NASA's Lunar Robotic Program

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Abstract

Before returning humans to the Moon for mankind's seventh lunar landing, NASA will embark upon a series of robotic missions with International partnership, executed within the construct of an integrated program, designed specifically to prepare the way for this further human exploration. The Lunar Precursors Robotic Exploration Program (LPRP) will acquire knowledge about the moon and its environment, as well as to develop operational experience and infrastructure, all needed to bring about sustained human exploration in the lunar environment. This paper presents an overview of the program in its early stages, a review of the currently planned missions, highlights of several of the program's important features and objectives, and a discussion of the challenges faced as we move forward to prepare for a return of people to the Moon.

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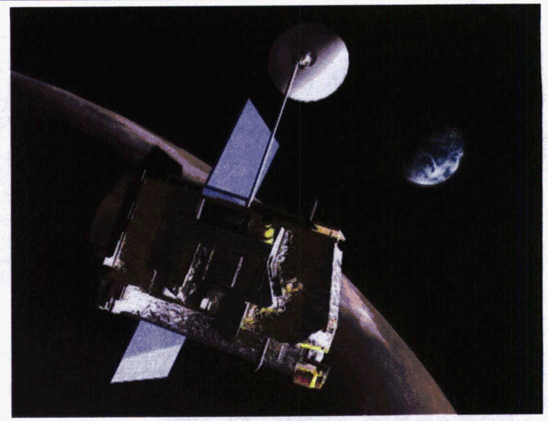
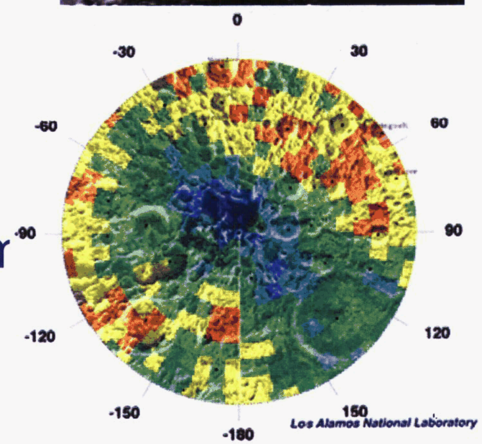
NASA's Robotic Lunar Exploration Objectives

Implementation Objectives for lunar robotics:



- Global mapping of the lunar surface
- Find optimal landing site(s) for robotic and human explorers
- Find and characterize resources that make explo-
- ration affordable and sustainable
  - Locate and quantify frozen water
  - Locate and quantify other lunar resources
- Field test new equipment, technologies and approaches, e.g., for dust mitigation and radiation environment

- Support demonstration, validation, and establishment of heritage of systems for use on crewed missions
- Determine how life will adapt to space environments
- Investigate the origin and evolution of our solar system by studying the Moon
- Emplace infrastructure to support human exploration



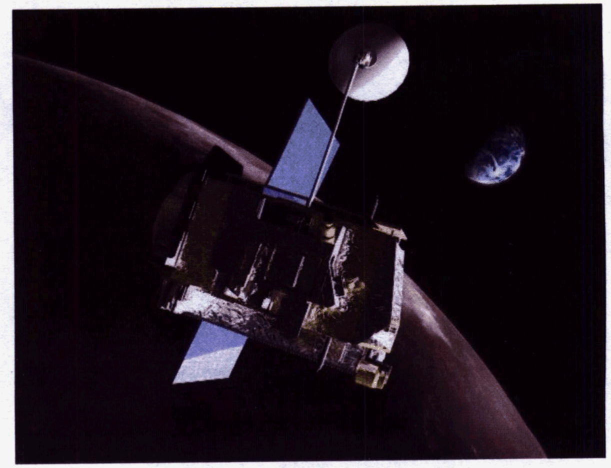
Lunar Precursor Robotic Program

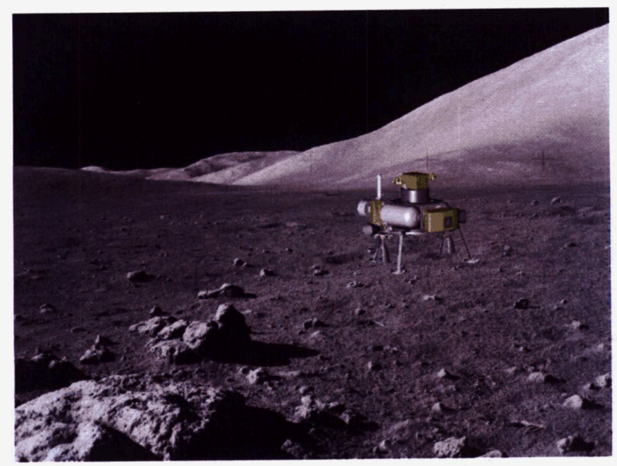
"Starting no later than 2008, initiate a series of robotic missions to the Moon to prepare for and support future human exploration activities", NPSD-31

- Primary responsibility of the NASA Lunar Robotic Precursor Program is to develop and execute missions to achieve NASA's robotic lunar exploration objectives.
- This will be accomplished by:
  - Defining a robust and sustainable architecture for robotic precursor missions that accomplish defined objectives
  - Identifying key assumptions and guidelines
  - Identifying system interfaces
  - Obtaining stakeholder and exploration community buy-in
  - Defining specific requirements for each precursor mission
  - Establishing and overseeing projects to execute mission design, development, integration, test and operation

Robotic Precursor Missions

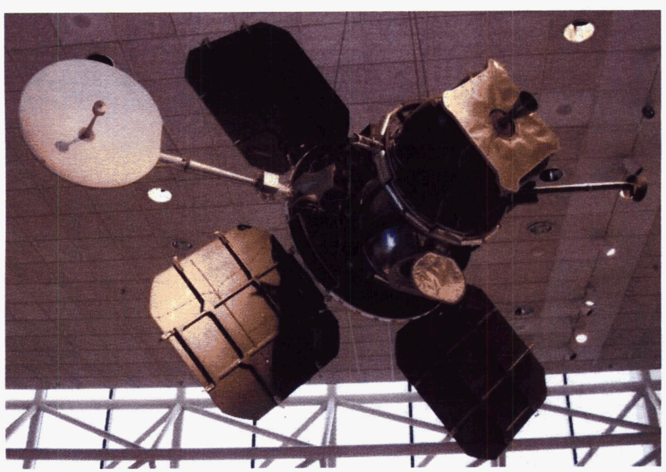
- **Provide early information for human missions**
  - Key knowledge needed for human safety and mission success
  - Infrastructure elements for eventual human benefit
  - Results will guide human exploration
- **Resolve many unknowns are at the North and South Poles**
  - Knowledge of the environment – temperatures, lighting, etc.
  - Resources/deposits – composition and physical nature
  - Terrain and surface properties - dust characterization
  - Support infrastructure – navigation/communication, beacons
- **Make exploration more capable and sustainable**
  - Surface systems
  - Operations
  - Science community



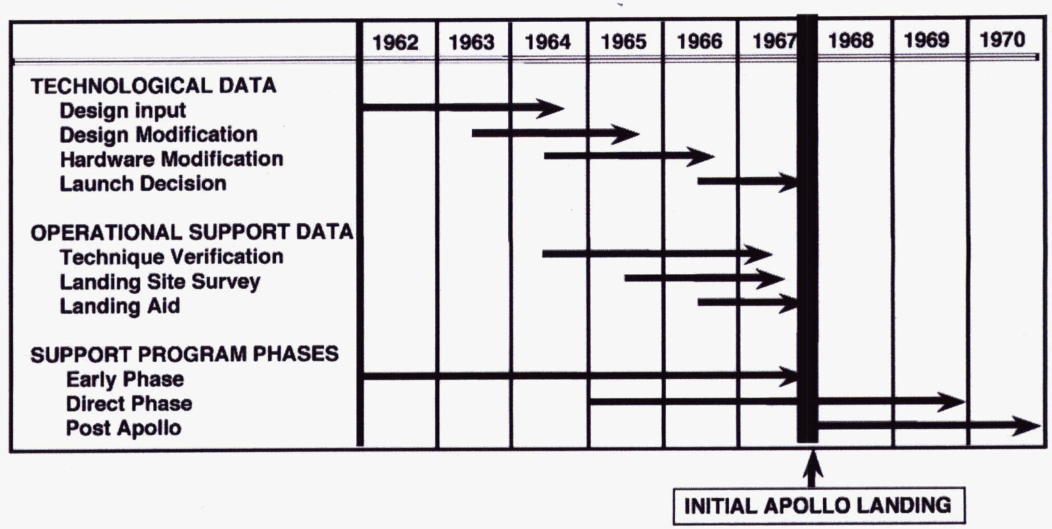


Apollo Robotic Precursors

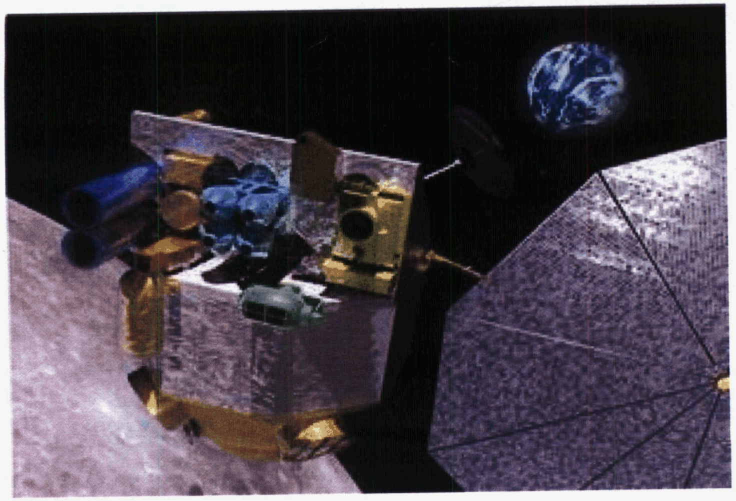
- **Apollo had three (Ranger, Lunar Orbiter and Surveyor) robotic exploration programs with 21 precursor missions from 1961-68**
  1. Lunar Orbiters provided medium & high resolution imagery (1-2m resolution) which was acquired to support selection of Apollo and Surveyor landing sites.
  2. Surveyor Landers made environmental measurements including surface physical characteristics.
  3. Ranger hard landers took the first close-up photos of the lunar surface
- **Exploration needs the above information to go to new sites AND resource data to enable sustainable exploration.**



Lunar Orbiter Mock-up in Smithsonian Air & Space Museum, Washington DC



First Two LPRP Missions



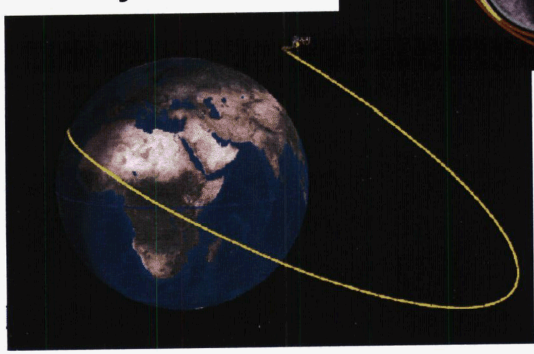
- *Lunar Reconnaissance Orbiter (LRO)*
- **Lunar mapping, topography, radiation characterization, and volatile identification**
- **50km polar orbit**
- **Critical Design Review: October 2006**
- **Launch: Late October 2008**

- *Lunar CRater Observation and Sensing Satellite (LCROSS)*
- **Investigate the presence of water at the South Pole via a kinetic impactor and sheparding spacecraft**
- **Preliminary Design Review: August 2006**
- **Launch: Late October 2008 (co-manifested with LRO)**

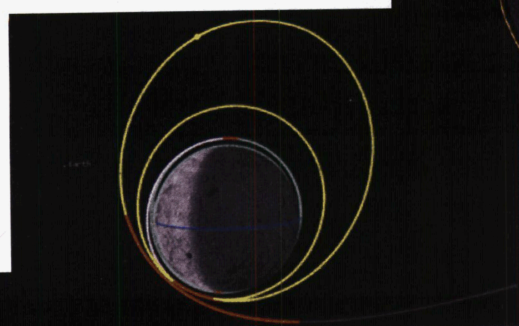
LRO Mission Overview

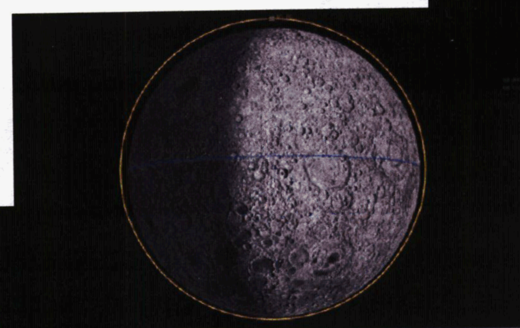
Launch: October 31, 2008

Minimum Energy Lunar Transfer ~ 4 Days

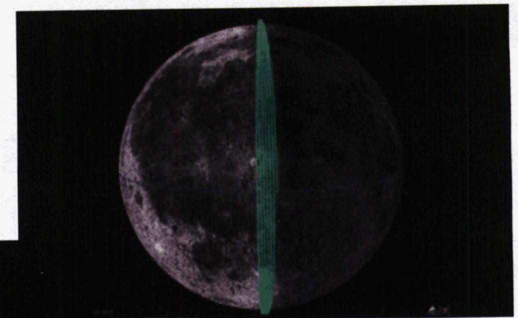


Lunar Orbit Insertion Sequence, 4 Maneuvers, 2-4 Days

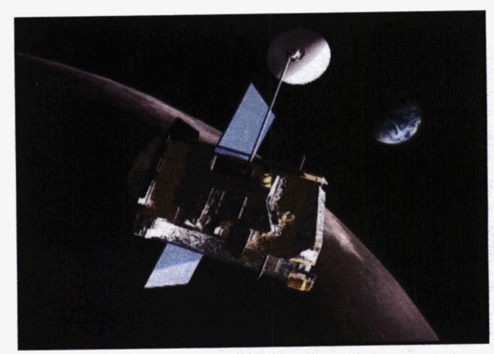




Commissioning Phase, 30 x 216 km Altitude Quasi-Frozen Orbit, Up to 60 Days



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



Nominal End of Mission: February 2010

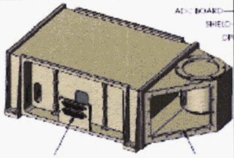
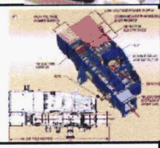
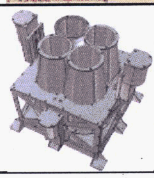
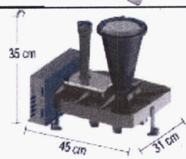
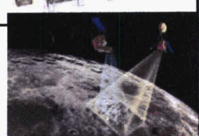
LRO Comparison to Recent Missions

- **Previous and currently planned missions do not provide comparable image resolution, topography and resource identification.**

	Key Exploration Capabilities	Resolution	Coverage Duration
Clementine	• High Resolution and multispectral Imaging • Topography • LWIR	25m/pixel and 150m multispectral 60 km spatial/100m radial 200-400 m/pixel (>200K)	Polar coverage 2-month duration
Lunar Prospector	• *No imager on-board* • Neutron Detector • GRS	140 km ≈140 km	Polar coverage 18-month duration
LRO	• High Resolution and multispectral Imaging • Topography • Neutron detector • Thermal mapping	0.5 m and 100 m multispectral 50m spatial/1m radial 10 km 350 m (>25K)	Polar coverage 1-yr duration

- **LRO will improve capabilities to support Exploration.**

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

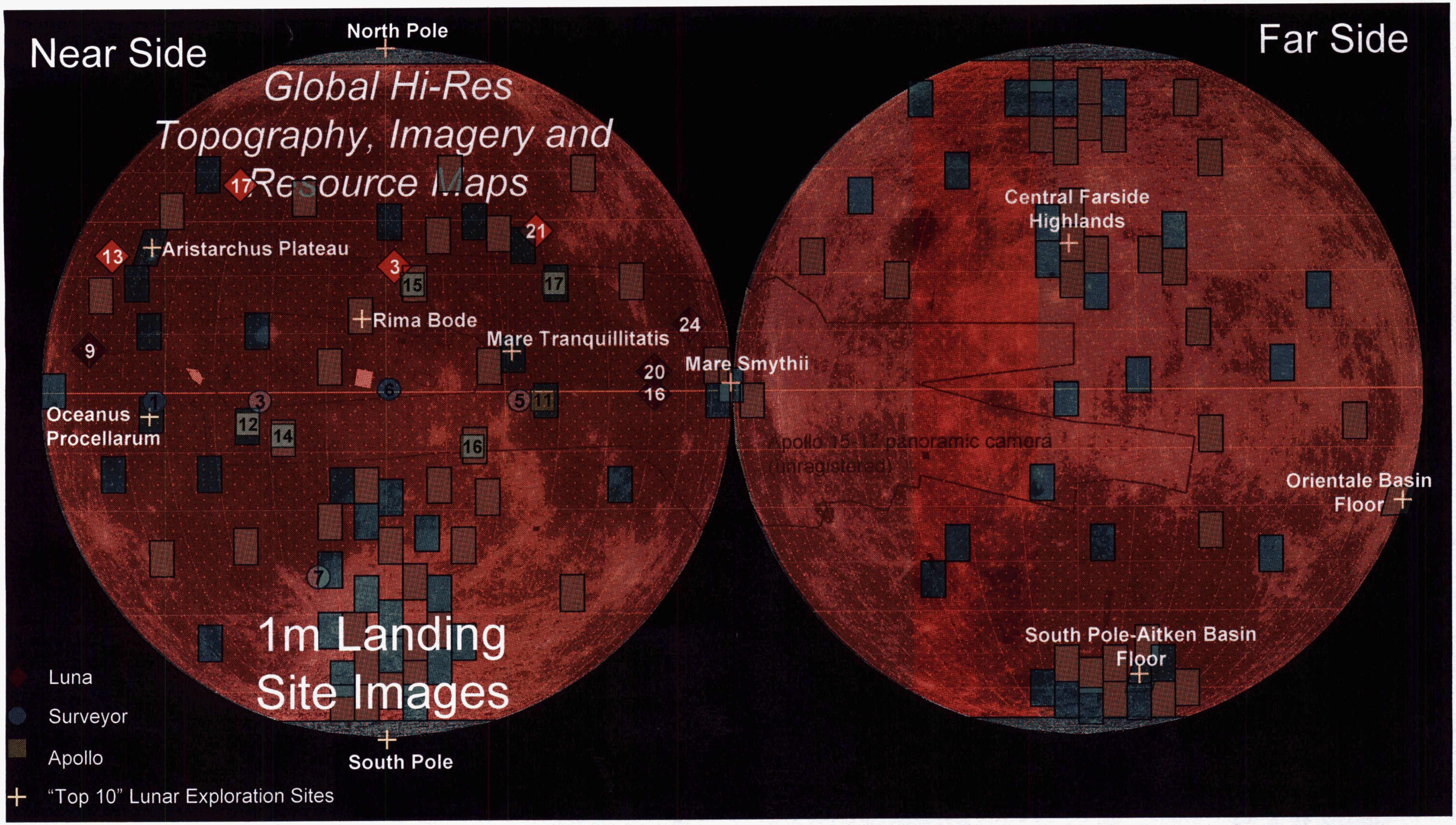
LRO is Fundamental to Exploration and Supports Science Goals

- **LRO will supply the comprehensive atlas of the moon and its resources necessary to enable human return to the moon.**

- LRO builds and expands upon predecessor and planned Lunar missions filling in gaps and significantly improving accuracy.

- In addition, LRO addresses key priorities of 2003 National Academy of Sciences Decadal Survey.

LRO Enables Global Lunar Surface Access

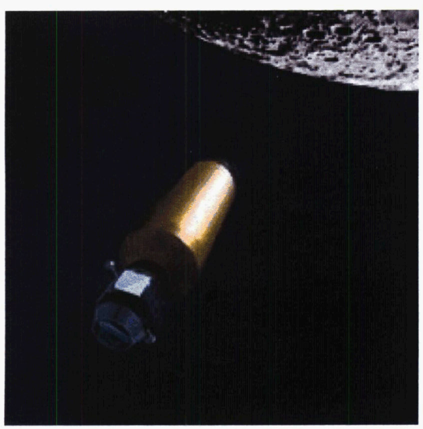


Current Apollo heritage image set covers only 4 of 10 ESAS sites.

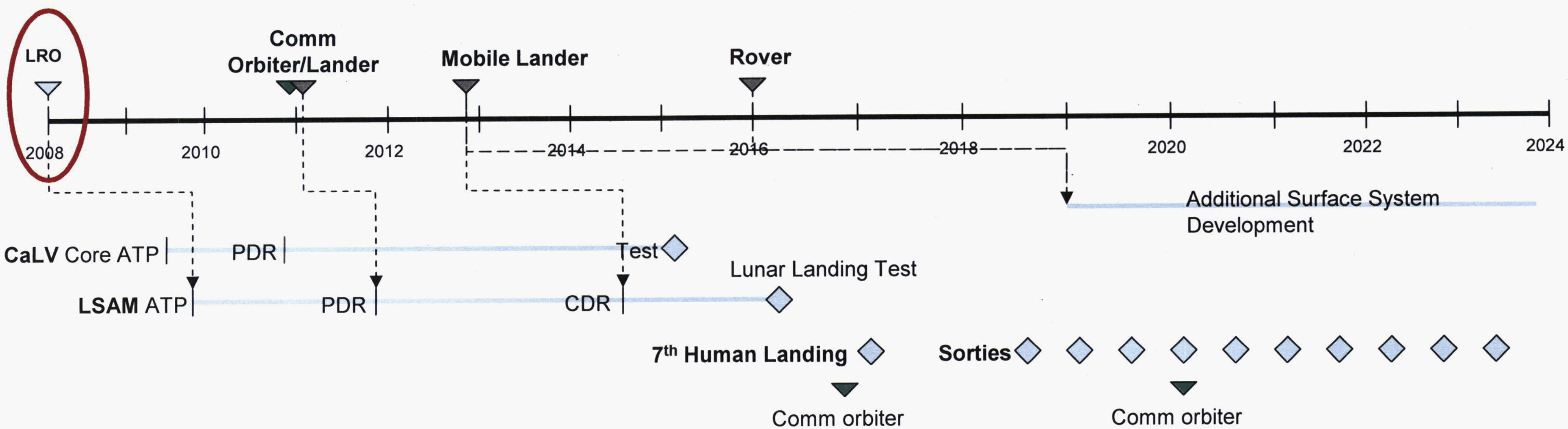
After ESAS and Apollo sites, hundreds of other high priority surface sites will be acquired.

LCROSS Provides Unique Opportunity

- **The LCROSS uses the spent Earth Departure Upper Stage (EDUS) of the launch vehicle as a kinetic impactor and a sheparding spacecraft for control and science observation**
- **The sheparding spacecraft will:**
  - Target the kinetic impactor to a permanently shadowed region of a lunar pole
  - Observe the impact
  - Fly through the ejecta plume
  - Measure the concentration of water ice in the ejecta plume
  - Measure water vapor in the ejecta plume
  - Measure the extended OH exosphere
  - Characterize the lunar regolith within the ejecta plume
  - Become a second impactor, targeting an area near the first impactor



LRAS Architecture - LRO left in place



- **There are compelling reasons to conduct robotic precursor missions**
- **At first order, it appears the existing budget can accommodate all high priority near-term requirements**
- **The robotic precursor missions support Constellation milestones**
- **LRAS identified promising opportunities that may increase efficiency and reduce budget demands**

- **LRAS Recommend Baseline Option**
  - LRO could be first orbiter
  - Decisions concerning ISRU and robotic missions starting beyond 2012 depend on results of earlier missions

What does the future hold?

- Continue coordination with:
  - NASA Exploration, Science and Space Ops Mission Directorates and their respective programs
  - Lunar Science Communities
  - International Interests
  - Industry
  - Educational Institutions
- Develop a robust and sustainable robotic lunar exploration architecture
- Baseline an LPR Architecture in late 2006
- Initiate next LPRP mission in mid-2007