



The Lunar Reconnaissance Orbiter Mission Overview & Status

NLSI Lunar Science Forum 2009

July 21, 2009

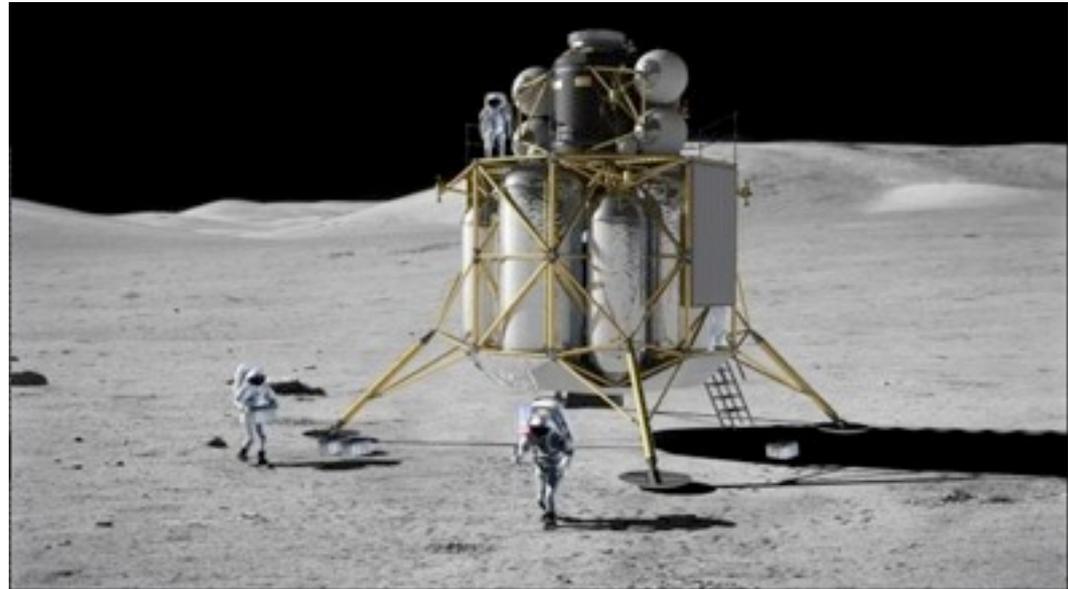
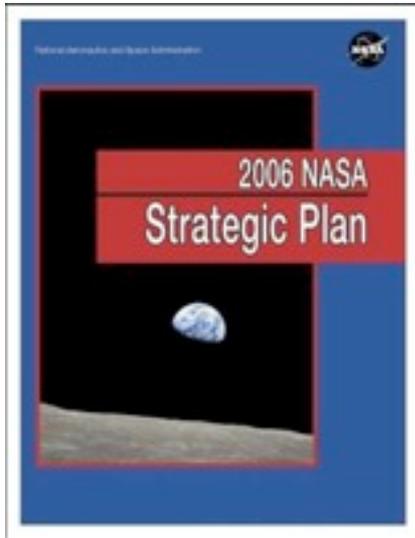


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LRO Mission Overview



LRO Driving Objective



- **Strategic Goal 6: Establish a lunar return program having the maximum possible utility for later missions to Mars and other destinations.**
 - 6.1. By 2008, launch a Lunar Reconnaissance Orbiter (LRO) that will provide information about potential human exploration sites.
- NASA moved LRO launch to June 2009 to accommodate both other national launch priorities and problems with missions ahead of LRO in the launch manifest





LRO Mission Objectives



Objective: The Lunar Reconnaissance Orbiter (LRO) mission objective is to conduct investigations that will be specifically targeted to prepare for and support future human exploration of the Moon.

Locate Potential Resources

- Hydrogen/water at the lunar poles
- Continuous solar energy
- Mineralogy

Safe Landing Sites

- High resolution imagery
- Global geodetic grid
- Topography
- Rock abundances

Space Environment

- Energetic particles
- Neutrons



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LRO Mission Overview



The Lunar Reconnaissance Orbiter Mission Begins



LRO in Launch Configuration at KSC/Astrotech



LRO Mission Operations Center (MOC) and Engineering Support Room (ESR) at GSFC just prior to LOI-1



LRO Mission Overview



LRO/LCROSS Atlas V Launch on June 18, 2009



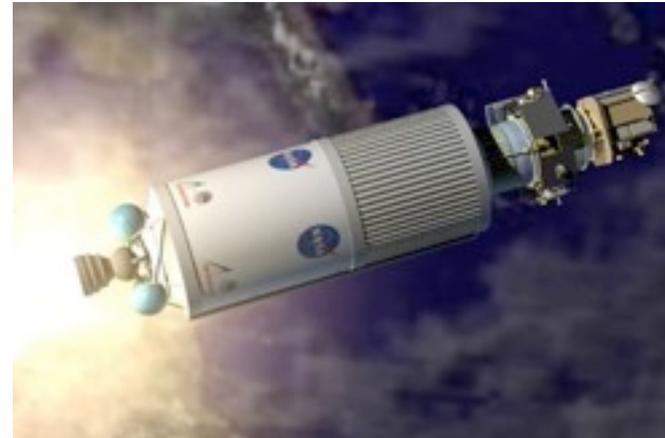
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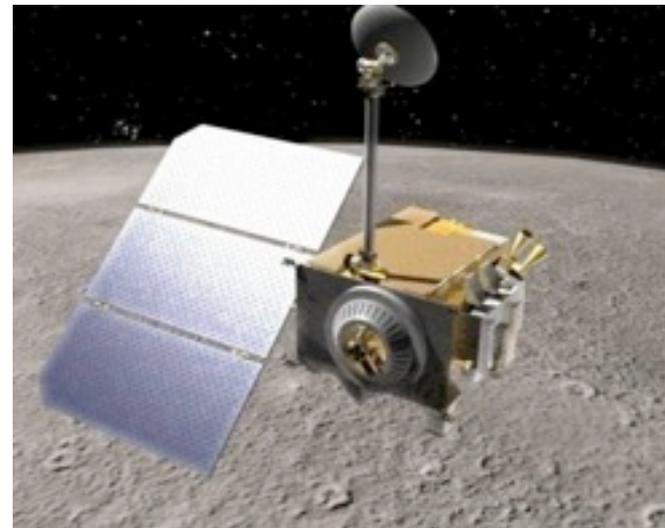
LRO Mission Overview



- **Launched June 18, 2009 on a Atlas V into a direct insertion trajectory to the Moon. Co-manifested with LCROSS lunar impactor mission.**
- **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 with planned 2 year extended science mission.**
- **Orbiter is a 3-axis stabilized, nadir pointed spacecraft designed to operate continuously during the primary mission.**
- **Investigation data products delivered to Planetary Data Systems (PDS) within 6 months of primary mission completion.**



LRO & LCROSS on Atlas-Centaur Upper Stage

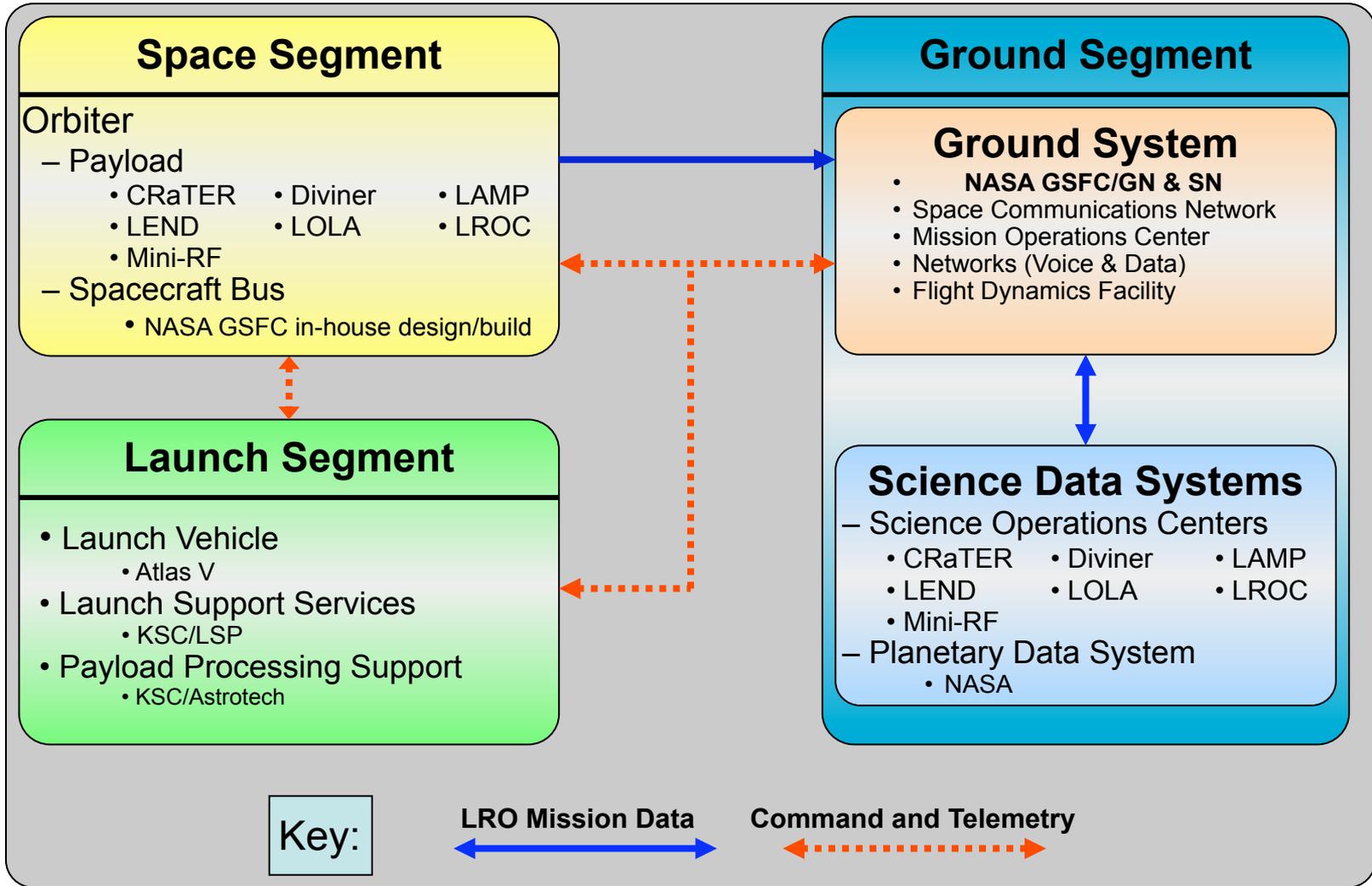


LRO in 50 km polar orbit





LRO Mission Segment Definition





LRO Mission – Background & Chronology



- The LRO mission was initiated in May 2004 at GSFC under the direction of NASA Code S.
 - *Anticipated to be Discovery mission class in scope to be launched in 2008*
 - *Assigned as an in-house GSFC development in response to the accelerated schedule*
 - *Competitive AO to solicit high heritage instruments released in late June 2004.*
 - *Class C risk classification (per NPR8705.4/NPR7120.5D) established consistent with cost, mass, and schedule constraints. Select tailoring of some aspects to B levels per GSFC practice. Single String Design Accepted.*

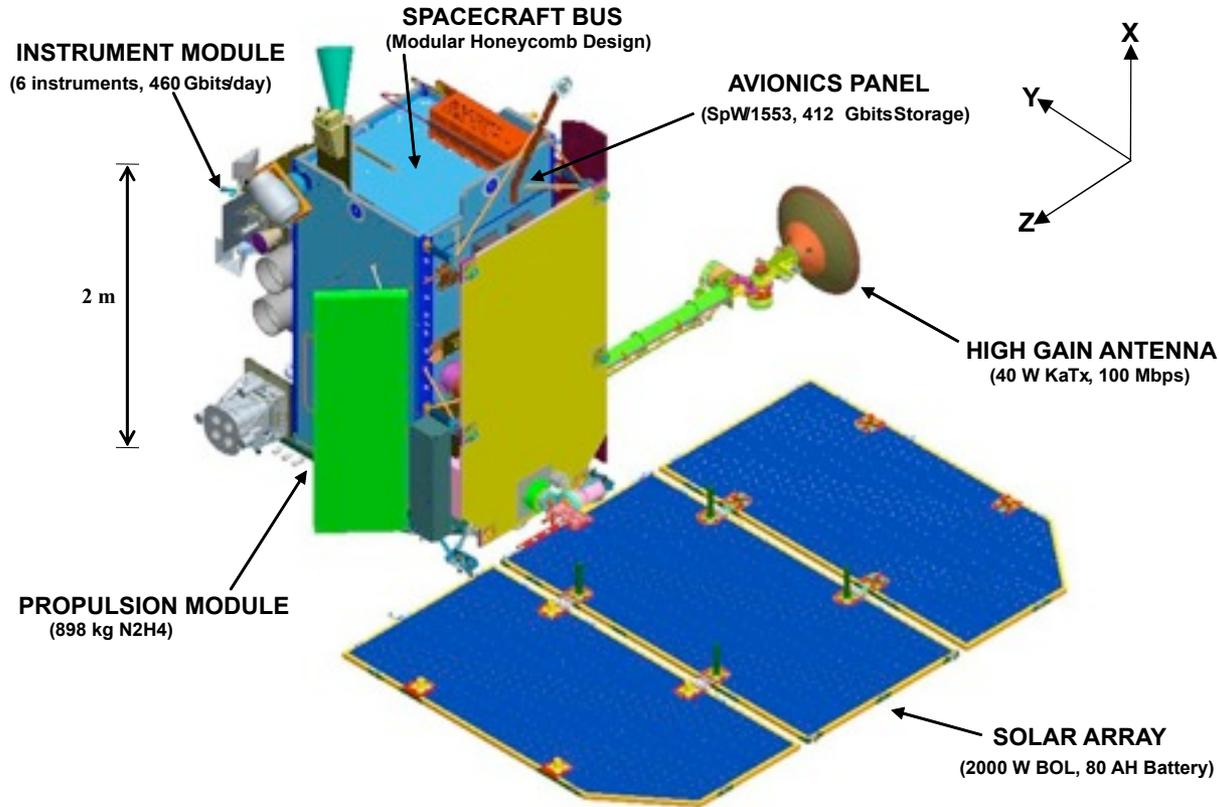
- LRO Chronology

<ul style="list-style-type: none"> - <i>ORDT convened and made recommendations to NASA about LRO objectives</i> - <i>Instruments selected (competitive AO)</i> - <i>Funding released to Project</i> - <i>Program moved from NASA SMD to ESMD</i> - <i>Mini-RF added to LRO</i> - <i>SRR</i> - <i>LRO moved to and redesigned for EELV instead of Delta II</i> - <i>PDR</i> - <i>Confirmation</i> - <i>CDR</i> - <i>I&T Starts</i> - <i>LPRP directs LRO to plan for March 2009 instead of December 2008 launch</i> - <i>PSR</i> - <i>FOR</i> - <i>MRR</i> - <i>Launch</i> - <i>Commissioning orbit (30x199km) established about the Moon</i> 	<ul style="list-style-type: none"> - <i>March 2004</i> - <i>December 2004</i> - <i>February 2005</i> - <i>February 2005</i> - <i>April 2005</i> - <i>July 2005</i> - <i>December 2005</i> - <i>February 2006</i> - <i>May 2006</i> - <i>November 2006</i> - <i>January 2008</i> - <i>July 2008</i> - <i>February 2009</i> - <i>March 2009</i> - <i>April 2009</i> - <i>June 18, 2009</i> - <i>June 27, 2009</i>
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The LRO spacecraft

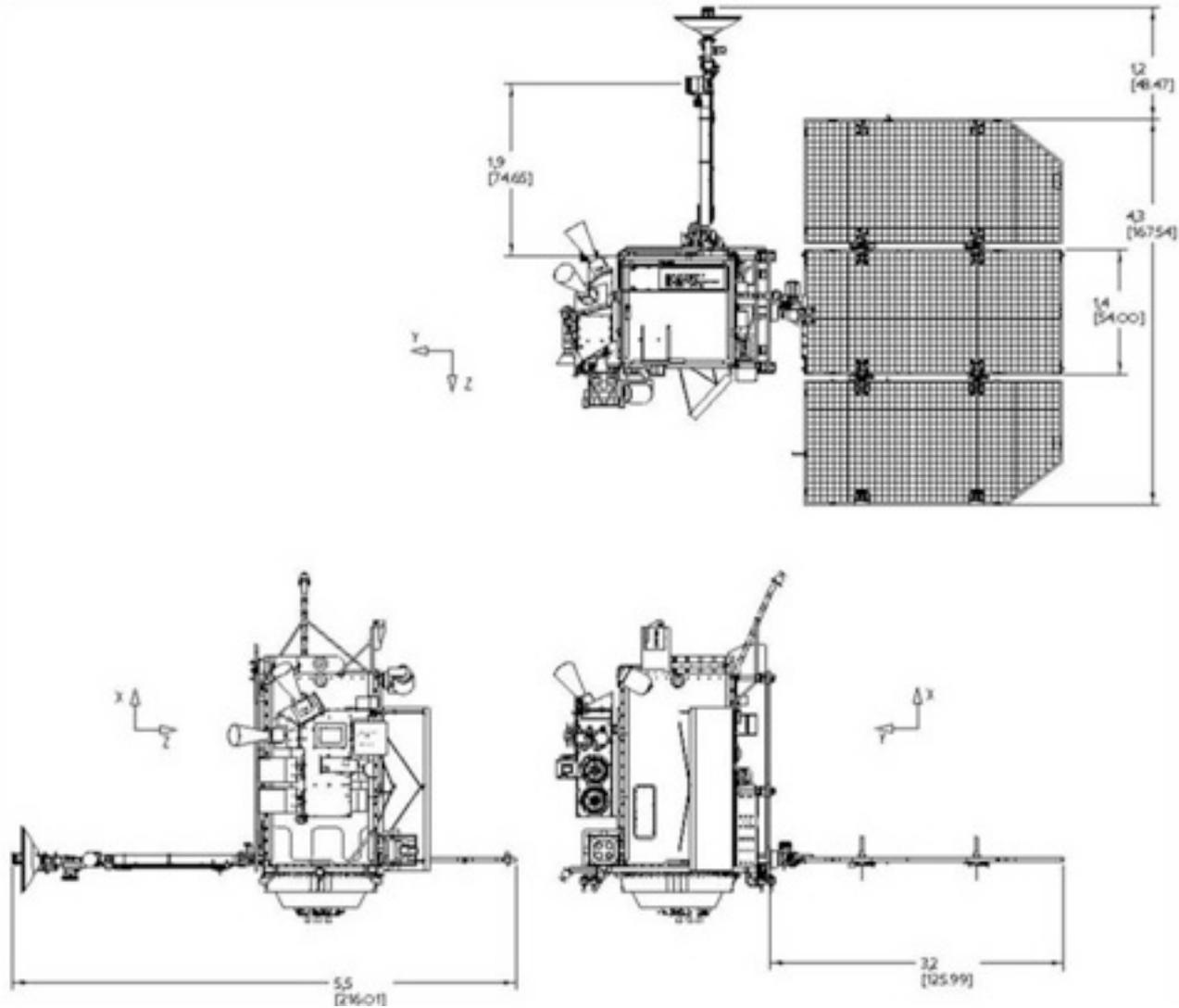


LRO Orbiter Characteristics		
Mass (CBE)	1916 kg	Dry: 1018 kg, Fuel: 898 kg (1313 m/sec)
Orbit Average Bus Power	647 W @ Beta 0	
Data Volume, Max Downlink rate	461 Gb/day, 100Mb/sec	
Pointing Accuracy, Knowledge	60, 30 arc-sec	





LRO Dimensional Layout (Deployed)



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LRO Mission Overview



The Lunar Reconnaissance Orbiter



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LRO Mission Overview



LRO Instruments and Investigations



LOLA: Lunar Orbiter Laser Altimeter

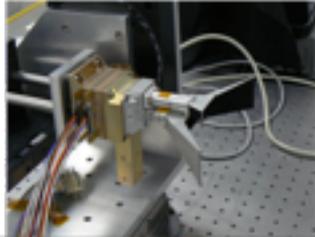
- Topography
- Slopes
- Roughness



Full Orbit
Autonomous

LROC/WAC: Wide-Angle Camera

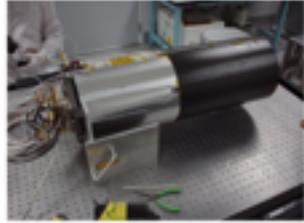
- Global Imagery
- Lighting
- Resources



Day Side
Autonomous

LROC/NACs: Narrow-Angle Cameras

- Targeted Imagery
- Hazards
- Topography



Day Side
Timeline Driven

LR: Laser Ranging

- Topography
- Gravity



GSFC LOS
Autonomous

DLRE: Diviner Lunar Radiometer Exp.

- Temperature
- Lighting
- Hazards
- Resources



Full Orbit
Autonomous

Mini-RF: Synthetic Aperture Radar

- Tech Demonstration
- Resources
- Topography



Polar Regions
Timeline Driven

CRaTER: Cosmic Ray Telescope...

- Radiation Spectra
- Tissue Effects



Full Orbit
Autonomous

LEND: Lunar Explr. Neutron Detector

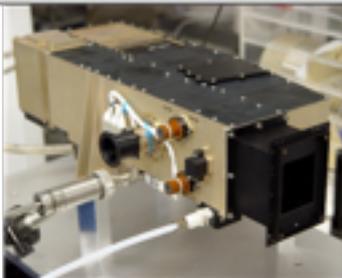
- Neutron Albedo
- Hydrogen Maps



Full Orbit
Autonomous

LAMP: Lyman-Alpha Mapping Project

- Water-Frost
- PSR Maps

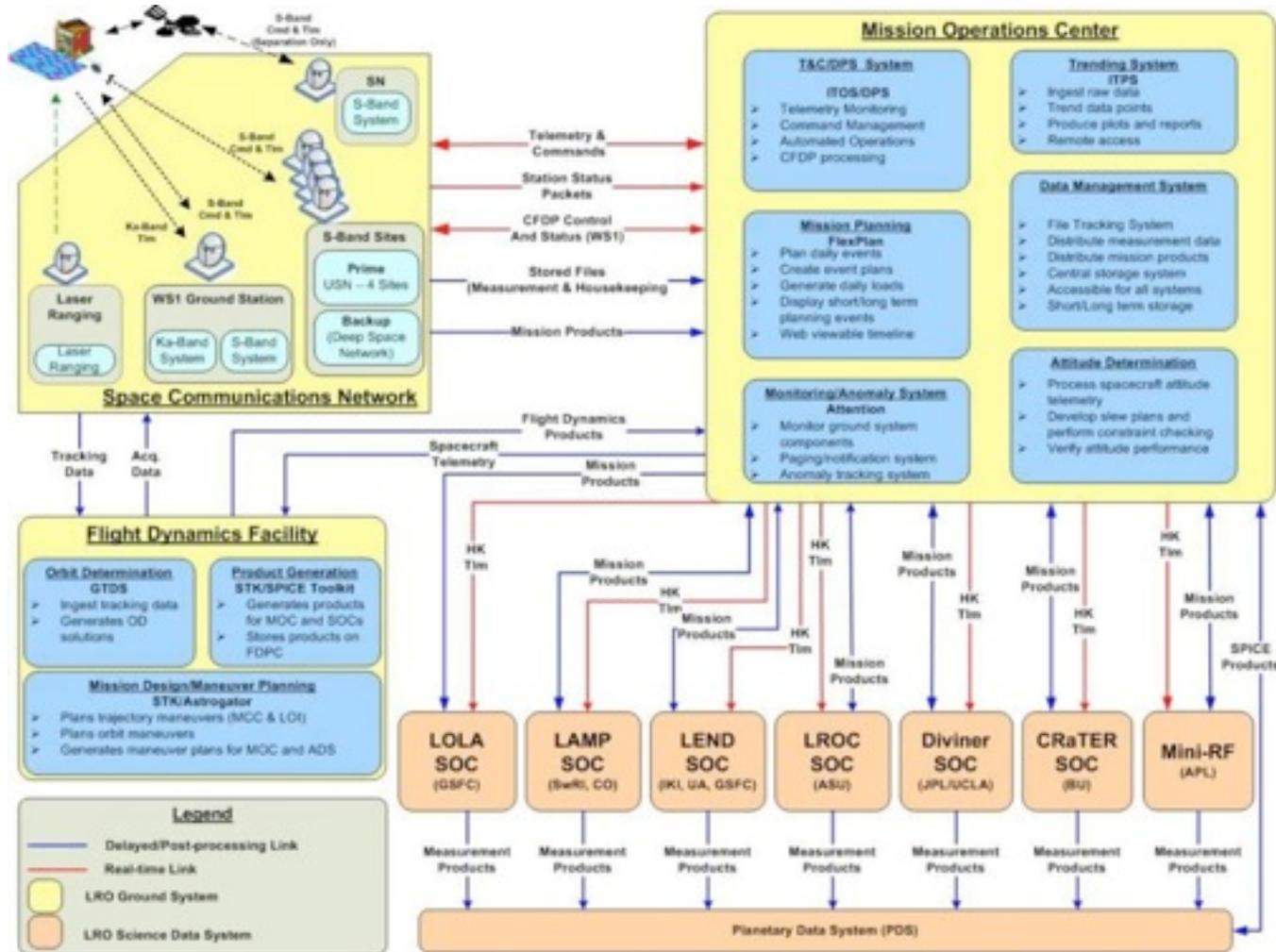


Night Side
Autonomous





LRO GS&O System Architecture





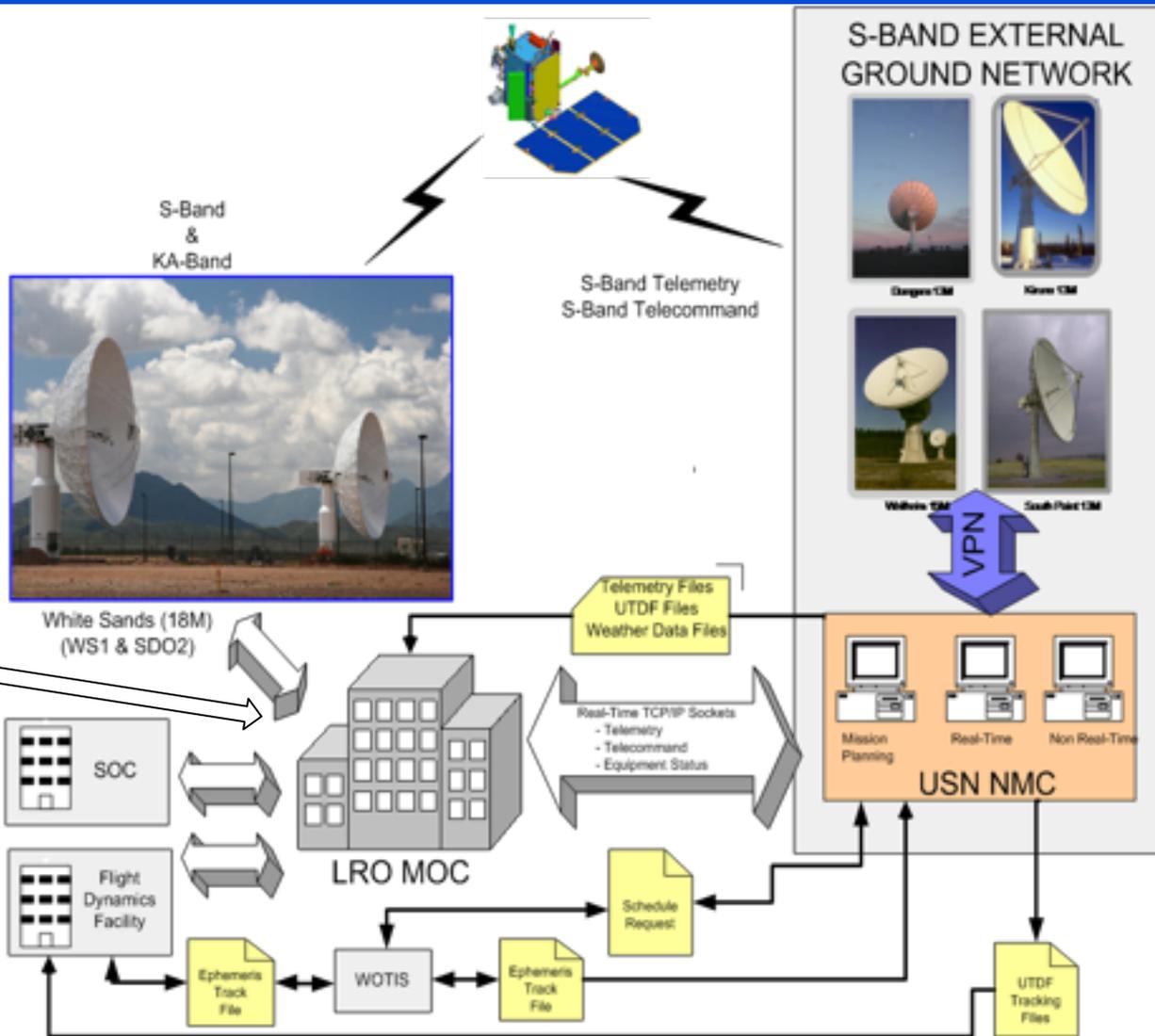
Space Communications Network Assets Employed for LRO Mission Operations



DSN
(Early Mission & Emergencies)



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LRO Mission Overview



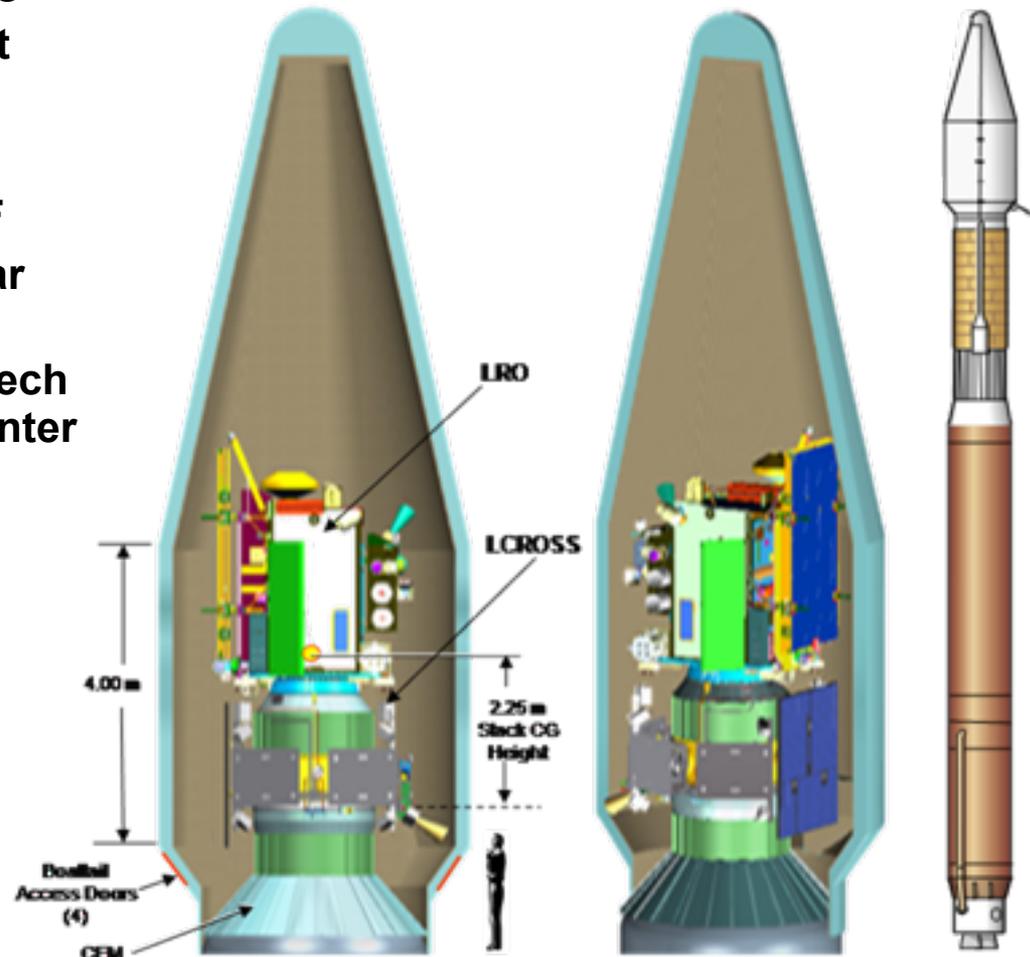
LRO-LCROSS Launch Segment



- Launch Services Provided by KSC
- Atlas V 401 through NLS Contract
- 2000 kg/C₃ ~-2.0;
Sun Exclusion thru Ascent
- 4m fairing; H/K data thru EELV I/F
- Co-manifested with LCROSS lunar mission
- Launch Site Processing at Astrotech including Fueling and Control Center



LRO Atlas Fairing at Astrotech



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LRO Encapsulation in Atlas V Faring

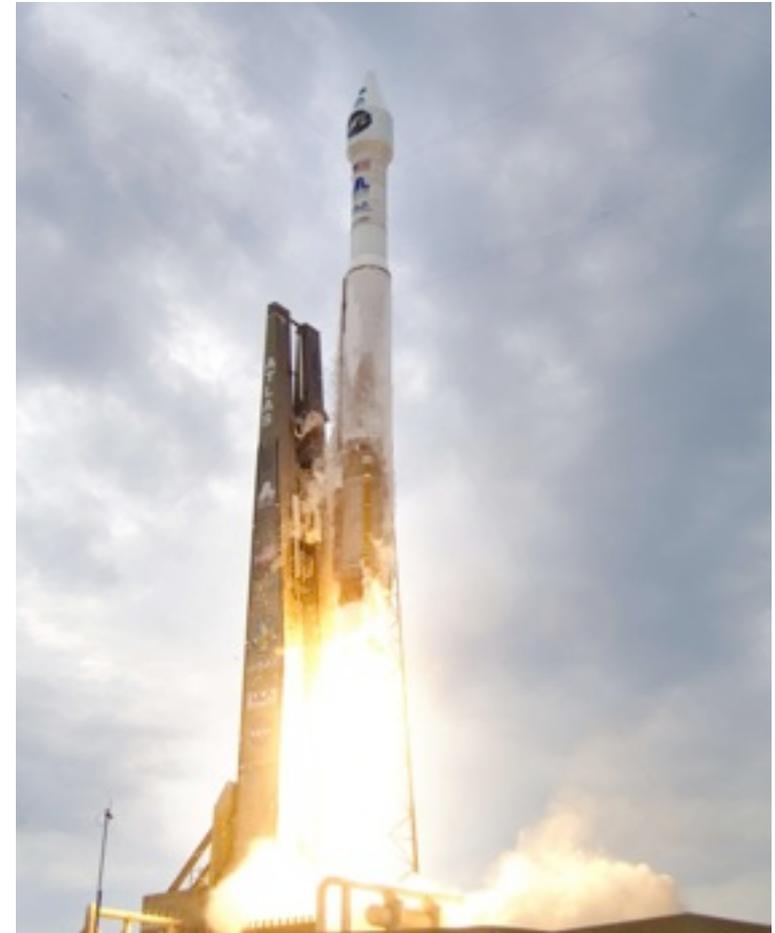
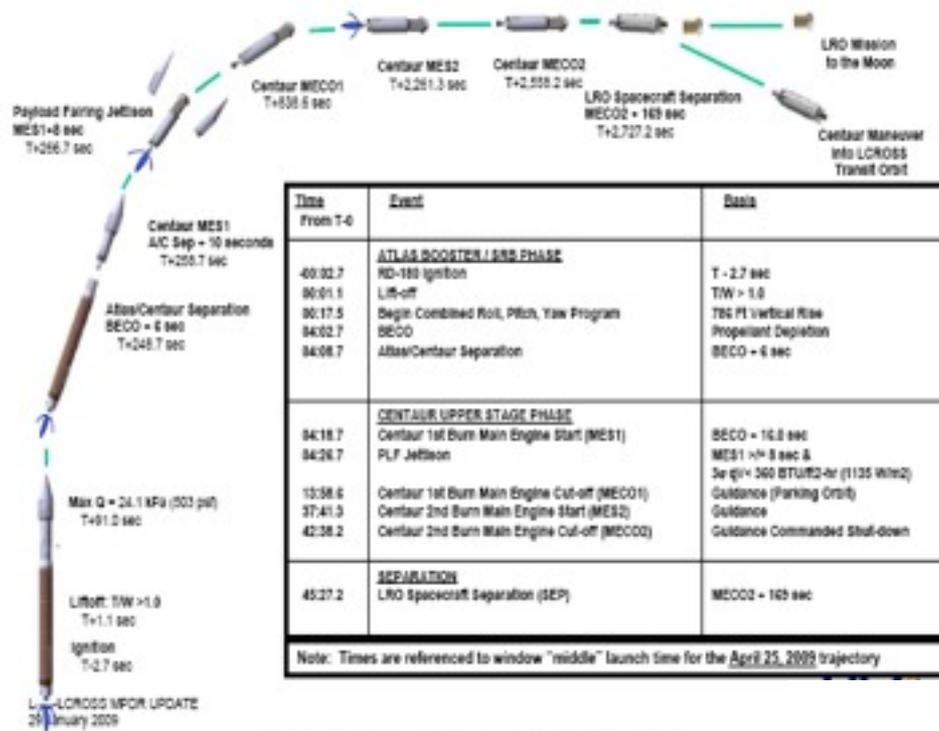


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LRO Mission Overview



LRO/LCROSS Launch Trajectory



LRO Launch on June 18, 2009

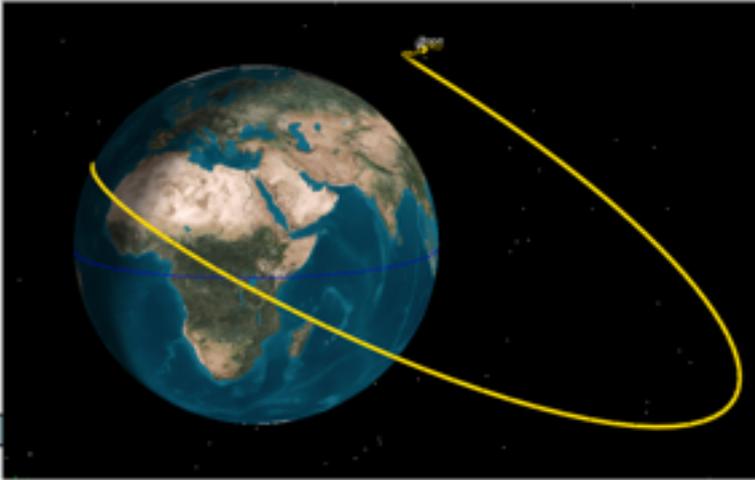




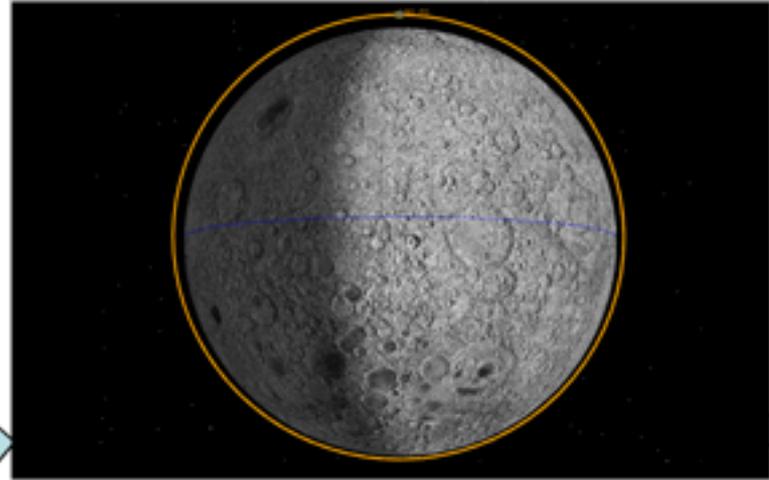
Mission Trajectory / Orbits Overview



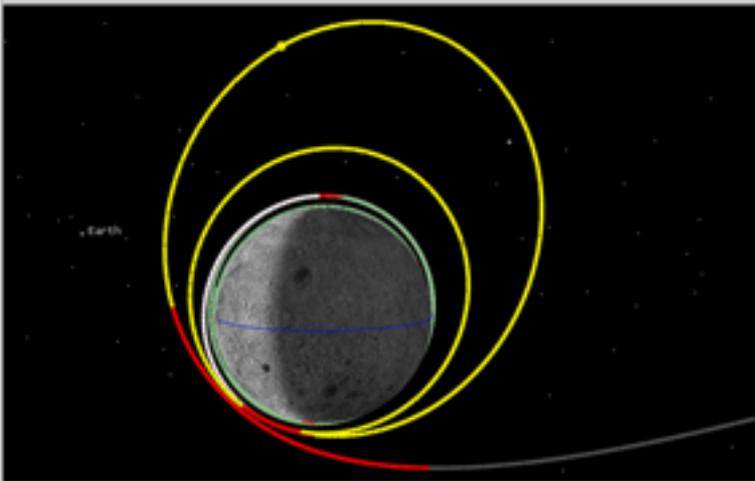
Minimum Energy Lunar Transfer: 4-5 days



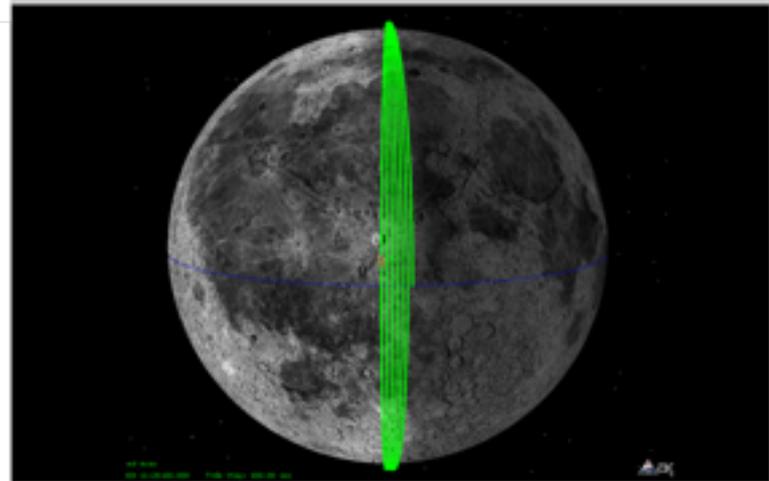
30 x 216 km Quasi-frozen Orbit: up to 60 days



Lunar Orbit Insertion Sequence (4): 4-6 days



50 km Polar Mapping Orbit: at least 1 year

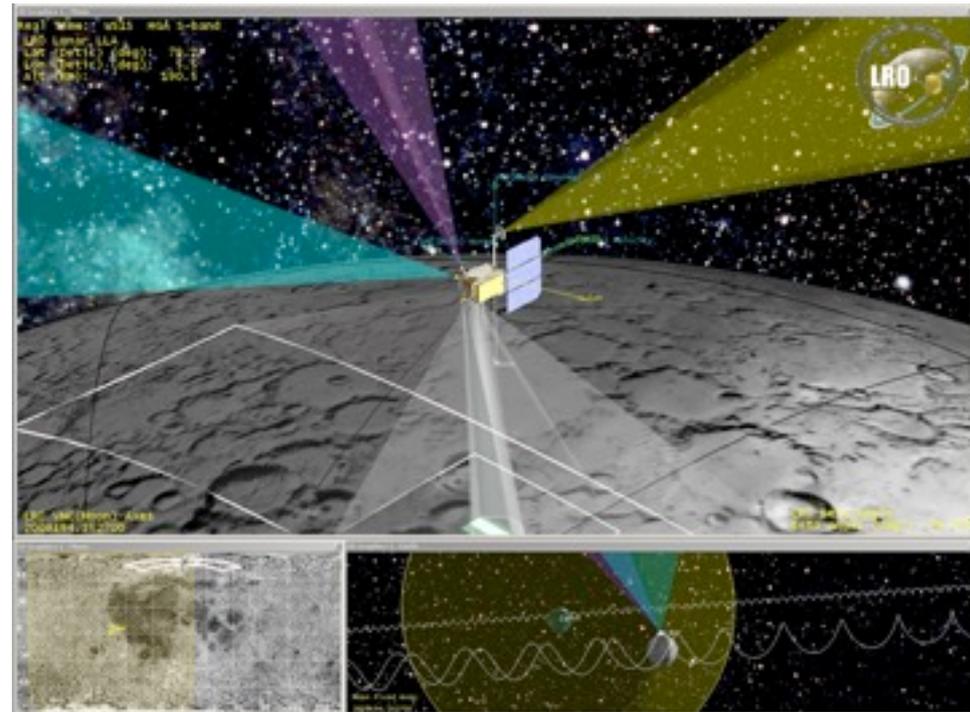




LRO Spacecraft & Operations Status



- Atlas V launch was nearly perfect with very little tip-off and TLI error.
- Initial Acquisition through Lunar Orbit Insertion (LOI) completed flawlessly.
 - Propulsion System performed perfectly
 - LRO arrived in Lunar Orbit with 147 m/s worth of extra ΔV above 65 m/s budgeted for extended mission and contingencies.
- Spacecraft Commissioning Completed
 - Gyro Calibrations
 - High Gain Antenna Calibrations
 - Safing Tables and RTSs Updated
 - Minor changes to ACS Controller gains/limits
 - One-way Laser Ranging Operating
 - All spacecraft subsystems operating nominally and meeting or exceeding specifications
 - ✓ Slewing & Pointing performance excellent
 - ✓ All temperatures well within limits
 - ✓ Communication & data transfer performance exceeds expectations
 - ✓ Power System healthy, battery capacity exceeds spec
 - ✓ Computer & Software executing flawlessly
- Minor issues being investigated and worked:
 - Ground ranging performance still does not meet specifications.
 - Small number of LROC image files corrupted by S/C



Screen snap from real-time STK display in LRO MOC. Driven by real-time spacecraft telemetry and on-board ephemeris.





Instrument Commissioning Status



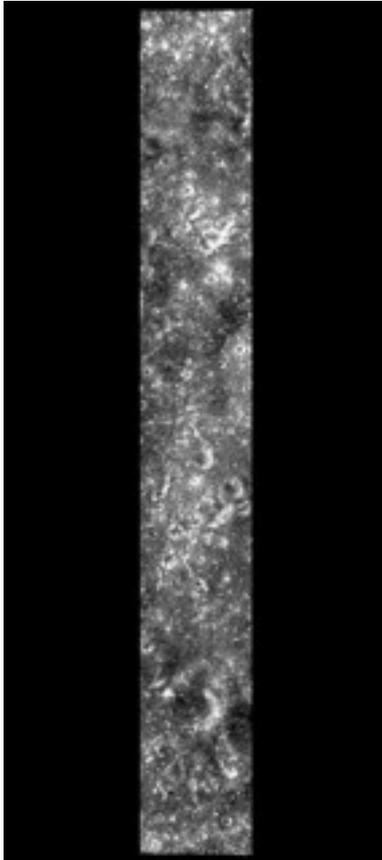
• Instrument Commissioning Ongoing

- All Instruments have been activated and are healthy.
 - LEND, CRaTER, DLRE, LOLA, & LROC taking data throughout this phase
 - LAMP to begin data collection in August
 - Mini-RF operated frequently both for calibration and LCROSS support

- LRO has completed 21 of 49 instrument commissioning/calibration activities thus far.

- LRO supporting LCROSS targeting during commissioning phase.

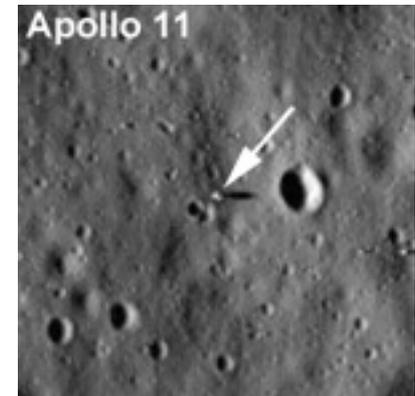
- MOI (maneuver to 50 km orbit) planned for 8/31/2009. End of Commissioning phase.



Mini-RF SAR S-band image strip –covering an area about 12 kilometers) wide and kilometers)long acquired over a region close to the moon's south pole.



LROC Narrow Angle Camera scanned its way towards the north pole at an altitude of 187 km, brushing past the crater Rozhdestvenskiy W.



LROC Narrow Angle Camera image of Apollo 11 site from 113 km altitude.





LRO Mission Overview



Reference Information





LRO Information Sources & Links



- The following Documents are posted on the GSFC WebDrive:
 - [LRO Mission Operations Plan, 431-PLAN-000064](#)
 - [LRO Launch and Early Mission Handbook, 451-HNBK-001299](#)
 - [LRO Spacecraft Operations and Description Manual, 451-OPS-001222](#)
 - [LRO Nominal Mission Management Plan, 451-PLAN-003594](#)

You have 30 days from 07-10-2009 to download the file(s) from the following URL:

<https://webdrive.gsfc.nasa.gov/longauth/400/Craig.R.Tooley.1/hLK9oC3>

Please use the following to login:

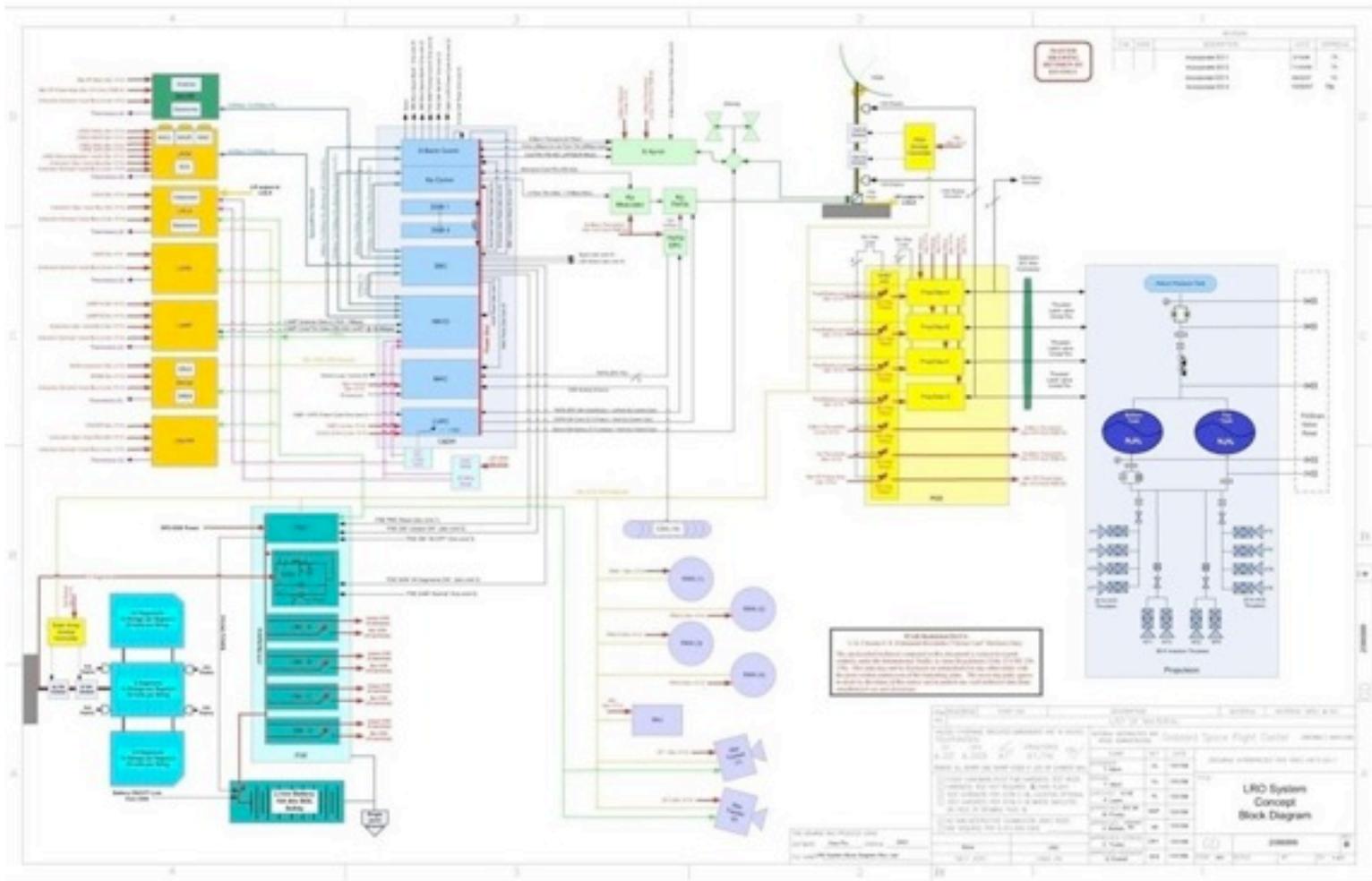
**username = LRO_info
password = LRO_info**

- Websites:
 - <http://lrouupdate.blogspot.com>
 - <http://www.nasa.gov/LRO>
 - <http://lunar.gsfc.nasa.gov/>
 - <http://roc.sese.asu.edu>



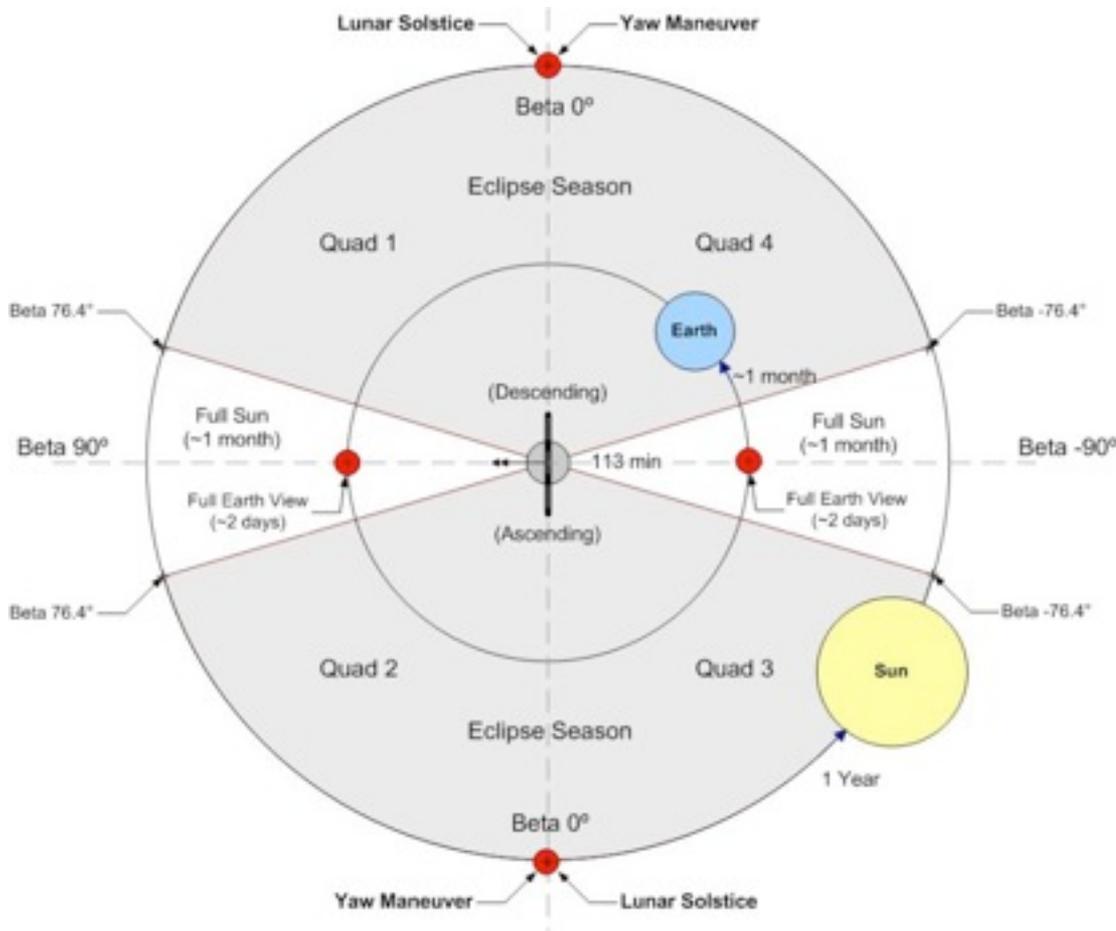


LRO System Block Diagram





The Moon-Centered Universe



- Twice a month, LRO's orbit will be in full view of the Earth for roughly 2 days.
- Twice a month, LRO will perform a momentum management maneuver while the ground has complete coverage.
- Once a month, LRO will perform a station-keeping (SK) maneuver while the ground has complete coverage.
- Twice a year, LRO's orbit will be in full view of the Sun for roughly one month.
- During the eclipse season, LRO will have a max. lunar occultation of 48 minutes.
- LRO's orbit will be targeted such that lunar solstice occurs near maximum occultation.
- Twice a year, LRO will perform a 180° yaw maneuver.
- Twice a year, the Moon will pass through the Earth's shadow (Lunar Eclipse).



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LRO Reserves & Margins at Launch



LRO Reserves & Margins at PSR				
Cost (reserve on Phase A-D cost-to-go)		15% (assumes funding for June 17 ILC)		
Cost (reserve on Phase E)		0% (as planned but residual A-D could be rolled over)		
Schedule days		12		
Technical Resource		Limit	CBE	Margin
Mass, Dry (kg)		1066.5	1018.4	4.7%
Power (W)		823	685	20.3%
RF Link - At Lunar Distance				
Uplink	HGA – S-Band	(WCS)	-	20.3 (dB)
	Omni – S-Band	(DSN)	-	15.9 (dB)
Downlink	HGA - S-Band	(WCS)	-	6.93 (dB)
		(USN)	-	4.64 – 7.44 (dB)
	HGA - Ka-Band	(WCS)	-	7.46 (dB)
RF Link – Worst Case (Tumble at Lunar Distance)				
Uplink	Omni – S-Band	(DSN)	-	15.9 (dB)
Data & Computational Margins				
Ka Downlink Utilization (min)		180	85.0	47%
Measurement Interruptions – Data Capture (Orbits)		234	80	193%
1553 Bus Utilization (kbits/sec)		300	193	35%
CPU (% utilization)		100%	29.6%	67%
EEPROM (Kb)		2048	983	23%
uP RAM (kB)		36864	18860	26%
PCI Bus (% utilization)		100%	21.8%	62%

