

# The International Lunar Network (ILN) and the US Anchor Nodes mission

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# SMD's Lunar Quest Program



- ✧ Lunar science flight projects line in SMD's 2009 budget
  - Robotic missions to accomplish key scientific objectives
  - Provide useful data to ESMD and SOMD for returning humans to the Moon
- ✧ Mission 1: **LRO**, which will transition after one year of operations to SMD for a 2-year nominal science mission
- ✧ Mission 2: Lunar Atmosphere and Dust Environment Explorer (**LADEE**), launch in 2011
- ✧ Mission 3: US delivery of two landed payloads as part of the International Lunar Network (**ILN**) – *first US robotic lunar landers since 1968!*
- ✧ These projects provide a robotic lunar flight program for the next decade, complement SMD's lunar R&A initiatives to build a robust lunar science community, and increase international participation in NASA's exploration plans



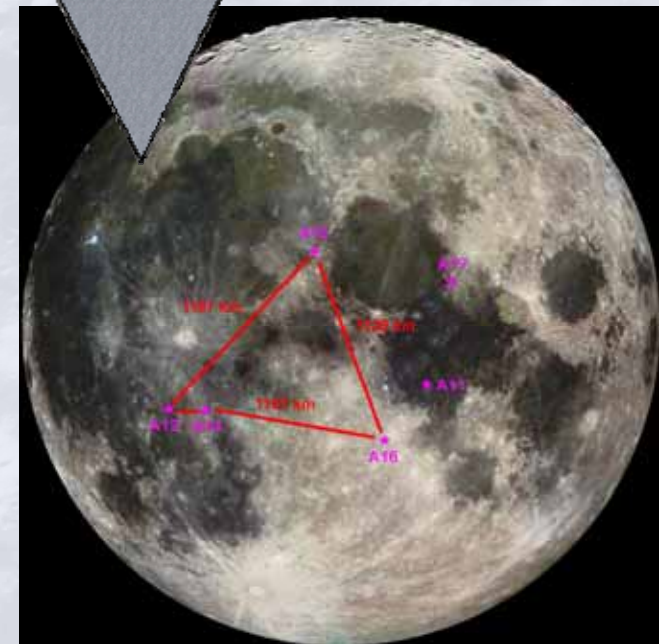
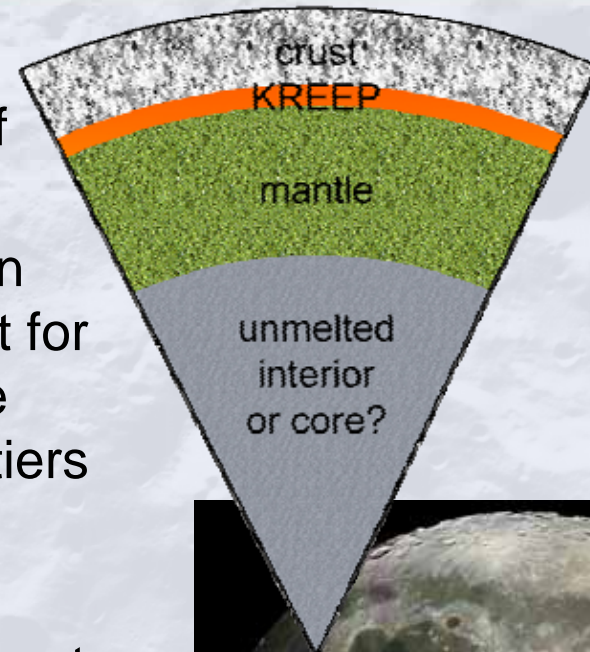
# The ILN and the Anchor Nodes

- ✧ The International Lunar Network (ILN) is a cooperative effort designed to coordinate individual lunar landers in a geophysical network on the lunar surface.
  - Each ILN station will fly a core set of instruments requiring broad geographical distribution on the Moon, plus additional passive, active, ISRU, or engineering experiments, as desired by each sponsoring space agency.
  - 24 July 2008: ILN Charter Signing Ceremony formed ILN Landing Site, Communications, and Core Instrument Definition Working Groups.
- ✧ The US is currently planning to provide two ILN nodes (the Anchor Nodes) in 2012-2014 – *this mission*.
  - Anchor Nodes Science Definition Team
  - Engineering Pre-Phase A
  - SMD is also considering a second pair in 2016-17.



# Geophysical Network Proposals

- ✧ The Moon is an **active, differentiated, terrestrial** body, preserving a record of early planetary evolution.
- ✧ A Lunar Geophysical Network has been recommended by the Scientific Context for the Exploration of the Moon (2007), the Tempe meeting (2007), and New Frontiers in the Solar System (2008)
- ✧ The next generation of geophysical measurements have to improve on current knowledge. This can be accomplished by a network of nodes having a wider geographical placement, more sensitive instrumentation, and a longer baseline of observations than the Apollo network.





# Anchor Nodes SDT

- ✧ The goal of a Lunar Geophysical Network is to understand the interior structure and composition of the moon
- ✧ Science Definition Team formed in March 2008 to to address what science is uniquely enabled by the synergy of a network:
  - define and prioritize the scientific objectives for the ILN Anchor Nodes
  - define measurements required to address the scientific objectives
  - define instrumentation required to obtain the measurements
  - define criteria for selection of the initial two sites
  - identify technical challenges.
- ✧ The first US mission should provide **anchor nodes** that substantially improve on the Apollo experiments and ensure that first-order science questions will be answered
- ✧ **Seismometry** is uniquely enabled by a network mission. **Heat flow** measurements, **EM sounding**, and **laser ranging** are highly complementary measurements at each site.
- ✧ Mission objectives  $\Rightarrow$  measurement and mission requirements





# Anchor Nodes Science Objectives

- ✧ Objective 1: Understand the current seismic state and determine the internal structure of the Moon.
  - Seismic data enable determination of the internal structure and composition of a differentiated planetary body. Understanding strong moonquakes are generated and where they occur has implications for a lunar base
- ✧ Objective 2: Measure heat flow to characterize the temperature structure of the lunar interior
  - Heat flow measurements constrain the abundance of radiogenic elements, lateral variations in crustal and upper mantle composition, and the nature of thermal evolution in a differentiated body.
- ✧ Objective 3: Use electromagnetic sounding to measure the conductivity structure of the lunar interior.
  - Interior temperature and composition can be inferred from conductivity - joint interpretation with seismology and heat flow. Also measures the space-physics environment.
- ✧ Objective 4. Determine deep lunar structure by installing next-generation laser ranging capability.
  - Highly accurate laser ranging reveals irregularities in lunar rotation due to tidal changes of the Moon's shape and the effects of internal layering. Ranging also enables tests of gravitational physics and improvement of the lunar orbit.



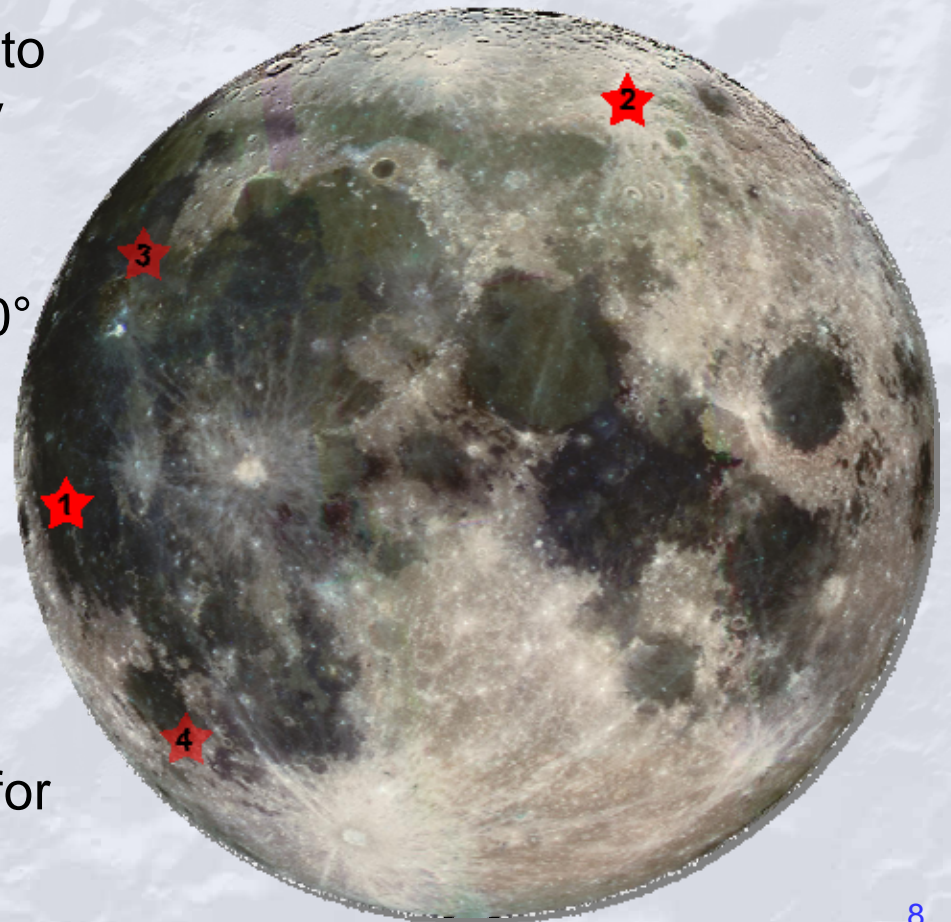
## Other SDT Findings

- ✧ *Operations:* Seismic stations must operate in concert with one another. This requires nodes to be simultaneously and continuously operational.
- ✧ *Number of nodes:* 4 nodes is the minimum number to accurately locate a shallow moonquake anywhere on the lunar surface; 2 is the minimum to investigate the lunar core
- ✧ *Lifetime:* To achieve new science, seismic stations must operate for sufficient time to receive enough signals (6 years for 4 nodes/shallow moonquakes; 2 years for 2 nodes/deep moonquakes)
- ✧ *Location:* If the network begins with one 2-node mission, new science can only be achieved with specific, non-polar site selection.



# Anchor Nodes Site Selection Criteria

- ✧ Strong science desire for farside placement. Due to dependency upon communications satellite, SDT also identified suitable nearside sites.
- ✧ Node 1 must be placed antipodal to a moonquake epicenter known by the Apollo network:  $-5^{\circ}\text{S}$ ,  $75^{\circ}\text{W}$  is only nearside site
- ✧ Node 2 must be placed within  $\sim 30^{\circ}$  of the same epicenter, so could also be nearside 2:  $30^{\circ}\text{N}$ ,  $75^{\circ}\text{E}$
- ✧ Nodes 3 and 4 should form a triangle with western node, preferably on the farside
- ✧ Site selection criteria will also involve desires from engineering for DV and comm







# Mission Design Parameters

- ✧ Develop a mission to emplace two scientific geophysical nodes onto the lunar surface that serve as anchor nodes for the International Lunar Network
- ✧ Launch in 2012 (goal) to 2014 (threshold), depending on resource availability
- ✧ Mission is Category III, Class D
- ✧ Provider: MSFC and APL
- ✧ Instrument selection will be competed in the context of the SDT and the ILN Working Groups results
- ✧ Mission length: Minimum of 2 years of surface operations
- ✧ Land at specific, nonpolar regions of the Moon
- ✧ Initial mission goal of \$200M life cycle cost, including launch vehicle
- ✧ Pre-Phase A kicked off in March 2008; Phase A entry expected early 2009



# Pre-Phase A Highlights

## ✧ Power Subsystem Trade (GRC)

- Objective: Recommend high-level power system options covering potential locations being considered by the science definition team. Document criteria used to determine viable/nonviable options. Provide results to spacecraft design and integration teams.
- Result: Derivative ASRG is enabling for minimum lander mass vehicle

## ✧ Inter-center Concept Evaluation Team (ICET)

- Objective: Identify and assess existing technologies to enable emplacement of multiple lunar surface science instrument packages.
- Membership: MSFC, APL, ARC, and JPL
- Traveled to JPL and ARC for site visits, with emphasis on leveraging existing technologies at the sub-system/component level.
- RFI issued with 18 industry responses. No “new” technologies identified.





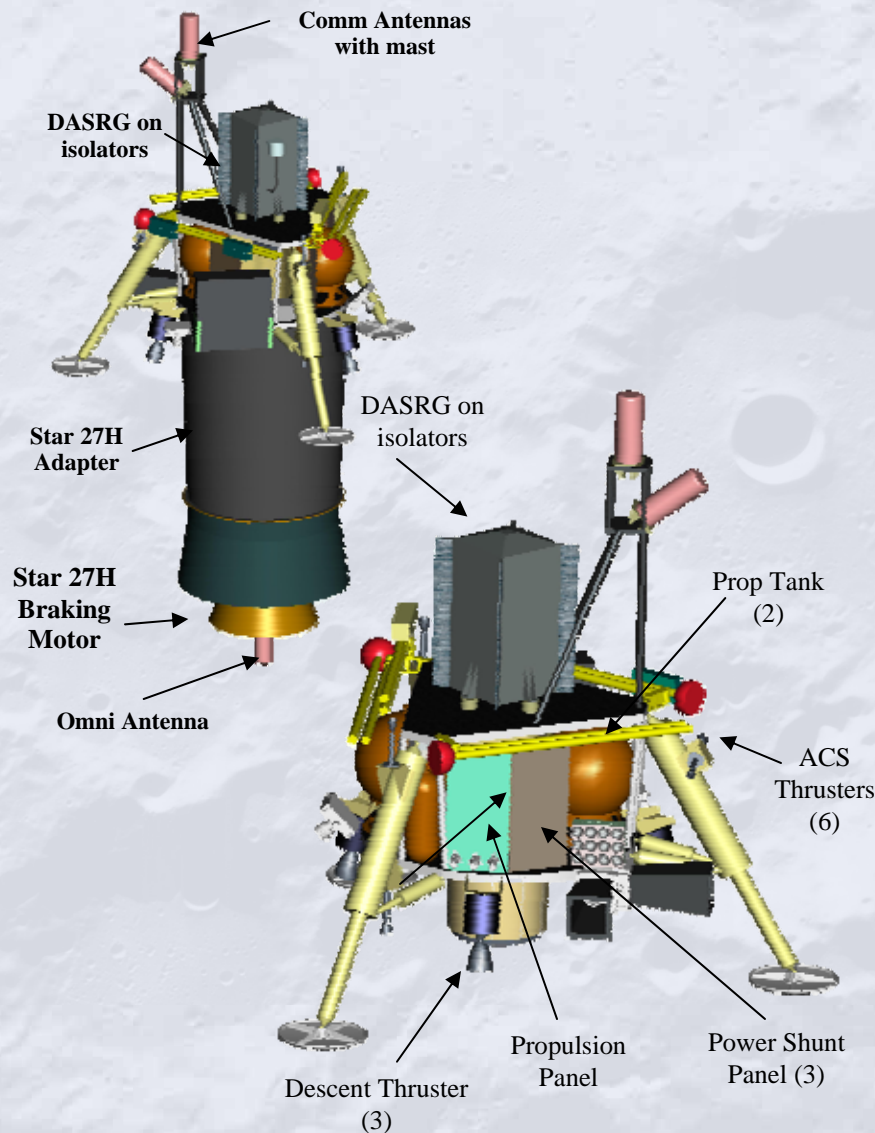
## Pre-Phase A Highlights (cont.)



- ✧ MSFC and APL conducted 3 evaluations in the APL Concurrent Engineering (ACE) laboratory. Detailed concept engineering analysis and parametric cost estimates drafted for each case:
  - Floor Science with soft lander and 1 instrument
  - Baseline Science with soft lander and 4 instruments
  - Hard landers and penetrators for baseline and floor science
  - Additional mission concept work to evaluate launching
    - one lander on a Minotaur V,
    - two landers on a Taurus II/Delta II/Falcon 9 and
    - four landers on an Atlas V 401.
  - Additional mission concept/cost estimation work completed to identify options for a \$200M mission
- ✧ ILN technical peer review conducted with members from JPL, Ames, GSFC, GRC, MSFC and APL on August 6
- ✧ Two technical ILN Integration Meetings were held with the SDT and several telecons.

Engineering assessments confirm concept feasibility with multiple solutions to achieve floor and baseline science.




# Baseline Science Lander Summary



- ✧ Direct trajectory to moon with solid stage providing braking burn.
- ✧ Structure includes composite decks and metal landing legs for soft landing.
- ✧ Liquid bi-propellant landing using high pressure lightweight thrusters and custom tanks.
- ✧ Power provided by Derivative ASRG (DASRG) nuclear power source with small batteries to handle peak power.
- ✧ Daily data transmission to DSN ground station
- ✧ Small warm electronics enclosure with heat pipes & radiator requires no heater power on surface.
- ✧ Landing cameras for horizontal velocity, drives sunlit landing (3-4 day launch window).
- ✧ Single string electronics with parts selected and tested for 8 year life & radiation tolerance.



# Lander / Launch Vehicle Summary

Launch Vehicle	Minotaur V	Taurus II	Delta II	Falcon 9 B1	Falcon 9 B2	EELV (Atlas V 401)	Key Lander Risks
<i>TLI mass*</i>	413 kg CCAFS	1250 kg	1285 kg	1925 kg	2680 kg	3580 kg	
DASRG Lander (Floor or Baseline Science) 		2 landers	2 landers	2 landers	2 landers (likely 3)	4 landers	- DASRG new development - Propellant tank new development
DASRG Lander (Floor Science) 	1 lander	Case 1 design preferred to accommodate baseline science					- DASRG new development - Mass Margins -- Propellant tank new development - Solid Motor new development
Battery / Solar Lander (Floor or Baseline Science) 					2 landers	2 landers	
Launch Vehicle Risks	<ul style="list-style-type: none"> <li>- Upgrade of Mino IV</li> <li>- First launch of Mino IV Plus Sep 2009</li> <li>- Requires Waiver to Commercial Space Act</li> <li>- Not approved for CCAFS</li> <li>- Is not certified for nuclear</li> </ul>	<ul style="list-style-type: none"> <li>- In design</li> <li>- Estimated First Launch Dec 2010</li> <li>- Is not certified for nuclear</li> </ul>	<ul style="list-style-type: none"> <li>- Cost risk associated with maintaining ground facilities</li> </ul>	<ul style="list-style-type: none"> <li>- In design</li> <li>- Estimated First Launch early 2009</li> <li>- Is not certified for nuclear</li> </ul>	<ul style="list-style-type: none"> <li>- In design</li> <li>- Estimated First Launch 2010</li> <li>- Is not certified for nuclear</li> </ul>		

Mass and power margins >30%

Mass and power margins 20-30%

\*excludes any modifications required for a nuclear launch



# International ILN Activities

- ✧ 12 March 2008:
  - ILN Informational Briefing to Potential Partner Agencies at LPSC
  - ILN charter WG formed
- ✧ 23-24 July 2008:
  - ILN Charter Signing Ceremony by nine nations
  - Initial Meetings of two ILN Working Groups: Core Instrument Definition WG and Navigation and Communications WG
- ✧ On-going Work:
  - Chartering and staffing new ILN working Groups (e.g. New Technologies)
  - The Core Instruments Working Group is now developing a “Science Objectives and Measurements” spreadsheet analogous to that developed earlier by the US ILN Anchor Nodes study
- ✧ 20 December 2008:
  - ILN Core Instrument Agreement



# Summary

- ✧ The International Lunar Network accomplishes high priority science by coordinating landed stations from multiple space agencies
- ✧ The Science Objectives of the network are to understand the interior structure and composition of the moon
- ✧ ILN Anchor Nodes are currently in development by MSFC and APL under the Lunar Quest Program
- ✧ Pre-phase A engineering assessments are complete and can achieve science requirements
- ✧ ILN Working Groups are ongoing and will provide guidance to mission payload and schedule

