Lunar Precursor Robotic Program: A Robotic Focus To The Vision

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Abstract. In April 2006, NASA, with help from the commercial and international communities, began developing a global Lunar Exploration Strategy. These activities resulted in themes that expanded on why we should return to the Moon and objectives that identify what we should do when we get there. NASA used these results to develop a Lunar Architecture designed to achieve the subset of the global Lunar Exploration Strategy objectives that fit within NASA's scope. A component of this architecture is the Lunar Precursor Robotic Program. This Program, anticipated to consist of both lunar orbiters and landers, is intended to meet many of NASA's lunar exploration objectives.

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NASA Lunar Exploration Activities: The Themes

National Aeronautics
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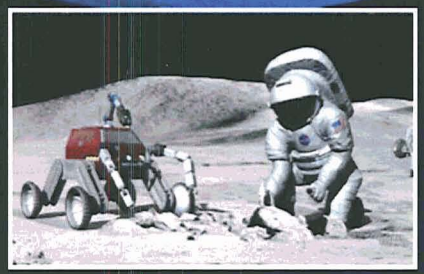
Global Exploration Strategy → **Themes & Objectives**

Human Civilization

Extend human presence to the Moon to enable eventual settlement

Global Partnerships

Provide a challenging, shared and peaceful activity that unites nations in pursuit of common objectives

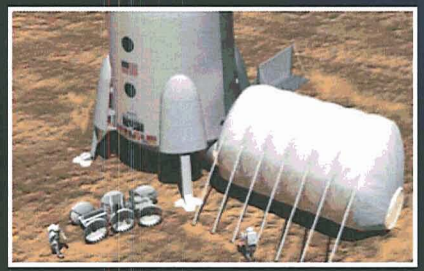


Scientific Knowledge

Pursue scientific activities that address fundamental questions about the history of Earth, the solar system and the universe – and about our place in them

Economic Expansion

Expand Earth's economic sphere and conduct lunar activities with benefits to life on the home planet



Exploration Preparation

Test technologies, systems, flight operations and exploration techniques to reduce the risks and increase the productivity of future missions to Mars and beyond

Public Engagement

Use a vibrant space exploration program to engage the public, encourage students and help develop the high-tech workforce that will be required to address the challenges of tomorrow

Key Architecture Decision: Sortie vs. Outpost

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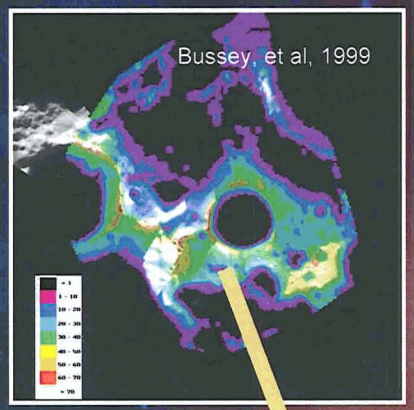
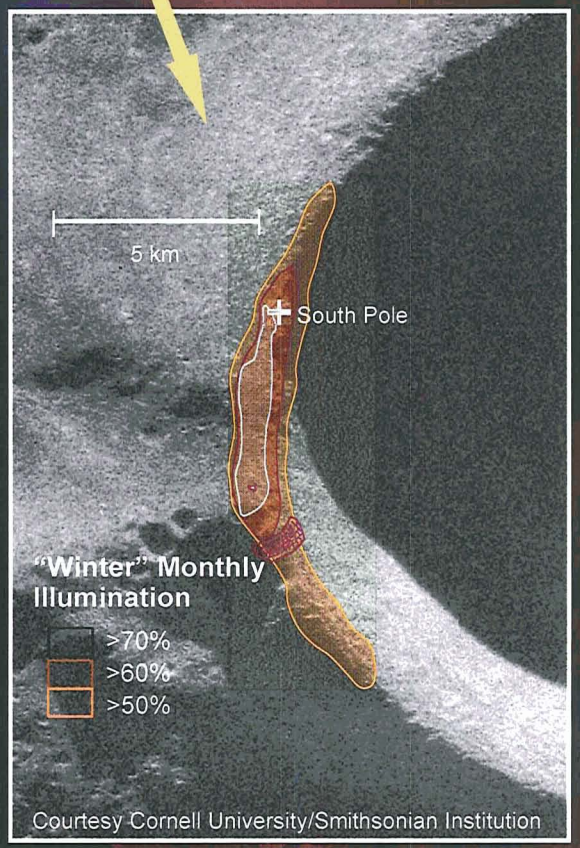
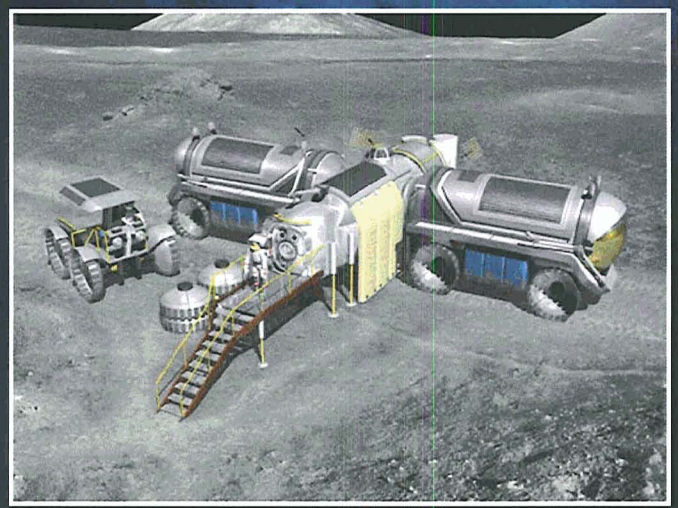
- What is the fundamental lunar approach?
- LAT concluded outpost first is best approach
- Top 2 Themes – "Exploration Preparation" and "Human Civilization" drive to outpost
- Enables global partnerships
- Allows development and maturation of ISRU
- Results in quickest path toward other destinations
- Many science objectives can be satisfied at an outpost







Outpost Site Location: A Lunar Pole

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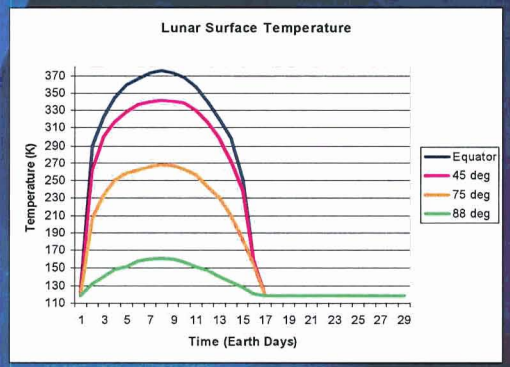
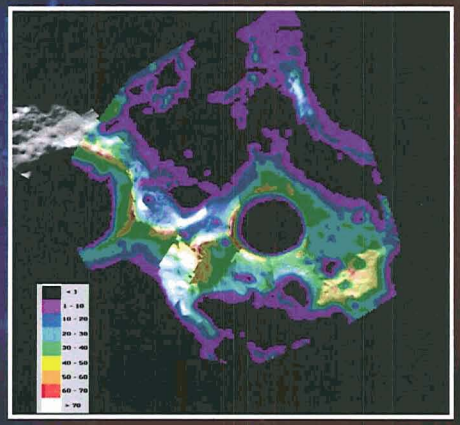
- **Safe**
  - Thermally Moderate
- **Cost Effective**
  - High percentage of sunlight
  - Allows use of solar power
  - Least Delta V required
- **Resources**
  - Enhanced hydrogen (possibly water)
  - Potentially other volatiles
  - Oxygen
- **Flexibility**
  - Allows incremental buildup using solar power
  - Enhanced surface daylight ops
  - One communication asset (with backup)
  - More opportunities to launch
- **Exciting**
  - Not as well known as other areas
  - Offer unique, cold, dark craters

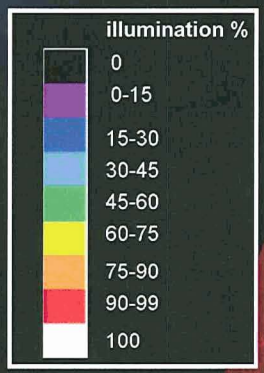


Calculated Values

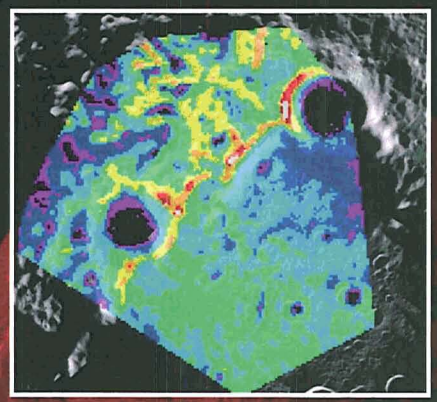
South Pole



Data obtained during southern winter (maximum darkness)



North Pole



Data obtained during northern summer (maximum sunlight)

Global Mapping/Imaging of Lunar Surface: We need much better resolution

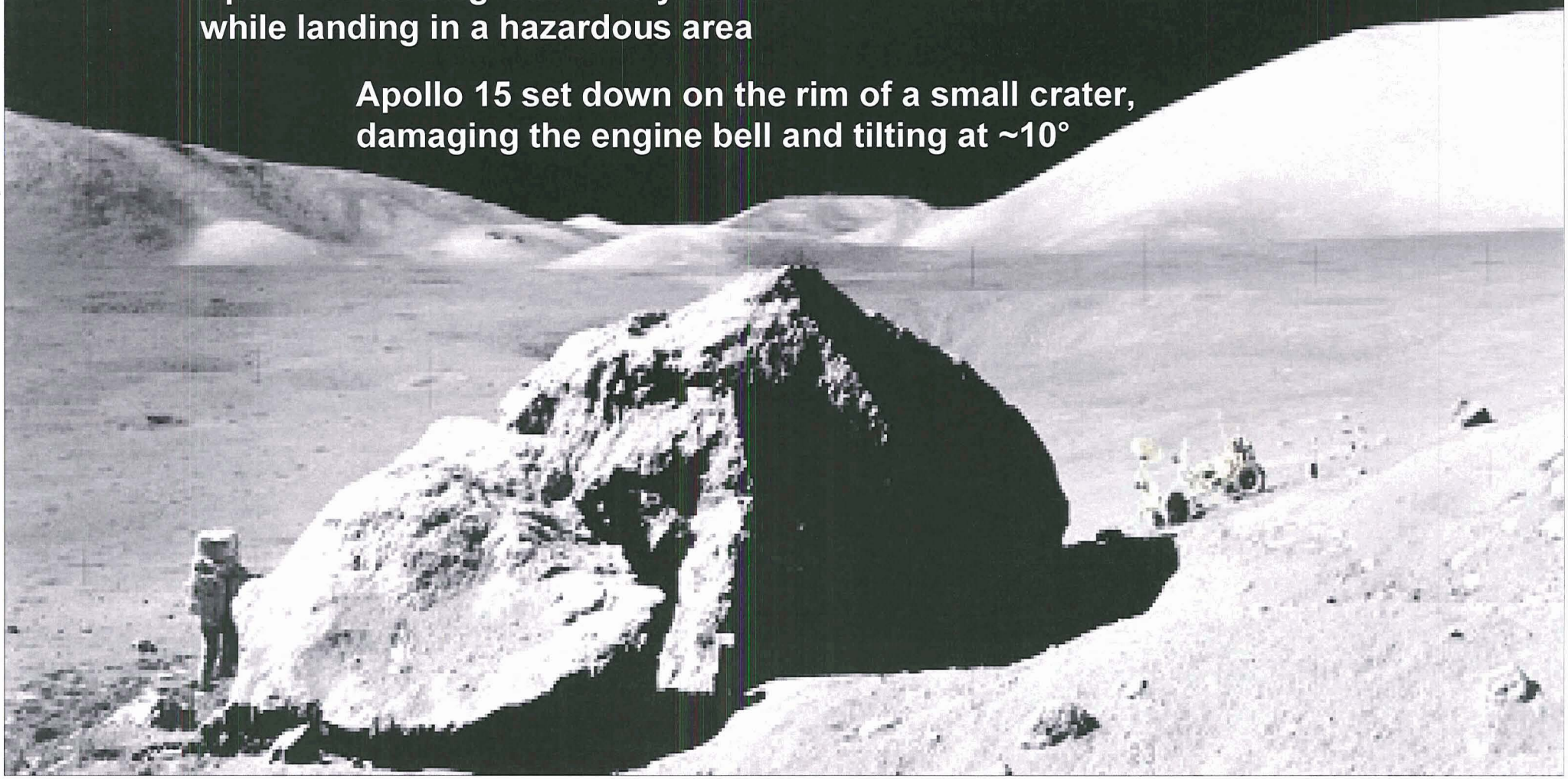
Even though Lunar Orbiter provided 1-2 meter resolution images to support candidate Apollo & Surveyor landing sites

With existing lunar maps/images, (25 meter resolution)

We would not see this rock!

Apollo 11 landing was nearly aborted while landing in a hazardous area

Apollo 15 set down on the rim of a small crater, damaging the engine bell and tilting at ~10°



Lunar Exploration Architecture: Precursor Robotic Program

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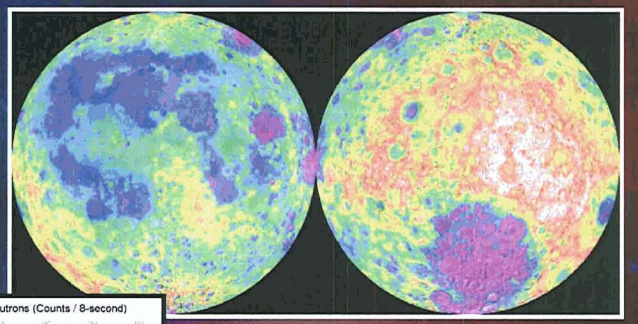
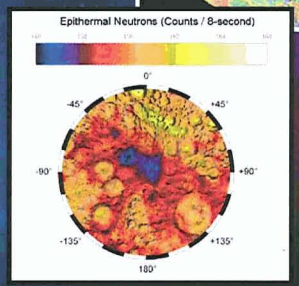
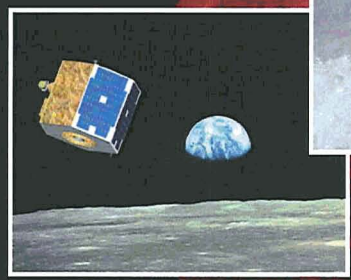
- **Robotic Precursor Missions**
  - Global lunar surface mapping and landing site reconnaissance
  - Obtain key lunar environment data
  - Find and characterize resources that make exploration affordable and sustainable, including potential ISRU demonstrations
  - Biological response to lunar environments
  - Scientific exploration
  - Early and sustained public engagement
  - Field test and verify new equipment, technologies and approaches prior to crewed missions
  - Human mission risk reduction
- **Implementation**
  - LRO/LCROSS (Launch in 2008)
  - Notional Medium Lander at potential Outpost site (Launch in 2011 or 2012)
  - Notional Small Satellite for communications demo (Launch in 2011 or 2012)







Lunar Precursor Robotic Program: The First Missions

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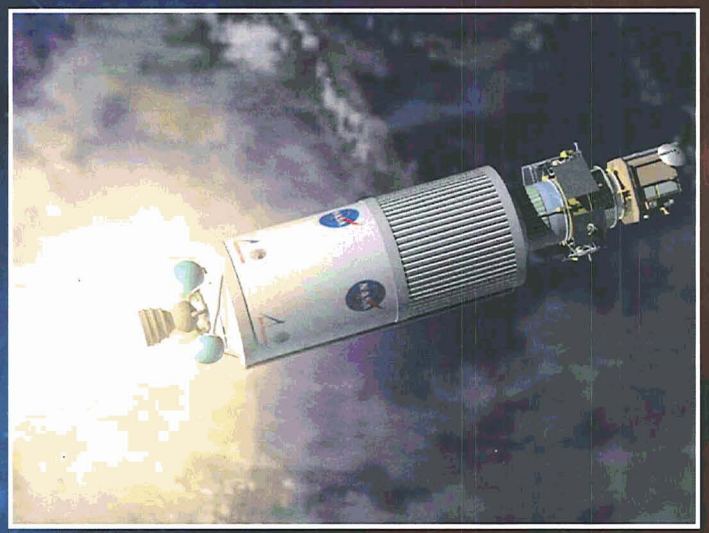
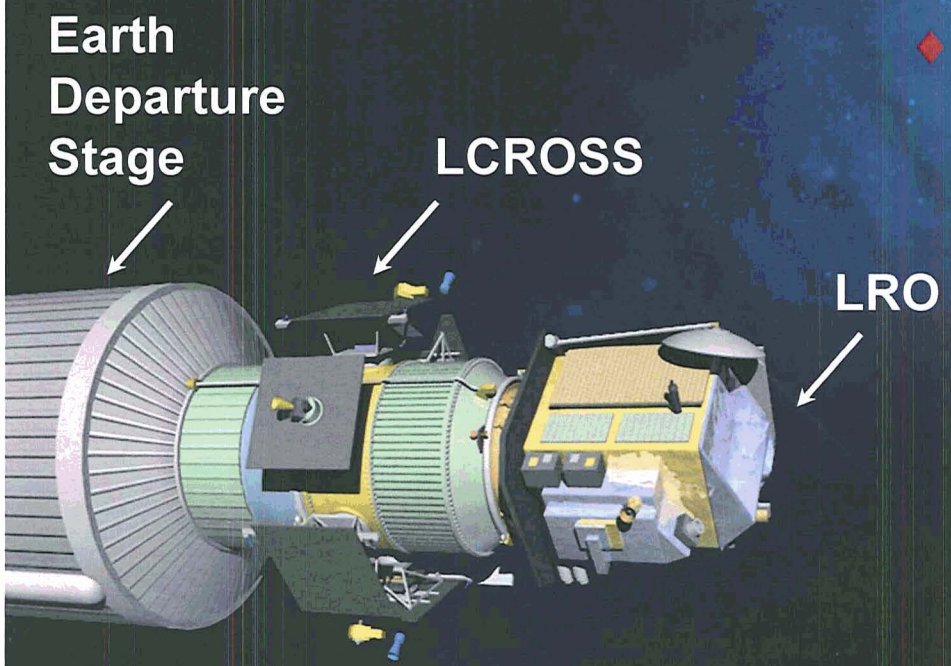
- **Lunar Reconnaissance Orbiter (LRO)**
  - Lunar mapping, topography, radiation characterization, and volatile identification
  - 50 km circular polar orbit
  - Critical Design Review: October 2006 (Completed)
  - Launch: October 2008



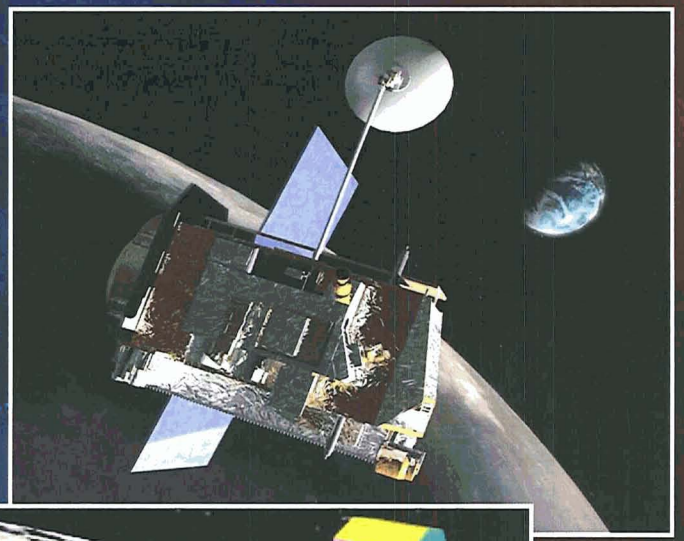


- **Lunar CRater Observation and Sensing Satellite (LCROSS)**
  - Investigate the presence of water at one of the lunar poles via a kinetic impactor and shepherding spacecraft
  - Preliminary Design Review: August 2006 (Completed)
  - Critical Design Review: February 2007
  - Launch: October 2008 (co-manifested with LRO)

LRO Mission Summary

Managed by the Goddard Space Flight Center

National Aeronautics
and Space Administration



- **Description:** One year mission in a 50 km polar lunar orbit, 3-axis stabilized spacecraft
- **Objectives:**
  - Characterize the lunar radiation environment, biological impacts, and potential mitigation
  - Develop a high resolution global, three dimensional geodetic grid of the Moon and provide the topography necessary for selecting future landing sites
  - Detailed assessment of the resources and environments at the Moon's polar regions
  - High spatial resolution assessment of the Moon's surface addressing elemental composition, mineralogy, and regolith characteristics

The LRO Instrument Suite: Supporting Exploration Data Needs

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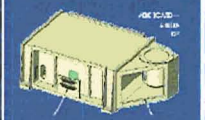
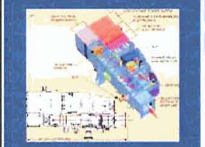
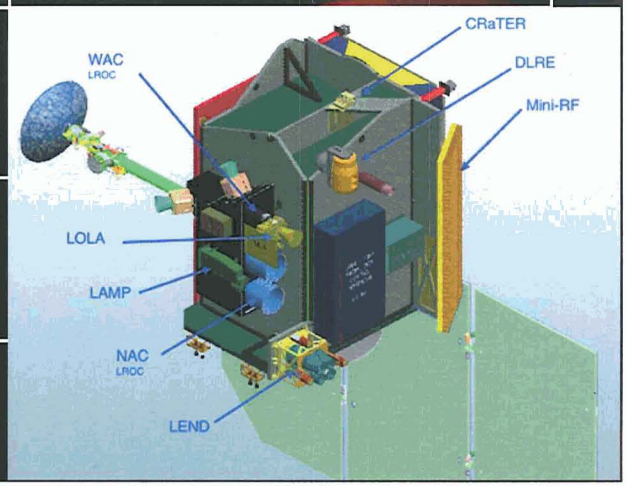
	Instrument	Navigation/ Landing Site Safety	Locate Resources	Life in Space Environment
	CRaTER Cosmic Ray Telescope for the Effects of Radiation			♦ High Energy Radiation ♦ Radiation effects on human tissue
	DLRE Diviner Lunar Radiometer Experiment	♦ Rock abundance	♦ Temperature ♦ Mineralogy	
	LAMP Lyman 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	



LCROSS Mission Summary

Managed by the Ames Research Center

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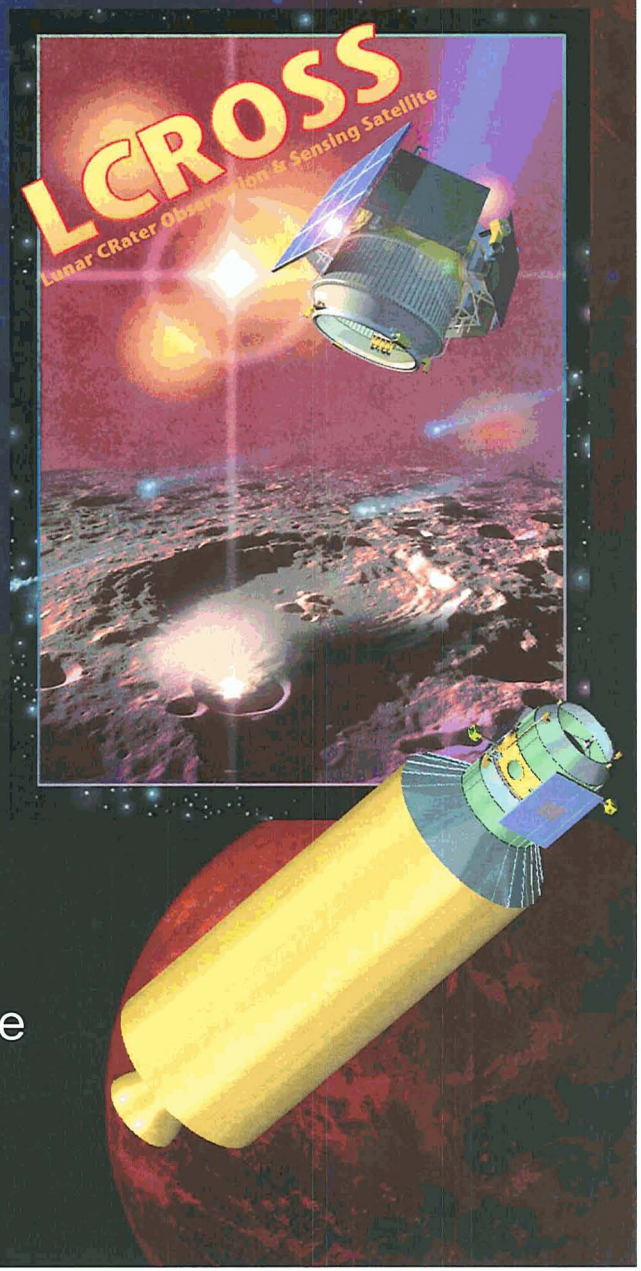
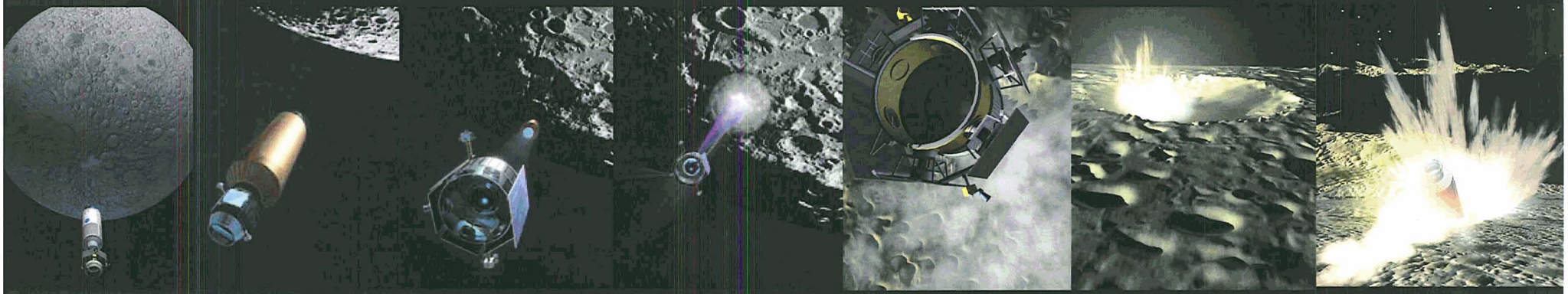
and Space Administration

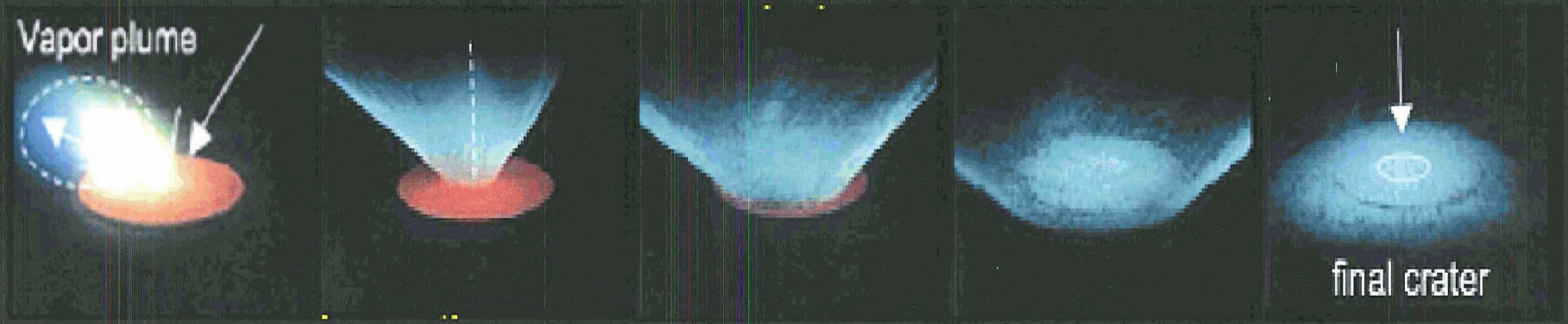
- **Description:** Use spent launch vehicle Earth Departure Upper Stage (EDUS) as a kinetic impactor and a shepherding spacecraft for control and observation

- **Objectives:**
  - 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
  - Shepard becomes a second impactor, targeting an area near the first impactor



Impact!





Flash

Curtain

Crater

The Future?
A Notional Lander Mission

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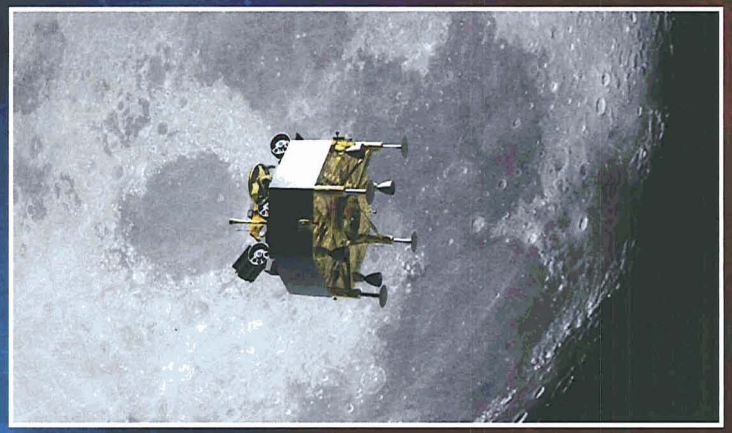
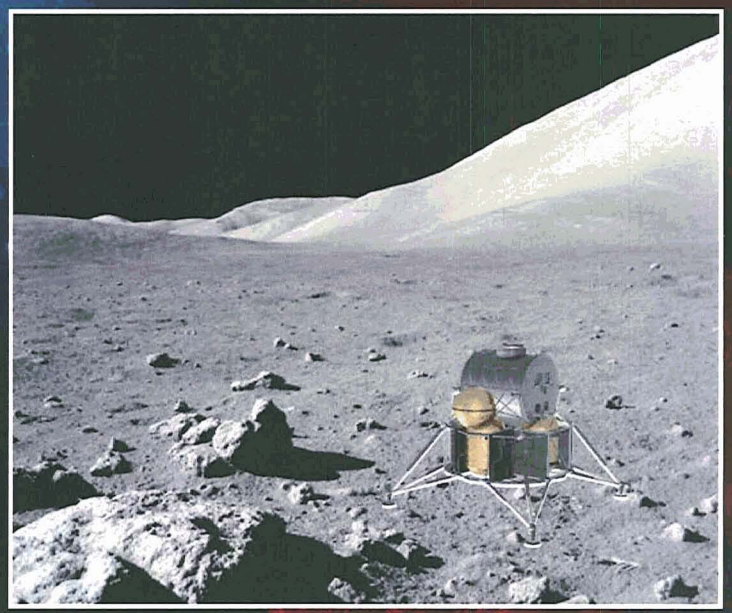
and Space Administration

- **Description:** Medium-class Lander, land in sunlight near lunar pole, answers first-order questions about poles and provides ground truth for orbital sensing

- **Objectives: Notional**
  - Standard design - delivery of future payloads
  - Characterize sun illumination
  - Precision landing & hazard avoidance
  - Biological radiation response
  - Characterize lunar dust and other environments
  - Direct local measurement of neutron flux, soil hydrogen concentration in sunlit area for correlation with orbital mapping
  - Possible delivery of mini/micro-rover for near-field survey





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And Beyond?
A Notional Small Satellite Mission

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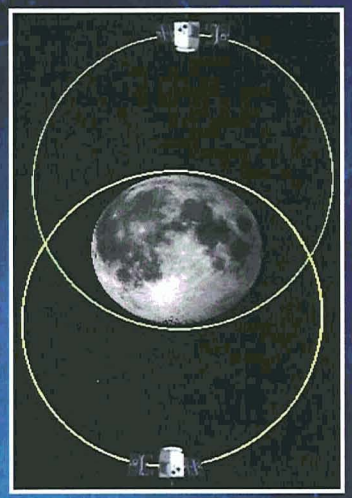

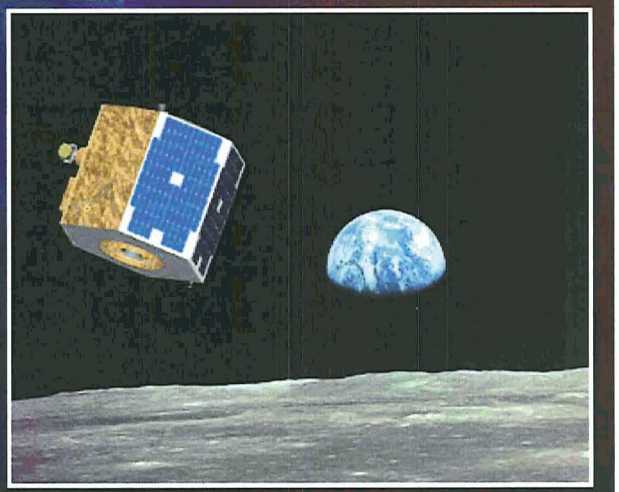

- **Description:** 3-axis Stabilized Platform, 100-200 kg-class bus, 30-40 kg payload capacity, body mounted solar arrays ~ 100 W

- **Potential Objectives:**
  - Communications relay satellite technology
  - Packet-switched RF relay capability
  - 2 Way RF support For Local Users
  - Advanced, low cost communications demonstrations
  - Laser based communication
  - Space based routers
  - Lunar navigation system (GPS), X-NAV (GPS using natural X-ray pulsars)
  - Bi-static radar imaging experiment (two satellites)
  - High resolution neutron spectroscopy (< 5 km/pixel)
  - Second generation remote sensing applications (deep structure, surface composition)
  - High resolution secondary ion mass spectroscopy chemical mapping
  - Lofted dust characterization
  - Lunar exosphere composition and evolution
  - VLF radio astronomy demonstration

(NOTIONAL)

And Then What?
Potential Robotic Field Test and Verification

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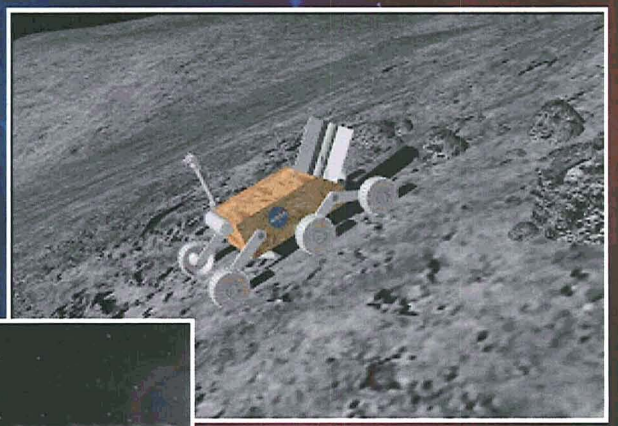
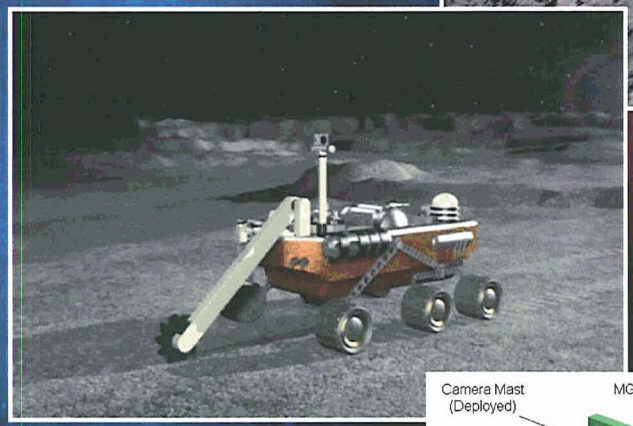
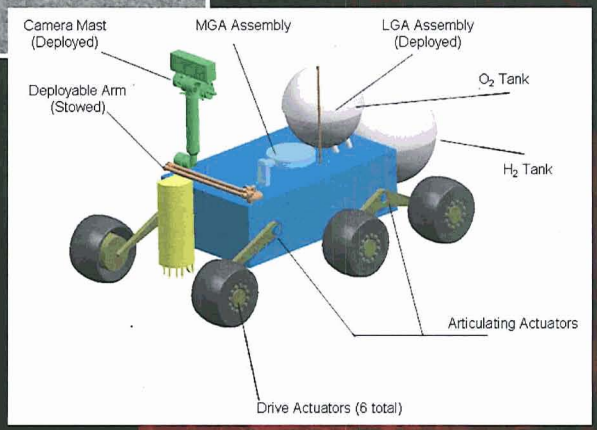
- **In-Situ Resource Utilization (ISRU)**
  - Locate
  - Assessment
  - Excavation
  - Transportation
  - Extraction
  - Processing
  - Storage
  - Waste Disposal
- **Dust Mitigation**
- **Radiation Effects**
- **Cryo-Propellant Capability Demonstrations**
- **Long-Duration, Long Distance Mobile Surface Operations**
- **Robotic Assembly**
- **Robotic Emplacement of Equipment**







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Partners Needed: The Bigger Picture

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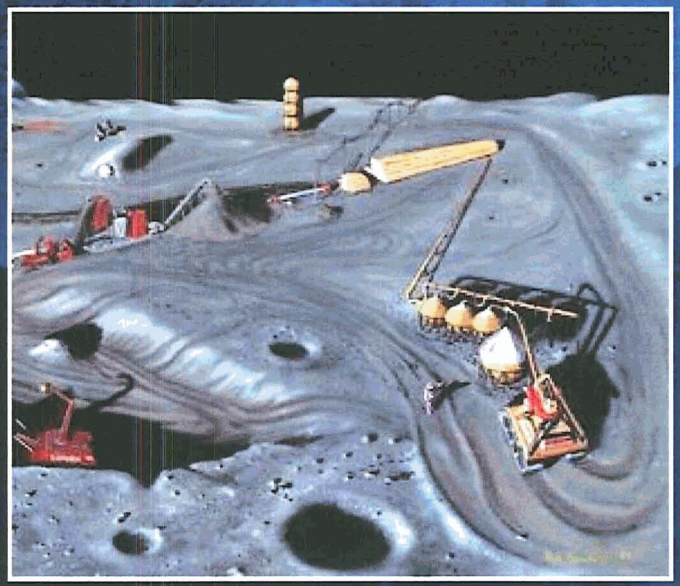
- The themes and objectives were developed by a broad community, and are global in nature



- Fully implementing the themes and objectives requires international and commercial involvement in lunar development
  - Engage international partners
  - Engage the commercial sector
  - Explore new methods of collaboration
- Supporting economic expansion is important
- NASA is trying to take industry's commercial needs into account
- Opportunities for industry to leverage off of NASA's lunar activities
- As we move into further refinement of our architecture, NASA will be looking for partnerships in multiple areas

Conclusions:

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- The Lunar Precursor Robotic Program is a necessary beginning to renewed human lunar exploration
- The first two missions, LRO and LCROSS, are well into development and on schedule for launch in October 2008
- Beyond LRO/LCROSS, Lander and Small Sat Missions have been notionally defined, however mission approval, objectives, payloads, specific experiments and capabilities are still under development
- There is need to insure Key Data and Information is identified and obtained by the LPRP, that it is properly analyzed and interpreted, and that it is provided to stakeholders
- The Global Community should and will contribute to humanity's return to the Moon by jointly participating in this exciting endeavor
- The Vision for Space Exploration paves a path for human return to the Moon, exploration of Mars and beyond… but robots have and will go there first!