Return to the Moon

NASA’s LCROSS and LRO Missions
Lunar Crater Observation & Sensing Satellite (LCROSS)
We’re returning to the Moon!

- NASA’s goals include objectives for robotic and human spaceflight:
  - Implement a sustained and affordable human and robotic program to explore the solar system and beyond;
  - Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;

- A lunar outpost is envisioned... but where will it be???
Previous U.S. Landing Sites

- Apollo
- Ranger
- Surveyor

Near-side

Far-side
Lunar Outpost Site Selection

Site Considerations:

1) General accessibility of landing site (orbital mechanics)
2) Landing site safety
3) Mobility
4) Mars analog
5) Power
6) Communications
7) Geologic diversity
8) ISRU considerations
Why look for water?

- Humans at a lunar outpost will need water:
  - Option 1: Carry it there.
  - Option 2: Use water that may be there already!

- Carrying water to the moon will be expensive!

- Learning to “Live off the land” would make a lunar outpost sustainability easier.
Living off the land

- Even compared to many meteorites, the Moon is highly depleted in volatile elements and compounds, especially water.
- However, oxygen does exist within various mineral structures. Hydrogen from the solar wind can also be obtained from the lunar soil.
- Very energy intensive to obtain these key raw materials (have to heat regolith to at least 700°C).
- Life would be much easier and cheaper if we could just find H₂O on the Moon.
• Circular polarization ratio (CPR) consistent with ice crystals in the south polar regolith.
• Later ground-based studies confirmed high-CPR in some permanently-shadowed craters.
• However, Arecibo scans have also found high-CPR in some areas that are illuminated, probably due to surface roughness.
• Are we seeing ice or rough terrain in dark polar craters?
Hydrogen has been detected at the poles by Lunar Prospector in 1999. Is it water ice???

Lunar Prospector neutron spectrometer maps of the lunar poles. These low resolution data indicate elevated concentrations of hydrogen at both poles; it does not tell us the form of the hydrogen. Map courtesy of D. Lawrence, Los Alamos National Laboratory.
How could there be water at the lunar poles?

The sun never gets more then several degrees about the polar horizon, thus topography can provide “permanent” shade.

Permanently shadowed regions (PSRs) may have temperatures < -200° C (-328° F).

Over the history of the Moon, when comets or asteroids impact the Moon's surface they briefly produce a very tenuous atmosphere that quickly disperses into space.

However, PSRs could act as cold-traps. Volatile gasses that enter could condense and accumulate for billions of years.
Where will we look?
How can we look for water?

Lunar Reconnaissance Orbiter
LRO

Lunar Crater Observation
and Sensing Satellite
LCROSS
Lunar Reconnaissance Orbiter

- LROC – image and map the lunar surface in unprecedented detail
- LOLA – provide precise global lunar topographic data through laser altimetry
- LAMP – remotely probe the Moon’s permanently shadowed regions
- CRaTER - characterize the global lunar radiation environment
- DIVINER – measure lunar surface temperatures
- LEND – measure neutron flux to study hydrogen concentrations in lunar soil
Impact the Moon at 2.5 km/sec with a Centaur upper stage and create an ejecta cloud that may reach over 10 km about the surface.

Observe the impact and ejecta with instruments that can detect water.
LCROSS Mission System

- Shepherding Spacecraft
- Centaur Upper Stage

14.5 m
LCROSS Shepherding Spacecraft
LCROSS Work Breakdown


**ARC, JPL, and GSFC** provide the Navigation and Mission Design role.

**Northrop-Grumman** provides the Spacecraft and Spacecraft integration with the Payload for this mission as well as launch systems integration support.

**JPL** is providing Deep Space Network services.

**KSC/Lockheed-Martin** is providing Launch Vehicle services (Atlas V – 401).
Payload/Spacecraft Details

- The Payload is the business end of the LCROSS Spacecraft, housing all scientific instruments used for the Mission.
- The Spacecraft provided by NGST consists of Command & Data Handling, Communications, Power, Propulsion, and Guidance, Navigation & Control systems.
- The Spacecraft consists of 6 radiator panels mounted on a central ring, housing the various systems.
- The Payload is mounted on one of these 6 panels.
- ARC personnel designed and fabricated the Payload using Commercial Off-The-Shelf (COTS) instruments except for the Total Luminance Photometer which was designed and built by ARC.
‘Low-Cost and Quick’ Achieved with a Little Help From a Friend

Northrop Grumman Technical Services is building LRO avionics

Use Existing Designs
Buy Parts Together

Share Software
Share Documentation
Make use of a Structure Already Designed to Carry Heavy Payloads During Launch

EELV Secondary Payload Adapter or ESPA Ring

Put LRO on top

Use ESPA ring to make LCROSS spacecraft

Attach bottom of ESPA Ring to top of rocket

But how do you make a spacecraft out of something that looks like a sewer pipe?
Answer: Put Equipment Around the Rim and Tank in the Middle

Integrated LCROSS Spacecraft

- Propellant Tank
- Solar Array
- ESPA Ring
- Equipment Panel (1 of 5)
Each Panel Carries Equipment to Operate LCROSS

Panel Structure without Insulation Blanket

Panel Structure with Insulation Blanket

Panel design also assists keeping electronics at correct operating temperature
Different Panels Perform Different Functions

 LCROSS Viewed From Above without Insulation
Panel Approach Makes LCROSS Easier to Put Together

LCROSS with Panels Laid Flat for Integration of Electronics
Other Equipment Includes Two Types of Antennas to Talk Back to Earth

- Omni (Low Gain) Antenna (1 on each side)
- Medium Gain Antenna (1 on each side)
And Sensors to Determine Spacecraft Attitude (Pointing)
Propulsion System Must Maneuver and Point the Spacecraft

5 lb Thruster for Maneuvers (1 of 2)

Propellant Tank (40.85” dia)

1 lb Thruster for Attitude Control (1 of 8)

Post Supports Thrusters (1 of 4)
# LCROSS Instruments

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Scheduled Launch: Late 2008

- Both LCROSS and LRO will share space aboard an Atlas V launch vehicle
- Launch will occur at Cape Canaveral
Centaur-LCROSS-LRO at TLI
LRO Separation
**LRO Mission Overview**

- On-board propulsion system used to capture at the Moon, insert into and maintain 50 km mean altitude circular polar reconnaissance orbit.

- 1 year exploration mission followed by handover to NASA science mission directorate.
LCROSS Lunar Flyby: L + 5 days
LCROSS Trajectory: The Long and Winding Road

- 3, 3.5, or 4 month cruise depending on launch date
- Flyby transitions to Lunar Gravity Assist Lunar Return Orbits (LGALRO)
- 3, 3.5, or 4 Lunar orbits about Earth (27 day period)
- 2, 2.5, or 3 LGALRO orbits about Earth (~38 day period)
- Long transit also provides time to vent any remaining fuel from Centaur
LCROSS Separation: Impact - 7 hrs
Centaur Impact
Centaur Impact
Into the Plume

• During the next 4 minutes, the Shepherding Spacecraft descends into the debris plume, measuring its morphology and composition, and transmitting this information back to Earth.
• The Shepherding Spacecraft then ends its mission with a second impact on the Moon.
Impact Observation Campaign
Ground-based Telescopes

Timing of impacts to allow simultaneous observations from Hawaii, Continental U.S., and South America.
The opportunity for ground based assets to observe the impact depends on the date and time of impact:

- Phase of the moon: $\theta > 30^\circ$ from new or full moon
- Moon position in the night sky: $< 3$ air masses ($\phi > 30^\circ$ from horizon) with $> 2$ hours of observing time
Participatory Exploration

- We cannot expect our audiences to be satisfied with being passive second-hand recipients of mission information.
- The act of participation is vital for students and the public in realizing the relevance of a mission, increasing their interest and buy-in for the mission.
- Stardust, Mars HiRISE, and Deep Impact are great examples.
LCROSS Education and Public Outreach

Numerous Components Including

- Student and Public Observation Campaign
- Student Telemetry Program
- Planetarium Program
- NASA Quest Challenges
- Museum Programs
- Cohort Programs
- Family Nights
- Impact Extravaganza
- Workshops
- Spacecraft Naming Contest
This is an exciting mission!

We believe reasonable grade amateur telescopes may be able to witness the impact plume.
Public and Student Observation Campaign

- Current estimates indicate that impact plume should be visible in 10 to 12-inch telescopes
- Modern amateur telescopes and CCD cameras are capable of recording details detectable only in professional equipment a few years ago
- Large numbers of such systems among amateurs and colleges
- Could contribute scientifically valuable data
- Critical not to oversell – we don’t know what we’ll see
Public and Student Observation Campaign

• Also have public and students optically track spacecraft during LGALRO transit
• Is this possible with amateur equipment?
Public and Student Observation Campaign
Yes! The strange case of J002E3:

J002E3 Rocket (Possible Saturn S-IVB stage)
March 29, 2003  21:45 PST
Distance 0.00298605 AU

Oakridge Observatory
37.2039°  -122.0539°  730M
NAD 1927

SAO 139517
  Mag 9.10

GSC 5546634
  Mag 15.1

GSC 5546172
  Mag 14.5

GSC 554680
  Mag 14.0

Image every 20 seconds

Rick Baldridge
Public and Student Observation Campaign

- Effective participation will be aided through online community for collaborating public observers
- Facilitate exchange of ideas, techniques, equipment recommendations
- Established through partnership with NASA CoLab
Ejecta Mass

The ejecta cloud will more-or-less look like an expanding conical section (an upside-down lampshade). The figure below (images from a hypervelocity shot at the NASA AVG) demonstrates this geometry.

Ejecta cloud optical depth modeled with a truncated conical section, the “upside-down lampshade” model.
**Impact Observation Strategy**

The LCROSS mission has multiple layers of observing:

- Bright Impact Flash
- Thermal OH Production
- Rapid Thermal Evolution
- Expansion of Plume
- Thermal Evolution
- $\text{H}_2\text{O}$ ice sublimation
- Photo-production of OH
- Residual Thermal Blanket
- Expanding OH Exosphere

The combination of ground-based, orbital and in-situ platforms span the necessary temporal and spatial scales: from sec/meters to hours/km.

*The LCROSS mission has multiple layers of observing*
ARC Vertical Gun Experiments
Student Telemetry Program

- **GAVRT** – Goldstone Apple Valley Radio Telescope run by Lewis Center for Educational Research
- 34m DSS-12 dish
- Used by thousands of K-12 students around the world
Student Telemetry Program

- Monitor spacecraft omni during LGALRO transit
- Conduct Doppler studies en route
- Monitor medium gain transmissions during terminal approach and determine time of LOS
- Outstanding partnership opportunity for other mission post LCROSS, including LRO!
Mounting ESPA Ring to Propulsion Tank Support
Spacecraft Structure
Moving Structure on to Pallet
Wrapped Up For Move to Highbay for Integration
Payload Mounted on Spacecraft Radiator Panel
Payload Instrument Suite
Questions