SpaceOps 2006
Presentation for Plenary Session 2 "Moon"
Rome, Italy
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Abstract of Conference Presentation

Title: Robotic Lunar Exploration

Abstract:
This presentation describes current Lunar Exploration plans and objectives. It begins with specific statements from the President's vision for U.S. Space Exploration which pertain to robotic lunar missions. An outline of missions' objectives is provided, along with a high-level schedule of events through the year 2025. Focus is then given to the Lunar Robotic and Precursor Program (LPRP) to describe objectives and goals. Recent developments in the Program are explained – specifically, the renaming of the RLEP program to "LPRP" and the movement of the program office to MSFC. A brief summary of the synergy expected between the robotic and crewed missions, with the LSAM descent stage Project is given. The Lunar Reconnaissance Orbiter mission, with its co-manifested Lunar Crater Observation and Sensing Satellite (LCROSS), is then described with an overview of the payloads and mission objectives. Finally, information is given about the expected future of the LPRP program and Exploration and the development of a comprehensive Lunar Exploration Architecture.

Robotic Lunar Exploration
Space Ops 2006 Conference
Rome, Italy
Final

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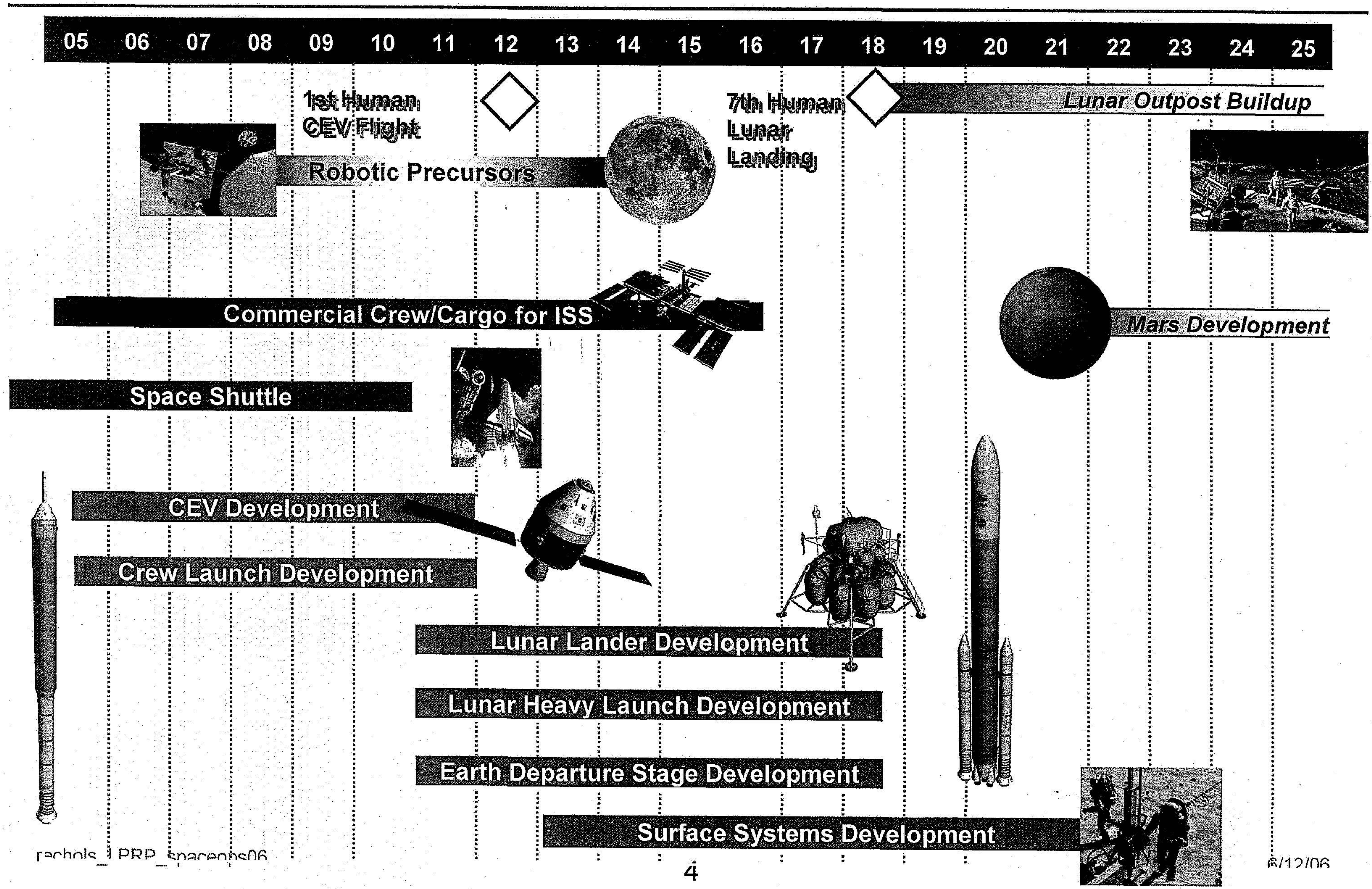
President's Vision for U.S. Space

- **The President's Vision for U.S. Space Exploration was outlined in a speech given on January 14, 2004**
- **Key excerpts on robotics…**
  - "Beginning no later than 2008, we will send a series of robotic missions to the lunar surface to research and prepare for future human exploration."
  - "Robotic missions will serve as trailblazers, the advanced guard to the unknown. Probes, landers and other vehicles of this kind will continue to prove their worth, sending spectacular images and vast amounts of data back to Earth."

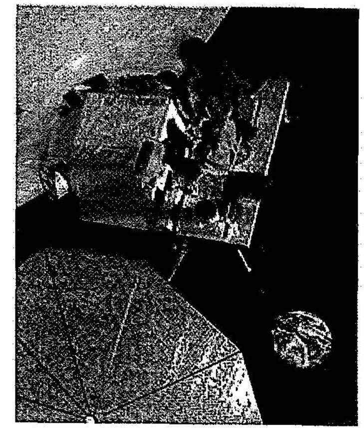
NASA's Exploration Roadmap

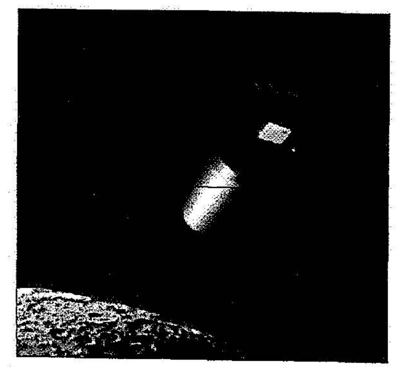


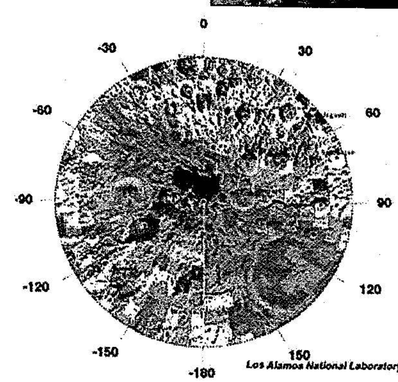
NASA's Robotic Lunar Exploration

Objectives to implement the President's Vision for lunar robotics:

- Global mapping of the lunar surface
- Find optimal landing site(s) on the Moon for robotic and human explorers
- Find and characterize resources that make exploration 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



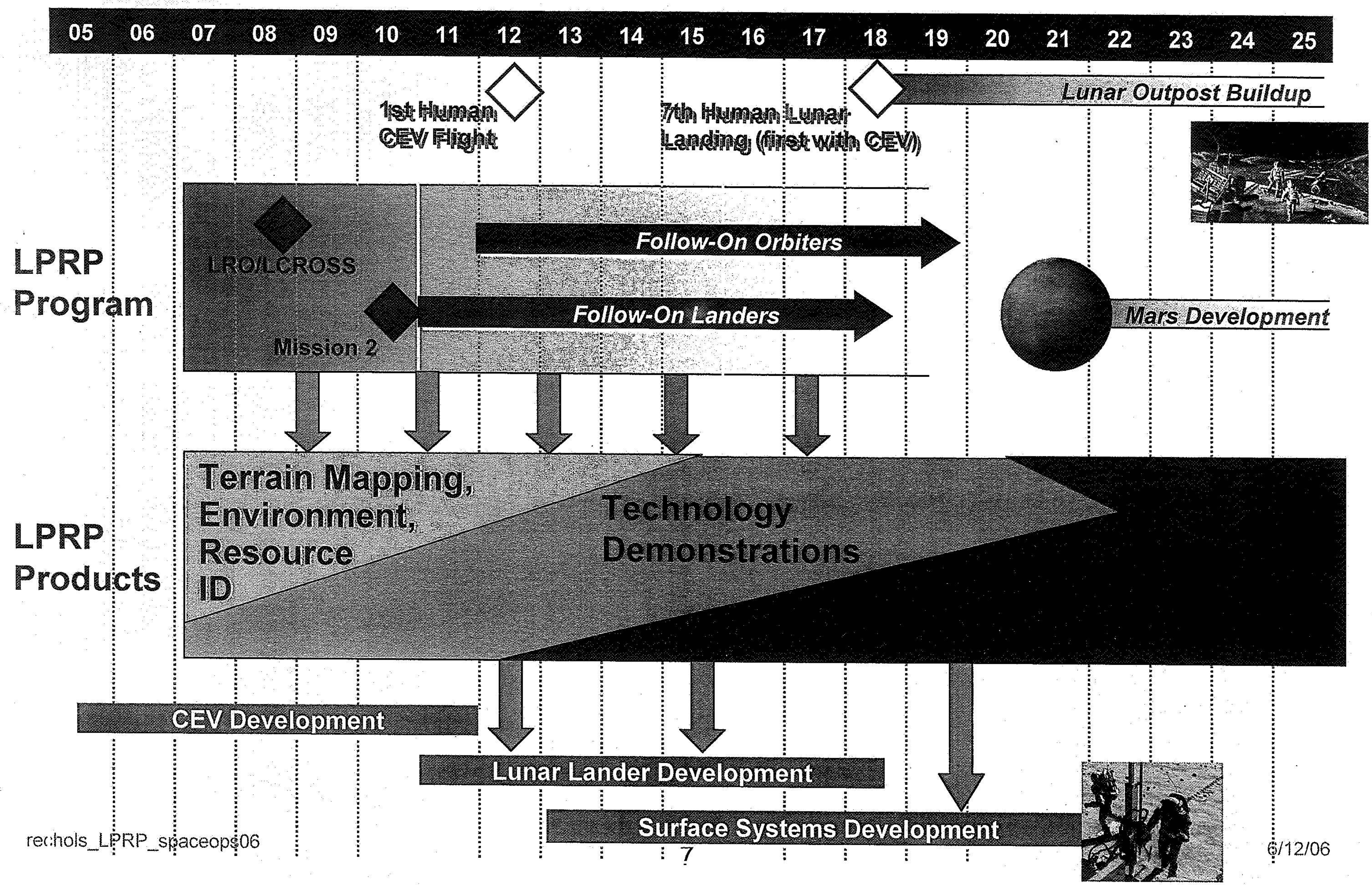




Lunar Precursor and Robotics Pro

- **Primary responsibility is to develop and execute missions to achieve NASA's robotic lunar exploration objectives.**
- **This will be accomplished by:**
  - Defining a robust and sustainable robotic exploration program with precursor missions and continuing into the human exploration campaign
    - We will continue international participation in the architecture definition process through workshops and similar events sponsored by NASA HQ.
  - Actively seeking international partnerships for exploration
    - NASA will develop the transportation infrastructure
  - Defining specific requirements for each precursor mission
  - Establishing and overseeing projects to execute mission design, development, integration, test and operation

LPRP Mission Timeline (Notional)



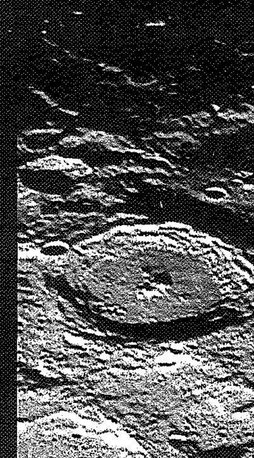
Recent Developments

- **The Robotic Lunar Exploration Program has been renamed the Lunar Precursor and Robotic Program (LPRP). The LPRP office will be located at the Marshall Space Flight Center (MSFC) and report to ESMD.**

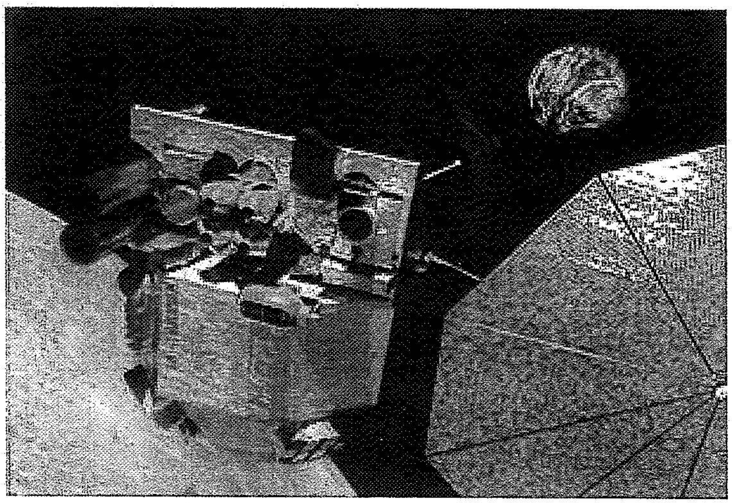
- **The program name is indicative of the fundamental understanding that the robotic missions are not to be single unrelated scientific or engineering investigations. Robotic missions will lead the way to human exploration, and play an integral role in achieving the Vision for Space Exploration.**
  - Robotic missions are to be complementary to crewed exploration
  - Perform "scouting" missions for terrain mapping, and for resource identification and characterization
  - Reduce risk to the crew by performing repetitive or high risk tasks robotically.
  - Maximize crew availability for exploration by accomplishment of infrastructure development, maintenance, and resource processing robotically.
  - Utilize crews where human intelligence and powers of observation are most valuable.

- **Location of program office ensures maximum synergy between the robotic landers expected to be developed as part of the second lunar robotic mission and the crewed landers**
  - MSFC has a long history of successful robotic and crewed missions
  - LSAM descent stage lander Project will be located at MSFC
  - Commonality between the robotic lander and LSAM are key to risk reduction for the crewed lander, and the cargo version of LSAM
    - Key evolutionary paths are precision landing and hazard detection and avoidance

Current LPRP Missions

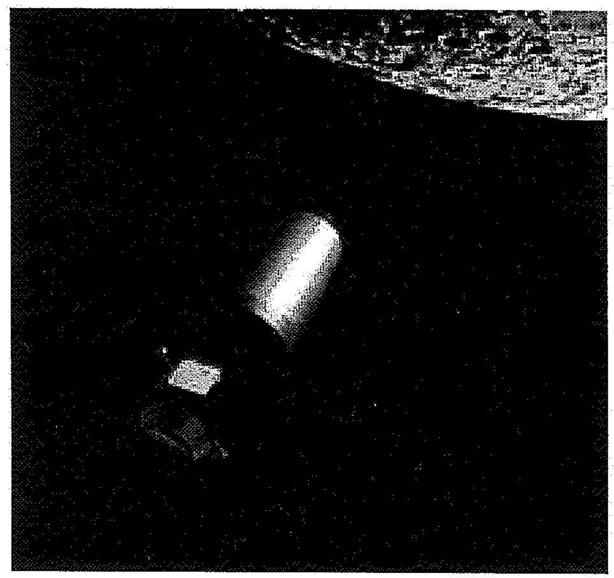


First Two LPRP Missions

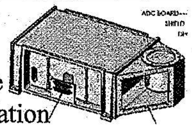
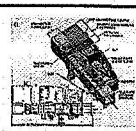
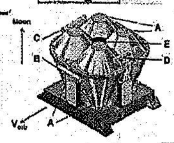
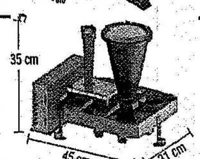
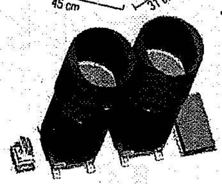
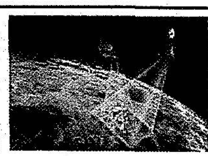


- *Lunar Reconnaissance Orbiter (LRO)*
- Lunar mapping, topography, radiation characterization, and volatile identification
- 50km polar orbit
- Critical Design Review: October 2006
- Launch: Late October 2008

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

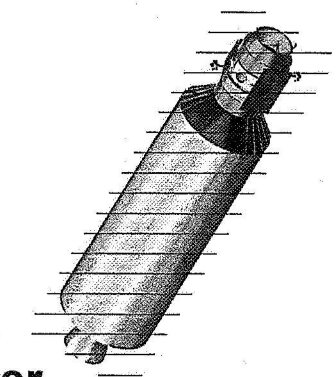


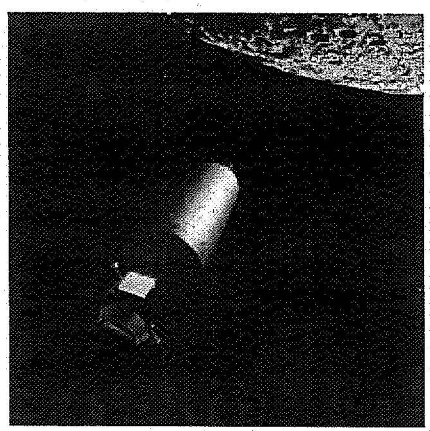
LRO Payloads Provide Broad Bene

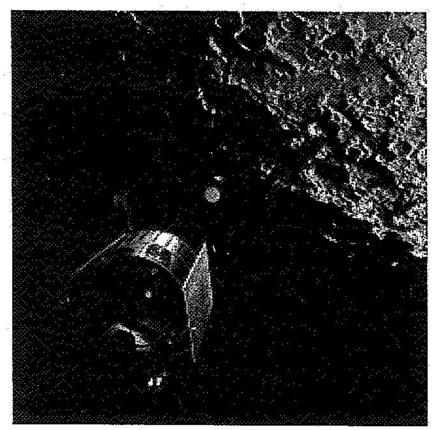
INSTRUMENT	Measurement	Exploration Benefit	Science Benefit
CRaTER Cosmic Ray Telescope for the Effects of Radiation 	*Lunar and deep space radiation environment and tissue equivalent plastic response*	*Safe, high performance, lighter weight space vehicles*	***Radiation boundary conditions for biological response***
DLRE Diviner Lunar Radiometer Experiment 	*500m scale maps of Temperature, Albedo, rock abundance and ice stability*	*Determines conditions for systems operability and water-ice location*	
LAMP Lyman-Alpha Mapping Project 	*Maps of frosts and landforms in permanently shadowed areas*	*Locate potential water-ice on the surface*	***Source, history, migration and deposition of polar volatiles***
LEND Lunar Exploration Neutron Detector 	*Maps of hydrogen in upper 1 m of Moon at 10km scales, neutron albedo*	*Locate potential water-ice in lunar soil*	
LOLA Lunar Orbiter Laser Altimeter 	*~25 m scale polar topography at < 10 cm vertical, surface slopes and roughness*	*Safe landing sites and surface navigation*	***Geodetic topography for geological evolution***
LROC Lunar Recon Orbiter Camera 	*1000's of 50cm/pixel images ($125km^2$), and entire Moon at 100m in UV, Visible Illumination conditions of Poles*	*Surface Landing hazards and some resource identification*	***Tectonic, impact and volcanic processes, resource evaluation, and crustal evolution***
Mini-RF (technology demonstration) 	*Radar imaging, possibly including bi-static imaging with Chandrayaan-1*	*Demonstrate new lightweight communication and navigation technology, Locate potential water-ice*	***Source, history, deposition of polar volatiles***

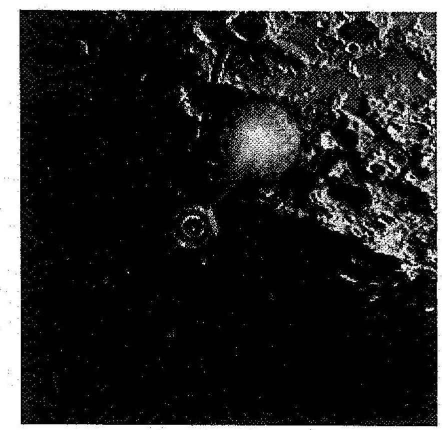
LCROSS Provides Unique Opportunity

- The LCROSS uses the spent Earth Departure Upper Stage (EDUS) of the launch vehicle as a kinetic impactor
- The LCROSS 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









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 (Human and Robotic). Study is underway now at NASA HQ led by Tony Lavoie, the LPRP Program Manager.**
- **Baseline an Exploration Architecture in late 2006**
  - Includes definition of surface activities for crewed missions and
  - Definition of robotic missions prior to crew arrival and those concurrent with crewed exploration activity
- **Initiate first LPRP lander mission in mid-2007**