National Aeronautics & Space Administration

Lunar Precursor and Robotic Program

Industry Day

Tony Lavoie/Program Manager
Julie Bassler/Deputy Program Manager
Leslie Curtis/Chief Engineer

October 20, 2006

Schedule

8:30 – 9:30	**LPRP Presentation**	**Tony Lavoie**
9:30 – 9:45	**Press Q&A**	**Steve Roy**
9:45 – 10:00	**Break**	**Convene to 1st floor Conference Room**
10:00 – 10:30	**Northrop-Grumman**	
10:30 – 11:00	**Cisco Systems**	
11:00 – 11:30	**Harris Corporation**	
11:30 – 12:00	**Center for Space Power**	
12:00 – 12:45	**Lunch**	
12:45 – 1:15	**General Dynamics**	
1:15 – 1:45	**ATK**	
1:45 – 2:15	**Boeing**	
2:15 – 2:30	**Break**	
2:30 – 3:00	**Draper Labs**	
3:00 – 3:30	**Ball Aerospace**	
3:30 – 4:00	**Teledyne Brown**	
4:00 – 4:30	**Raytheon**	

Primary responsibility of the NASA Lunar Precursor Robotic 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
- Building constituencies in the lunar exploration community
- Defining specific requirements for each precursor mission
- Establishing and overseeing projects to execute mission design, development, integration, test and operation
- Reduce risk for future human missions (Constellation program) through technology validation

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

Robotic missions:

Provide early strategic information for human missions

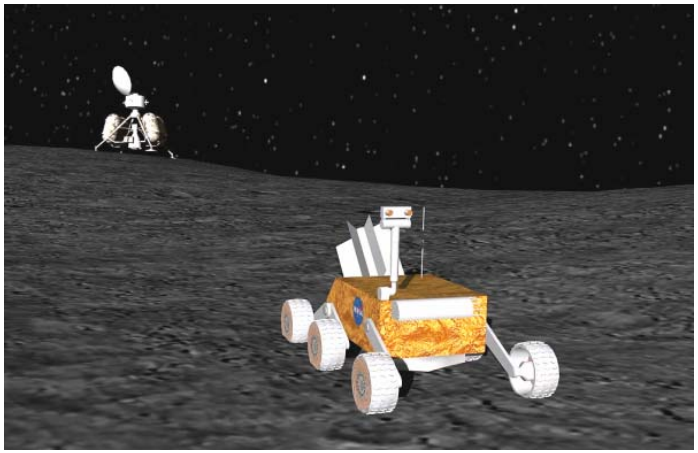
- Key knowledge needed for human safety and mission success
- Infrastructure elements for eventual human use
- Data will be used to plan and execute human exploration of the Moon

Resolve the unknowns of the lunar polar regions

- Knowledge of the environment – temperature, lighting, etc.
- Resources/deposits – composition and physical nature
- Terrain and surface properties - dust characterization
- Emplace support infrastructure – navigation/communication, beacons, teleoperated robots

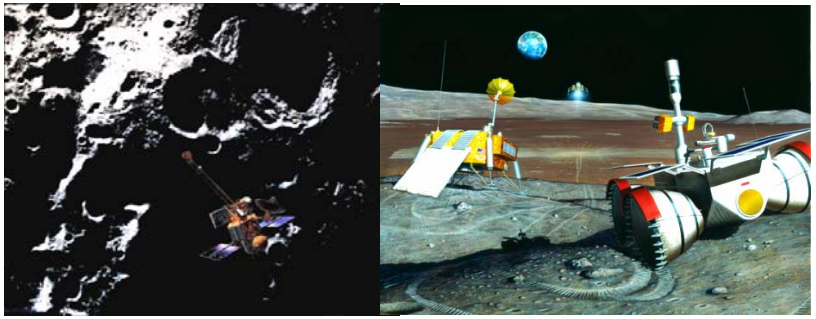
Make exploration more capable and sustainable

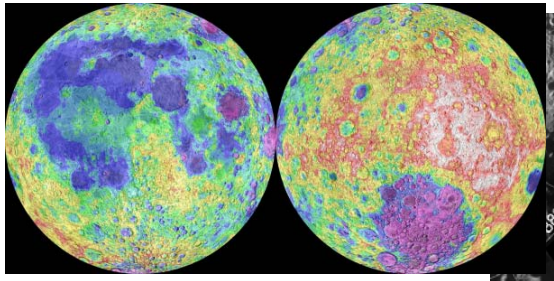
- Emplace surface systems
- Demonstrate new technologies that will enable settlement (ie, ISRU)
- Operational experience in lunar environment
- Create new opportunities for scientific investigation

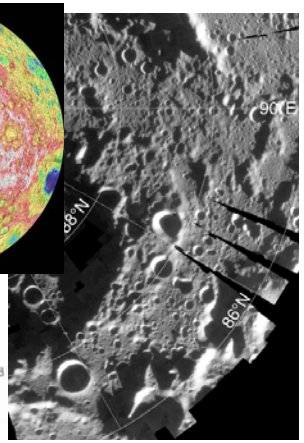


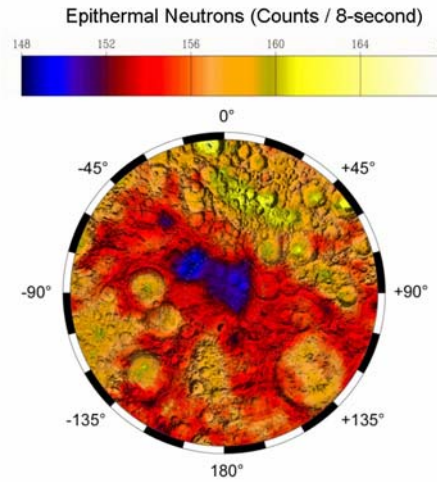
Objectives for lunar robotic missions:

- Global mapping of the lunar surface
- Identify optimal landing site(s) on the Moon for robotic and human explorers
- Find and characterize resources that make exploration affordable and sustainable
  - Locate and characterize lunar volatiles
  - Characterize sunlight and surface environment of poles
- Field test new equipment, technologies and approaches (e.g., dust and radiation mitigation)
- Support demonstration, validation, and establishment of heritage of systems for use on human missions
- Determine how life will adapt to space environments
- Emplace infrastructure to support human exploration
- Gain operational experience in lunar environments
- Provide opportunities for industry, educational and international partners









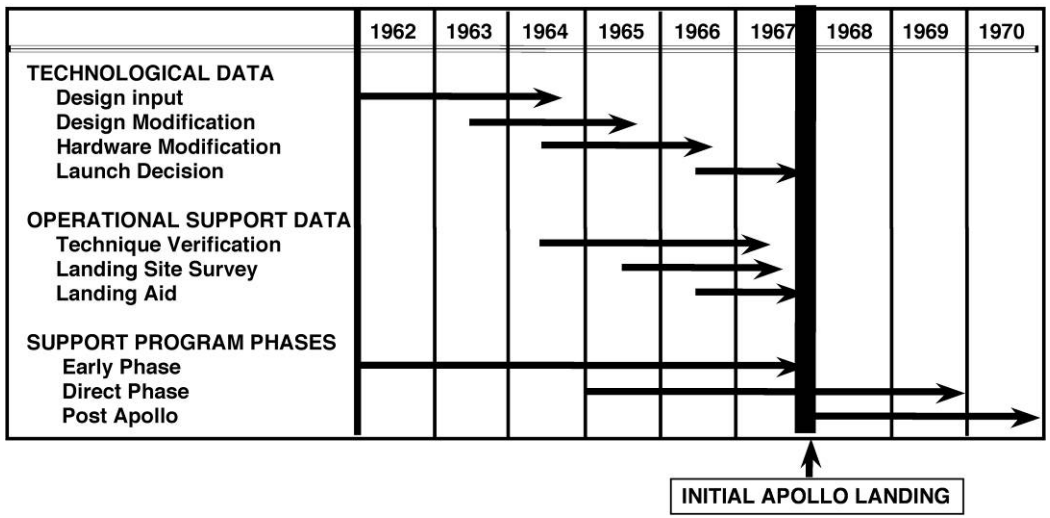
Apollo Robotic Precursors

Apollo had three (Ranger, Lunar Orbiter and Surveyor) robotic exploration programs with 21 precursor missions from 1961-68

1. Ranger hard landers took the first close-up photos of the lunar surface
2. Lunar Orbiters provided medium & high resolution imagery (1-2 m resolution), acquired to support selection of Apollo and Surveyor landing sites
3. Surveyor soft landers made surface environmental measurements including physical characteristics and chemical composition

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



Lunar Precursor and Robotic Program
LPRP in context of NASA's Exploration Architecture

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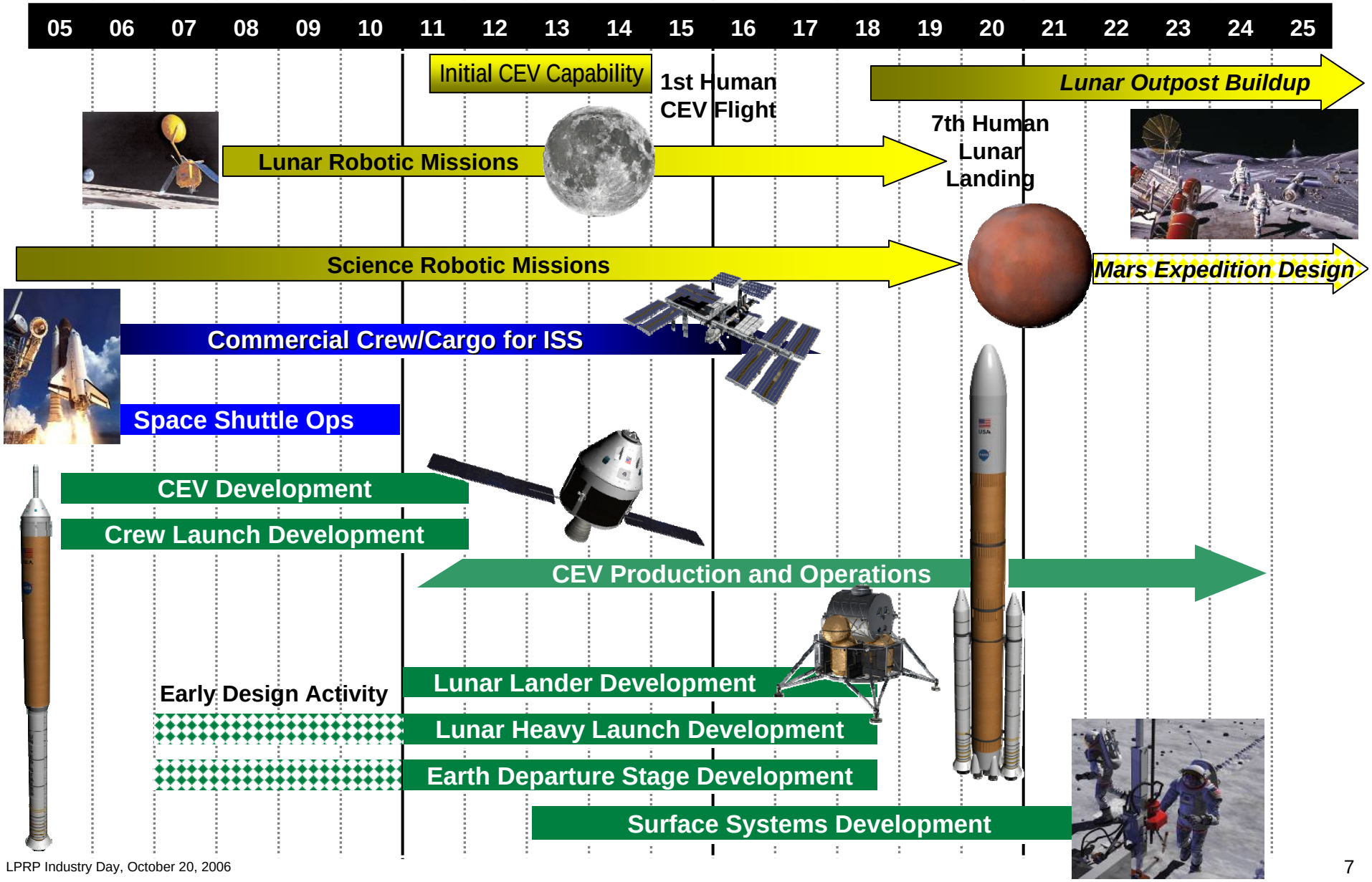
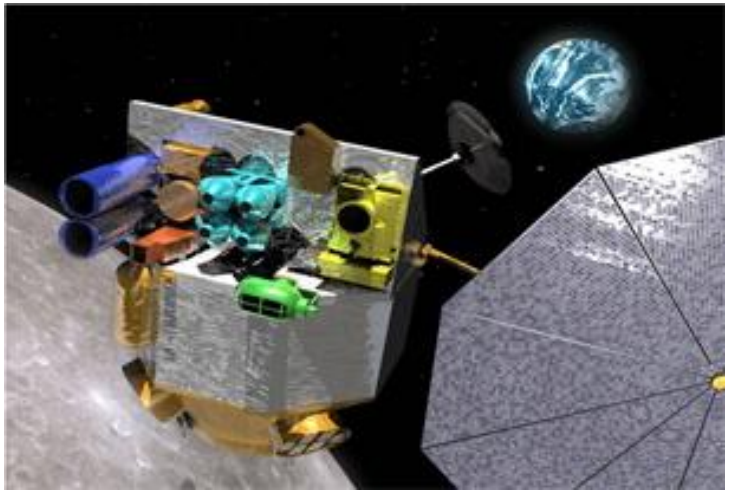


- Lunar Reconnaissance Orbiter and LCROSS
- Lander Sunlight Mission
- Small Satellite Mission
- Lander Crater Mission with Rover



Lunar Reconnaissance Orbiter (LRO)

Lunar mapping, topography, radiation characterization, and volatile identification

50 km circular polar orbit

Critical Design Review: October 2006

Launch: Late October 2008

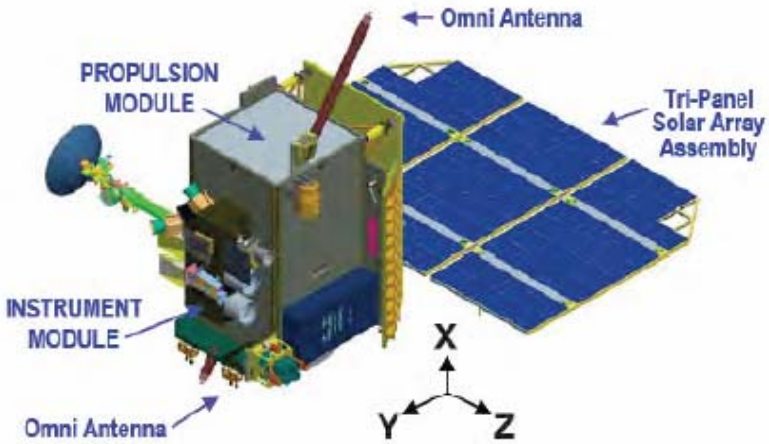
Lunar CRater Observation and Sensing Satellite (LCROSS)

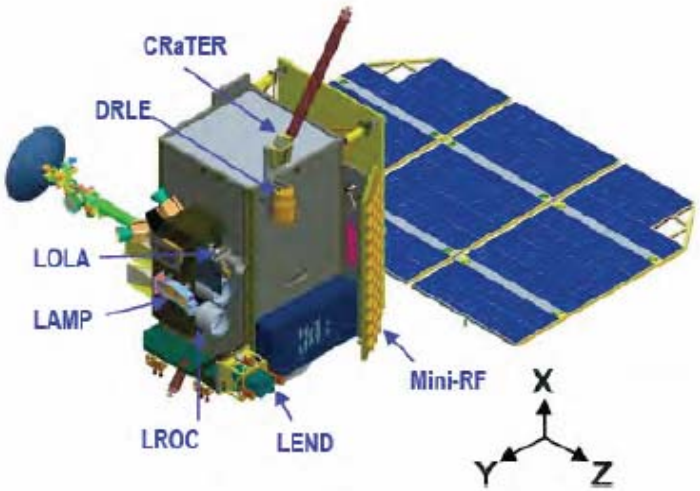
Investigate the presence of water at one of the lunar poles via a kinetic impactor and shepherding spacecraft

Preliminary Design Review: August 2006

Launch: Late October 2008 (co-manifested with LRO)

LRO Orbiter Overview - Configuration





LRO Orbiter Characteristics		
Mass (CBE)	1706 kg	Dry: 809 kg
		Fuel: 897 kg
Orbit Average Bus Power	681 W (Beta 0, S&Ka xmit)	
Measurement Data Volume, Max Downlink rate	572 Gb/day, 100Mb/sec	
Pointing Accuracy, Knowledge	60, 30 arc-sec	

LRO Comparison to Previous Missions

Mission	Key Exploration Capabilities	Resolution	Coverage Duration
Clementine	High resolution and multispectral imaging Topography LWIR	25 m/pixel and 150 m, multispectral 60 km spatial, 100 m radial 200-400 m/pixel (>200K)	Polar coverage 2-month duration
Lunar Prospector	*No imager on-board* Neutron Detector GRS	~ 30 km ~ 60 km	Polar coverage 18-month duration
LRO	High resolution and multispectral imaging Topography Neutron detector Thermal mapping	0.5 m and 100 m, multispectral 1 km spatial, 1 m radial 10 km 350 m (>25K)	Polar coverage 1-yr duration

Lunar Precursor and Robotic Program
LRO Comparison to Other Current Lunar Missions

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Lunar orbital missions 1994-2008
– Data and instruments

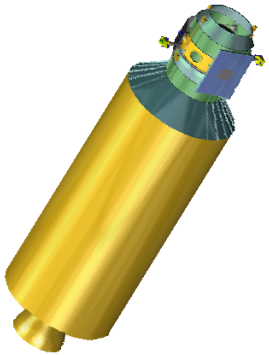
	Clementine	Lunar Prospector	SMART-1	Chang'E-1	Chandrayaan-1	SELENE	Lunar Reconnaissance Orbiter
Camera (VIS monochrome)	X		X	X (stereo)	X (stereo)	X (stereo)	X
Typical resolution (low/high, m)	250/60	-	200	?	5	10	100/0.5
UV imaging	X					X	X
IR imaging	X		X	X	X	X	
Thermal (broadband) IR	X						X
Multi-band UV-VIS-IR imaging	X		X		X	X	X
Gamma Ray Spectrometer		X		X	X	X	
Neutron Spectrometer		X					X
Alpha Particle Spectrometer		X				X	
X-ray Spectrometer			X	X	X	X	
Infrared Spectrometer			X		X	X	
Radiometer				X			X
Synthetic Aperture Radar					X		X
Radar Sounder				X		X	
Bistatic radar	X				X		X
Laser Ranging/Altimeter	X			X	X	X	X
Magnetometer		X				X	
Electron Reflectometer		X					
High-energy Detector				X		X	
Solar Wind Detector				X	X		
Solar X-ray monitor					X		
Lunar Radiation Environment							X
Plasma Analyzer						X	
Plasma Imager (Earth's plasmasphere)						X	
Radio Science (lunar ionosphere)						X	
Gravity	X	X	X	X	X	X (far side)	X

LCROSS Secondary Payload

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 shepherding spacecraft will:

- Target the kinetic impactor to a permanently shadowed region of a lunar pole
- Observe the impact and 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



- Lunar Reconnaissance Orbiter and LCROSS

Note: The concepts for Small Satellite and Lander are only Notional. No decision on Payloads has been made, and these have been notionally defined in the following charts only to aid in maturing further concept development.

- Lander Sunlight Mission
- Small Satellite Mission
- Lander Crater Mission with Rover

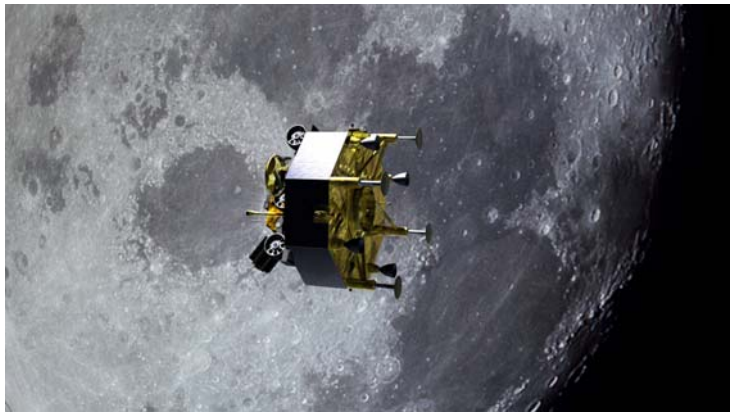
Lander Sunlight Mission (NOTIONAL)

Overview

Develop common lander to land in sunlight near lunar pole to characterize environment and deposits

Lander becomes standard design for delivery of future payloads

Sunlight mission answers first-order questions about poles and provides ground truth for orbital sensing



Concept of Operations - Notional

Precision landing & hazard avoidance

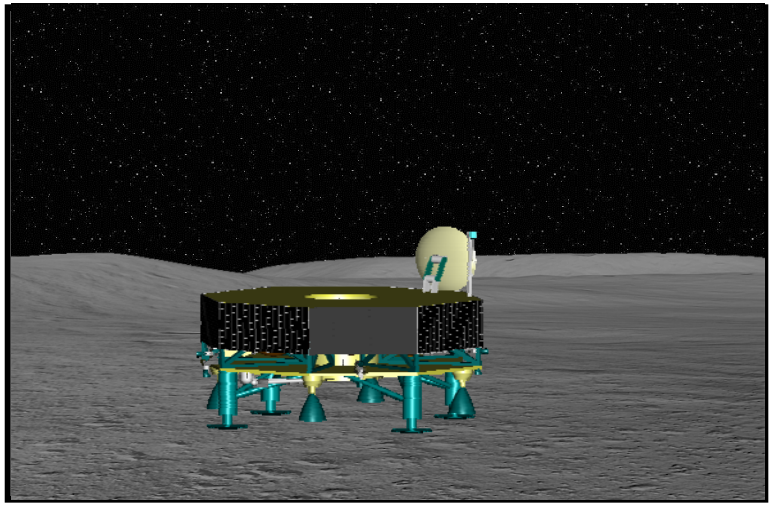
Characterize sun illumination over a seasonal cycle

Direct measurement of neutron flux, soil hydrogen concentration in sunlit area for correlation with orbital mapping

Biological radiation response characterization

Characterize lunar dust and charging environment

Possible micro-rover for near-field investigation (if funded separately)



Lunar Precursor and Robotic Program
Element Summary – Common Lander (NOTIONAL)

Overview

Common Lander designed to support all robotic missions with minimal modification

Mission specific "payload" capability of approximately TBD kg (driven by need to deliver rover)

Propulsion is combination of a solid rocket motor and a throttleable hypergolic bi-prop system

Power by solar arrays

Land within 100 m 3σ of a predetermined surface feature, avoiding hazards

Concept of Operations - Notional

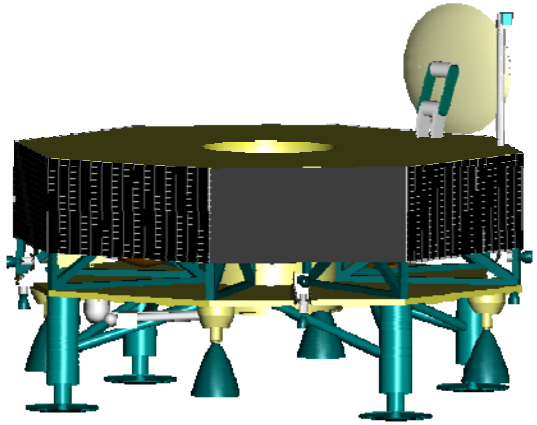
TLI orbit by an EELV; SRM breaking burn for direct insertion and landing

Liquid propulsion system controlling terminal descent and landing

Precision navigation and hazard avoidance to progressively demonstrate the ALHAT sensor compliment.

Two primary mission scenarios:

- Land at an illuminated location and perform fixed measurements over an extended period of time. Small mobility elements may be accommodated.
- Land and deploy a rover in a dark or illuminated area.



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Overview

Reference concept: Communications Relay Satellite Technology validation

Mission is designed to fly microsat to validate laser communications technologies, as well as packet-switched RF relay capability

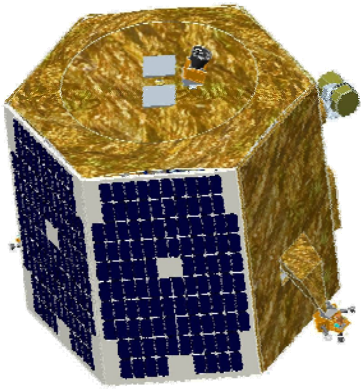
Concept of Operations - Notional

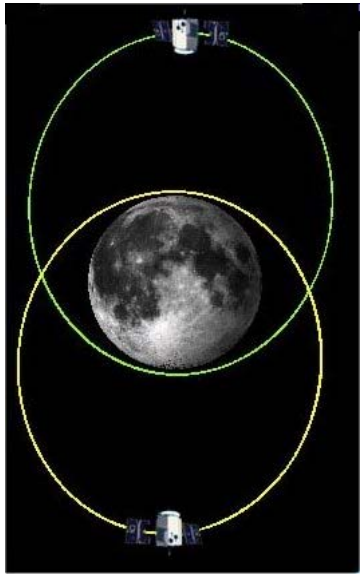
Lunar orbiter microsat bus

- 3-axis Stabilized Platform
- 100-200 kg-class bus; 30-40 kg payload capacity
- Body Mounted solar arrays, ~ 100 W
- Routine Spacecraft Comm & Tracking Via Low Rate S-band

SmallSat comm relay payload and mission profile

- 2 Way RF Support For Local Users
- Optical Transmit (100 mbps) Trunk Line To Single Terrestrial Ground Terminal
- Comm Supported With Internal IP Router
- 5 Hour Dwell Over Region In 8 Hour Orbit





Small Satellite Mission Options (NOTIONAL)

Science and Resource Evaluation

- Bistatic Radar Imaging Experiment (using two satellites, formation flying)
- Neutron spectroscopy: hydrogen mapping at high resolution (< 5 km/pixel)
- Second generation remote sensing applications (e.g., low frequency radar sounding for deep structure, surface compositional mapping)
- Secondary ion mass spectroscopy; provide high resolution chemical mapping of the surface
- Lofted dust characterization
- Lunar exosphere composition and evolution
- VLF radio astronomy demonstration

Infrastructure Emplacement

- Low cost advanced communications demonstrations
- Lunar navigation system (GPS elements)

Technology Demonstration Missions

- X-NAV (GPS using natural X-ray pulsars)
- Laser Comm
- Space Based Routers

- Lunar Reconnaissance Orbiter and LCROSS
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Lander Crater Mission with Rover (NOTIONAL)

Overview

Reference concept: fuel cell-powered rover, ranging > 25 km and obtaining > 22 subsurface measurements (each 1,000 m apart) to map and analyze polar volatiles

Navigation by integration of coherent ranging with an overhead relay satellite, IMU, and perhaps terrain relative navigation

Navigation by flash lamps and MER style hazard avoidance or 3-D scanning LIDAR

RTG-powered options are lighter and offer extended life, but are more costly

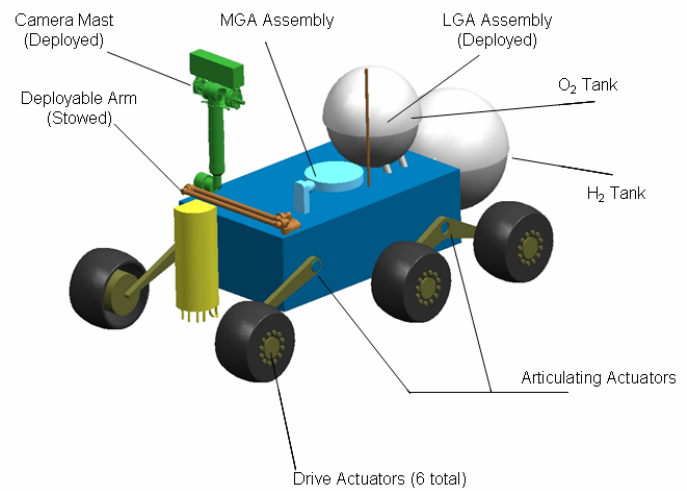
Concept of Operations - Notional

Rover delivered directly to the crater floor by the lander (which expires shortly after rover egress)

Rover traverses to selected sites obtaining ground penetrating radar and neutron spectrometer profiles along the way

Sampling at predetermined site, rover drills and samples material approximately every 50 cm to a maximum depth of 2 m

On-board analysis of volatile content and composition



Data from LPRP Missions

Global maps of morphology, topography, gravity

Polar deposits and physical properties from orbital sensing

Surface *in situ* analyses of the chemical and physical states of polar deposits

Survey and assay of potential resources and the future outpost site

Demonstration experiments of ISRU processing and materials handling

Engineering data from Risk reduction test objectives for the later human missions

Conclusions

LPRP is configured to support human lunar return by providing key strategic information, creating new capabilities, and retiring risk for future missions

Program is well defined conceptually, but details of mission payloads, modes of operation, and specific experiments and capabilities are still being worked

Initial missions are Lunar Reconnaissance Orbiter and LCROSS; both spacecraft will produce abundant, high-quality data requiring extensive scientific analysis to interpret and use for future exploration

Subsequent missions will land, characterize potential outpost sites, reduce risk to the human mission, and in the process of doing those things it will conduct scientific exploration

There is a need to develop a plan to insure that the data from the LPRP missions is properly reduced and analyzed to extract the maximum strategic information

The global community can assist humanity's return to the Moon by jointly participating in this exciting endeavor

What does the future hold?

LPRP will continue coordination and formalize collaboration with:

- Exploration, Science and Space Ops Mission Directorates and their respective programs
- Science community
- International Partners and their flight programs
- Industry and the private sector
- Educational institutions

LPRP is part of a robust and sustainable lunar exploration architecture

- Critical, yet modest investment for future Constellation efforts