE Diviner Lunar Radiometer Experiment 	• Rock abundance	• Temperature • Mineralogy		
LAMP Lyman Alpha Mapping Project 		• Surface Ice • Image Dark Craters		
LEND Lunar Exploration Neutron Detector 		• Subsurface Hydrogen Enhancement • Localization of Hydrogen Enhancement	• Neutron Radiation Environment	
LOLA Lunar Orbiter Laser Altimeter 	• Slopes • Topography/Rock Abundance • Geodesy	• Simulation of Lighting Conditions • Crater Topography • Surface Ice Reflectivity		
LROC Lunar Reconnaissance Orbiter Camera 	• Rock hazards • Small craters	• Polar Illumination Movies • Mineralogy		
Mini-RF *Technology Demonstration* 				• S-band and X-band SAR demonstration

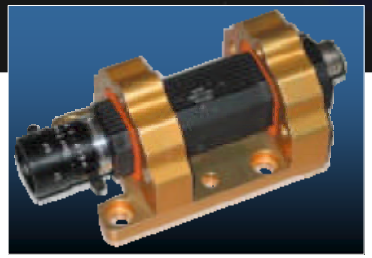
Lunar Crater Observation & Sensing Satellite

Ames Research Center (ARC) & NORTHROP GRUMMAN



Mid-Infrared Camera

- Curtain, Crater Temperature
- Curtain Morphology
- Water Ice

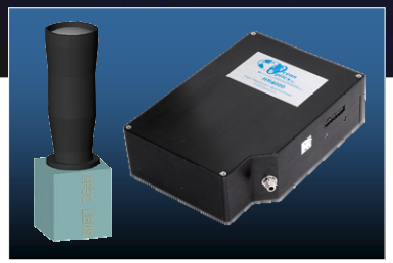


Visible Camera

- Impact Context
- Curtain Morphology

Near Infrared Camera

- Water Ice / Curtain Morphology
- NIR Context



Visible Spectrometer

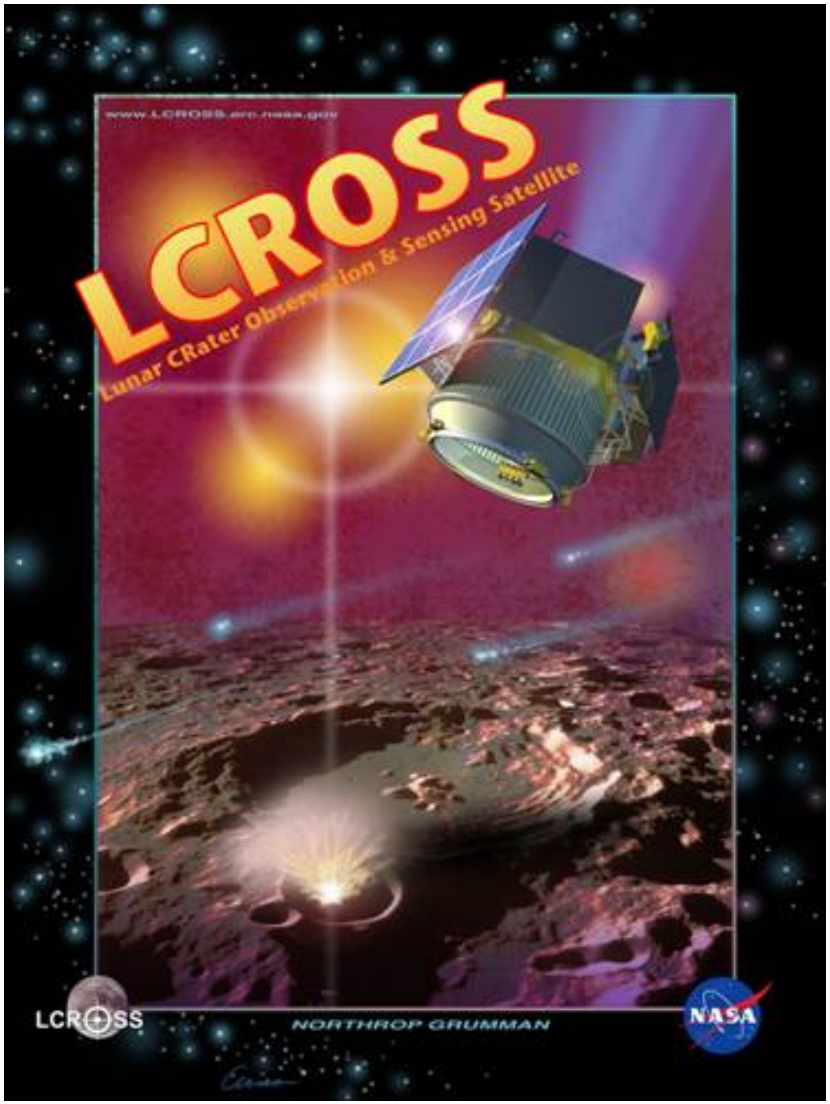
- Flash Spectroscopy
- Water Vapor
- Organics

Near Infrared Spectrometers

- Curtain Water Ice & Vapor
- Hydrated minerals

Mission Overview

- The LCROSS Mission is a Lunar Kinetic Impactor employed to investigate the presence & nature of water ice on the Moon
  - LCROSS is a 1000kg secondary payload riding on LRO launch vehicle in late 2008
  - LRO/LCROSS will launch on an Atlas V
  - LRO separates and LCROSS utilizes lunar gravity-assist to establish a high-ecliptic inclination, 3-4 month cruise orbit
  - LCROSS separates from 2300kg Centaur stage, to enable LCROSS to observe impact and measure ejecta plume
  - Centaur expected to excavate ~200 metric tons of regolith, leaving a crater the size of ~1/3 of a football field, ~15 feet deep.
  - The S-S/C becomes a ~700kg 'impactor' as well
  - Ground and space-based observation being organized

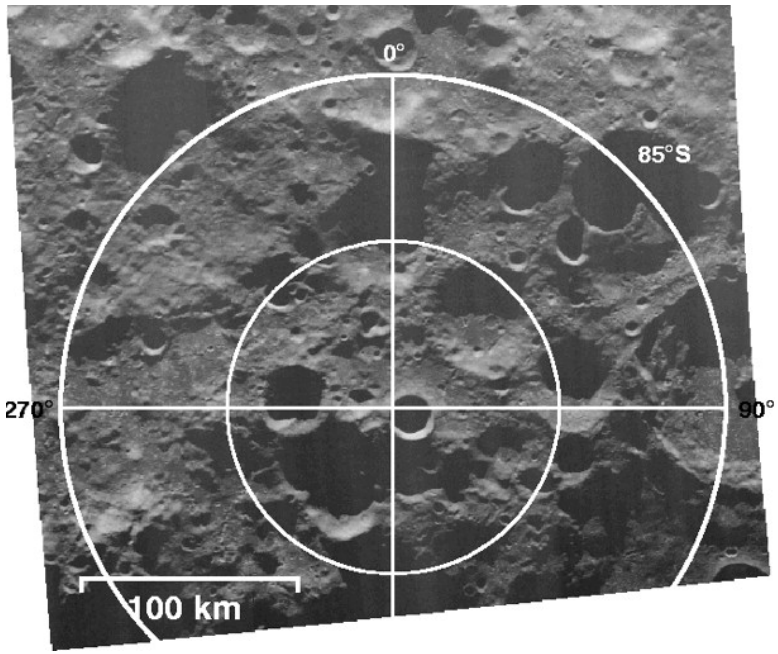


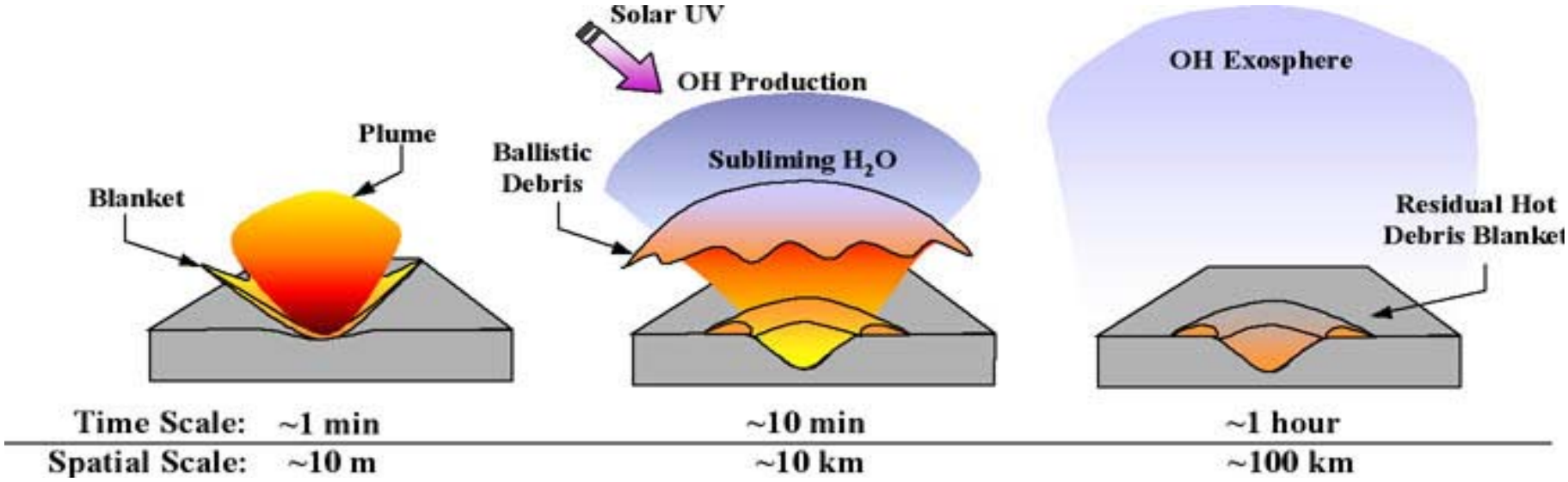
Mission Goals

Perform first *"in-situ"* analysis of regolith from a permanently shadowed region

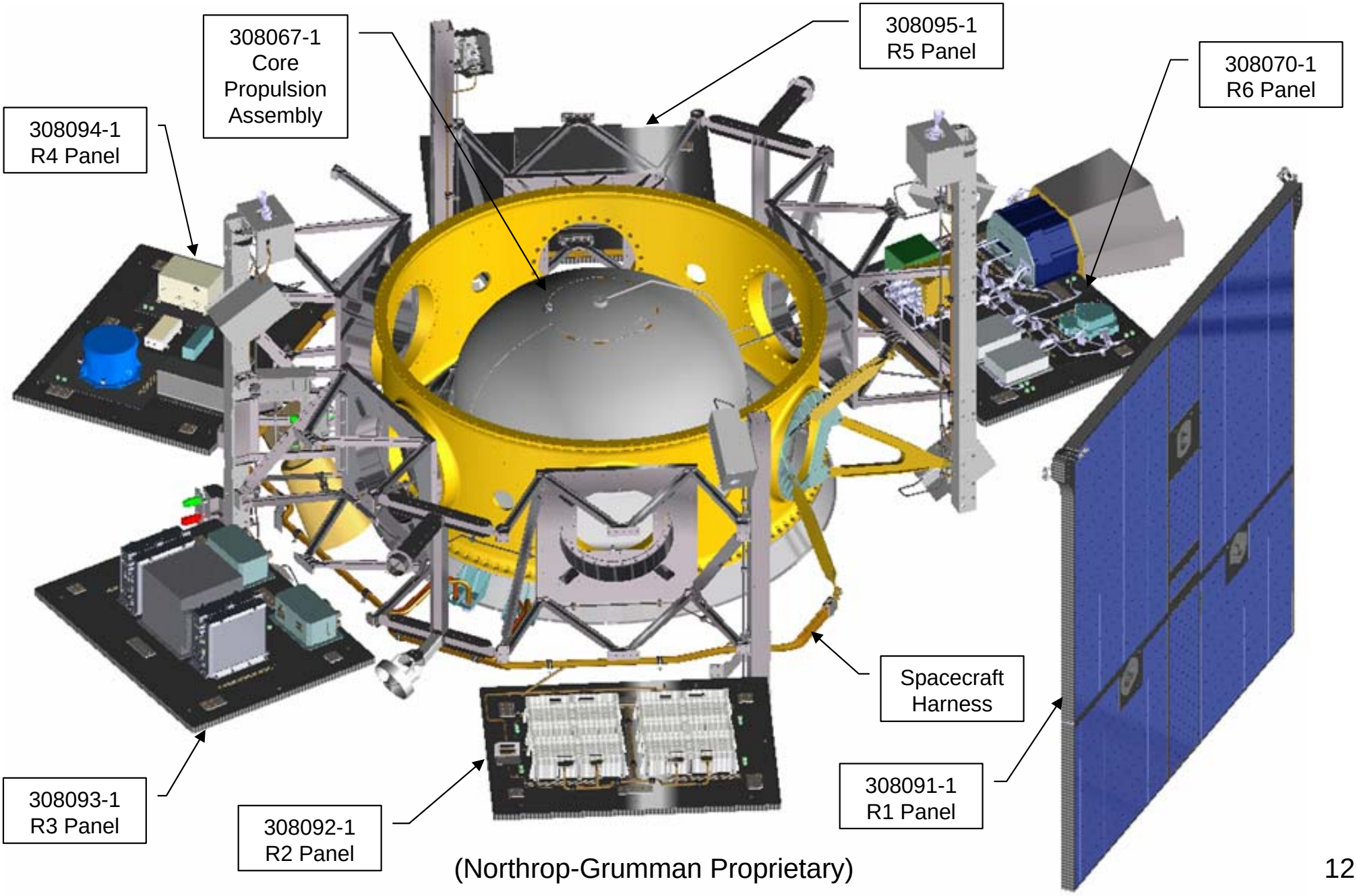
Science goals:

- Confirm the presence or absence of water ice in a permanently shadowed region on the Moon
- Identify the form/state of hydrogen observed by at the lunar poles
- Quantify, if present, the amount of water in the lunar regolith, with respect to hydrogen concentrations
- Characterize the lunar regolith within a permanently shadowed crater on the Moon



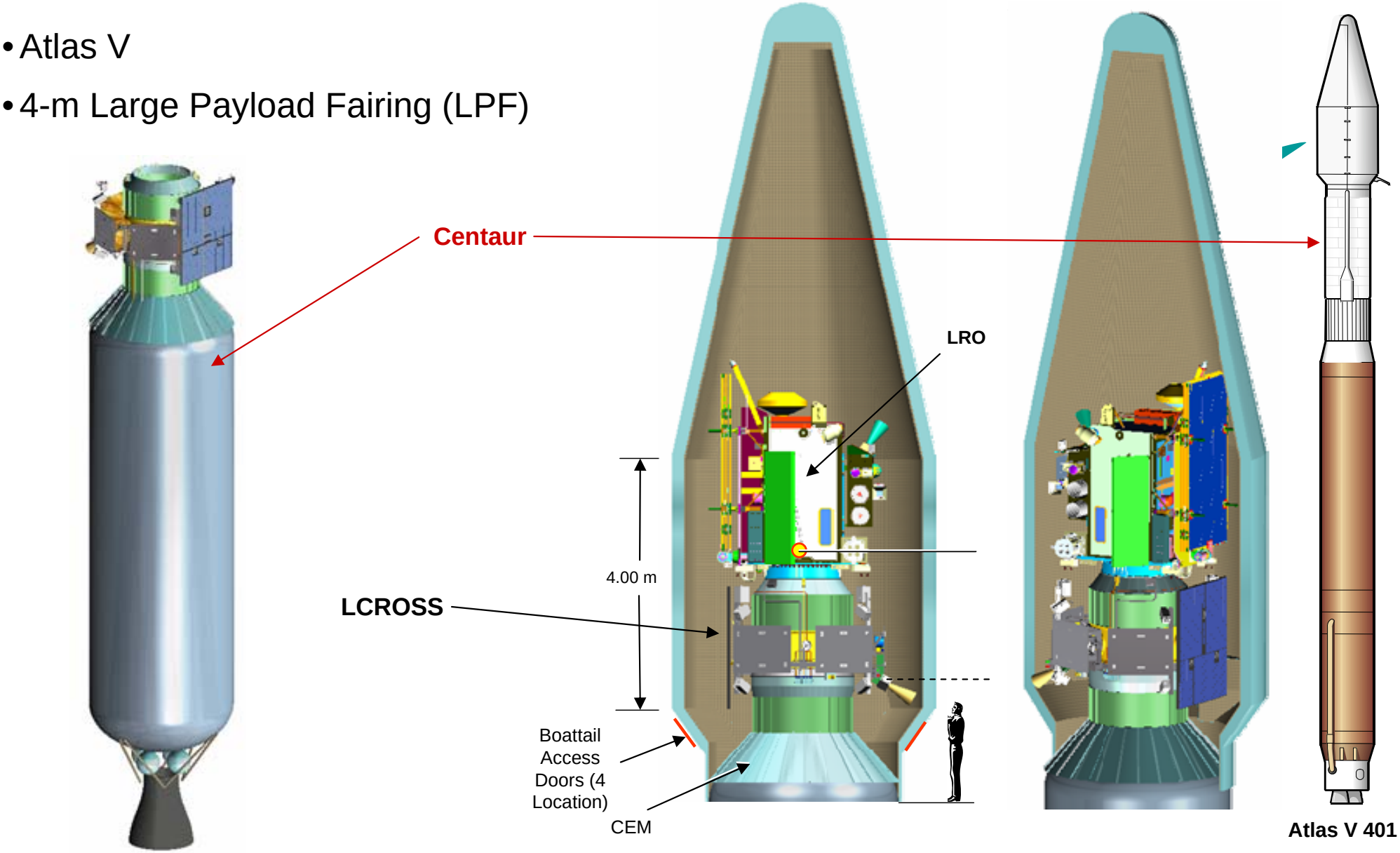


Shepherding Spacecraft Configuration



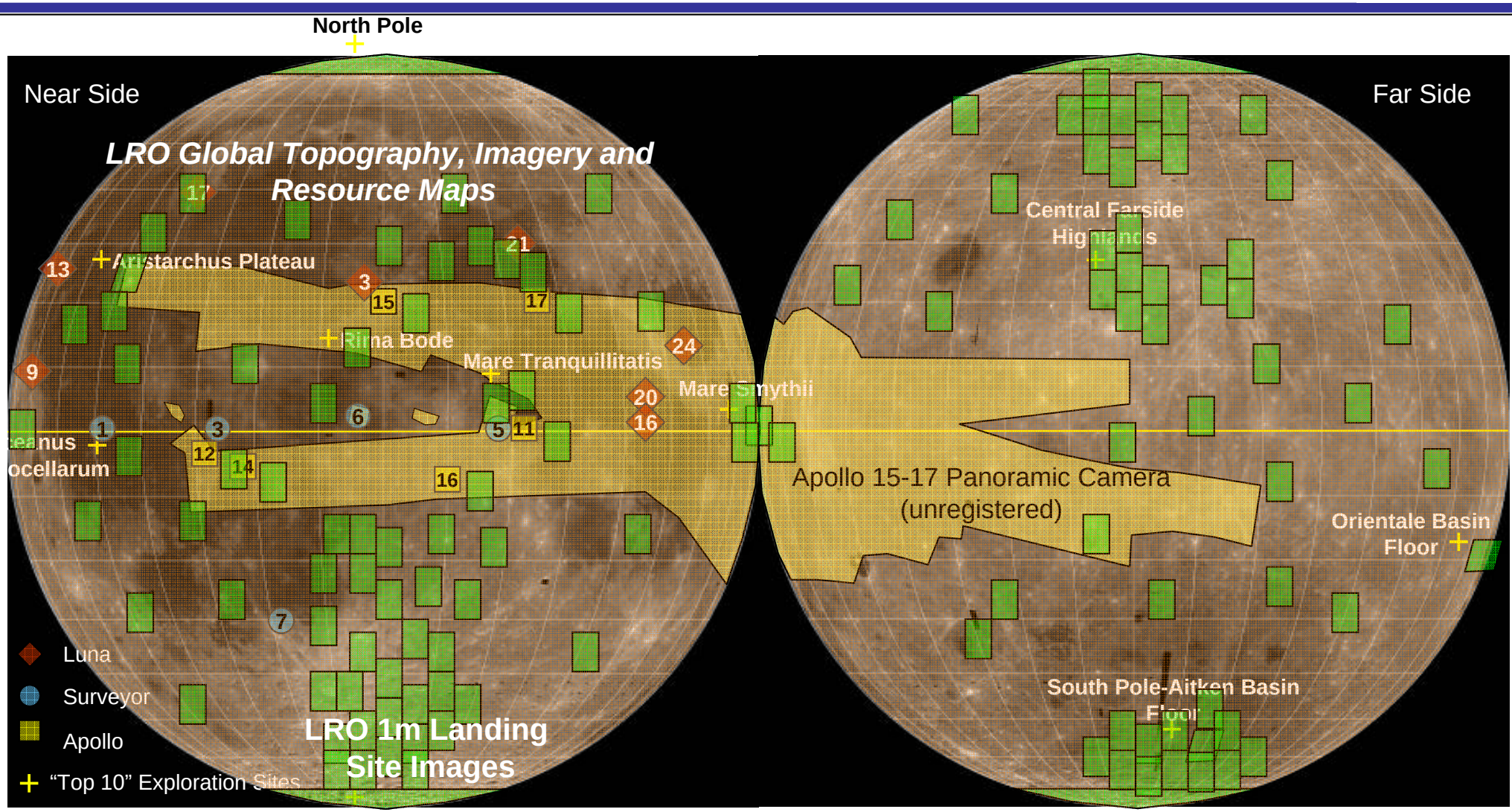
Launch Vehicle Integration

- Atlas V
- 4-m Large Payload Fairing (LPF)



LRO Mission

LRO Enables Global Lunar Surface Access



Current Apollo heritage image set only Covers 4 of 10 ESAS sites.

LRO extends coverage to entire Moon

Most other high priority sites identified lie outside Apollo heritage area