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APL

INTERNATIONAL LUNAR NETWORK ANCHOR NODES AND ROBOTIC LUNAR LANDER PROJECT UPDATE

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- ILN-derived Mission Concept Studies
  - Lunar Polar Rim (LPR) – rapid mission architecture for quickly demonstrating technology and landing on a polar rim
  - Lunar Polar Volatiles Stationary (LPVS) – single point lander to study volatiles in a Permanently Shaded Region (PSR)
  - Lunar Polar Volatiles Mobility (LPVM) – a lander with rover to study volatiles at multiple locations in a Permanently Shaded Region (PSR).
- Risk Reduction Status
- Summary

International Lunar Network (ILN)

- A series of US and International Partner provided Lunar Landers which act as common science nodes in a lunar geophysical network
  - Each Lander in ILN will provide a minimum core suite of instruments
  - NASA will provide 2 to 4 anchor nodes
- Letter of intent signed with eight other space agencies: Canada, Britain, Germany, France, Italy, Japan, India and Korea
- Four Working Groups: Enabling Technology, Communications, Core Instrumentation and Site Selection
  - Several Working Group reports are complete or in work

ILN Anchor Nodes mission

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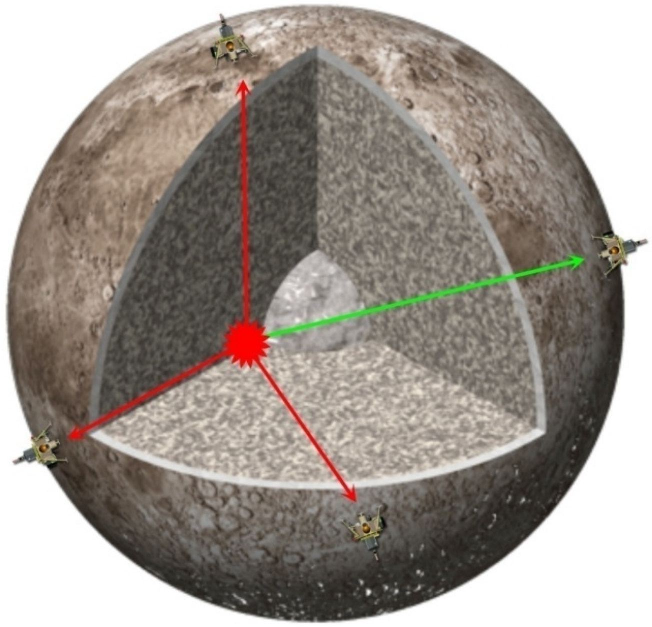
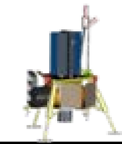
- In pre-phase A study with a technology risk reduction program since Spring 2008
- Initial Trade Study Report in the Fall of 2008
- Final Science Definition Team report released in January 2009

Key ILN Science Requirements (from SDT report)

- **Science Baseline:** Use seismometry, heat flow, electromagnetic sounding, and laser retroreflectors to obtain complementary geophysical data from a network of **four nodes** operating simultaneously and continuously for **6 years** (1 lunar tidal cycle)
- **Science Floor:** Determine the deep interior velocity structure of the Moon and place constraints on the core size/density by operating **2 broadband seismometers** simultaneously and continuously for **2 years** placed in specific non-polar locations
- ***There's a lot of room between these two definitions!!***



Comparison of ILN Lander Options

	Lander Option	
Note: All mass and power figures include 30% growth margin	Solar/Battery 	ASRG 
Wet Mass (Cruise/Lander) (kg)	**1164/422**	**798/260**
Generic max Landed Payload/Support Mass (kg)	**157**	**37**
Max Inst. Payload Mass for ILN (kg)	**25**	**30**
Max Inst. Payload Power for ILN (W)	**19.5 day/7.8 night**	**Up to 74** **Configuration dependent**
Launch Options	• ***2 on Falcon 9 B2**** • **2 on Atlas V 401 with 952 kg excess capacity** • **4 on Atlas V 531**	• **2 on Atlas V 401 with 1684 kg excess capacity** • ***4 on Atlas V 401**** • **Other LVs require RPS qual.**

Lander was sized for this launch configuration.

- **Both options are sized to perform ILN mission**
- **ASRG option has additional mass and power margin for growth or other payloads**
- **Solar-Battery option has significant total payload capacity for other Lunar missions**

ILN Anchor Nodes mission

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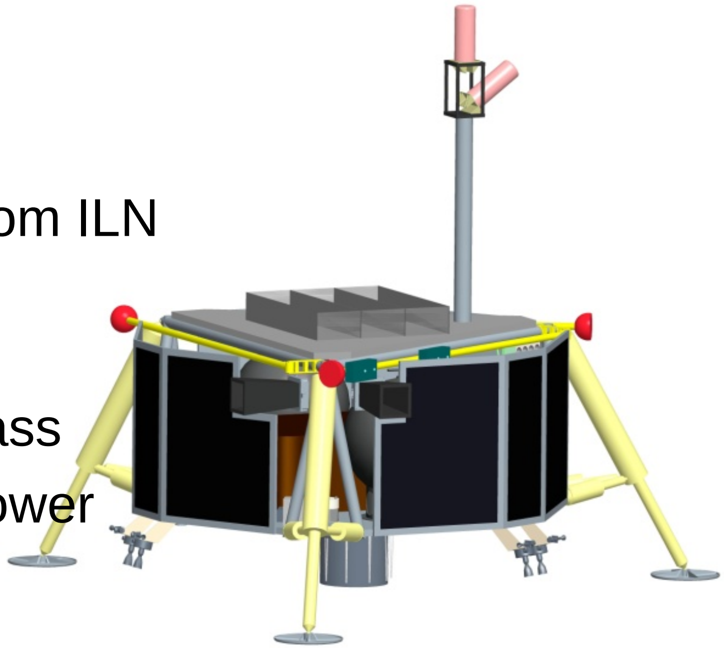
- Risk Reduction plans were developed, prioritized and initiated
- NASA HQ technical and cost review in June 2009
  - Extensive technical progress beyond usual Pre-phase A
  - Cost estimates consistent with the design
- Mission on hold awaiting Decadal Survey prioritization
- Project team examining lander bus applications to other lunar science missions *while maintaining ILN capability*

Lunar Polar Rim

- Mission Goals
  - Technology Demonstration – precision landing
  - ISRU demonstration
  - Science – dust & plasma, regolith properties
  - Microrover
- Single Solar Array – Battery Lander config from ILN SAB
  - Switched solar array and radiator locations
- Launch Vehicle: Delta II class or Falcon 9 class
- Lander Available Payload Mass / Payload Power driven by life requirement
  - Operate lunar day only: 109kg / 25W
  - Operate lunar day and survive lunar polar night: 76kg / 20 (day) / 5W (night)
  - Operate lunar day and night for 6 years: 19kg / 12W (ILN, 372 hr night)



Lunar Polar Volatiles Stationary

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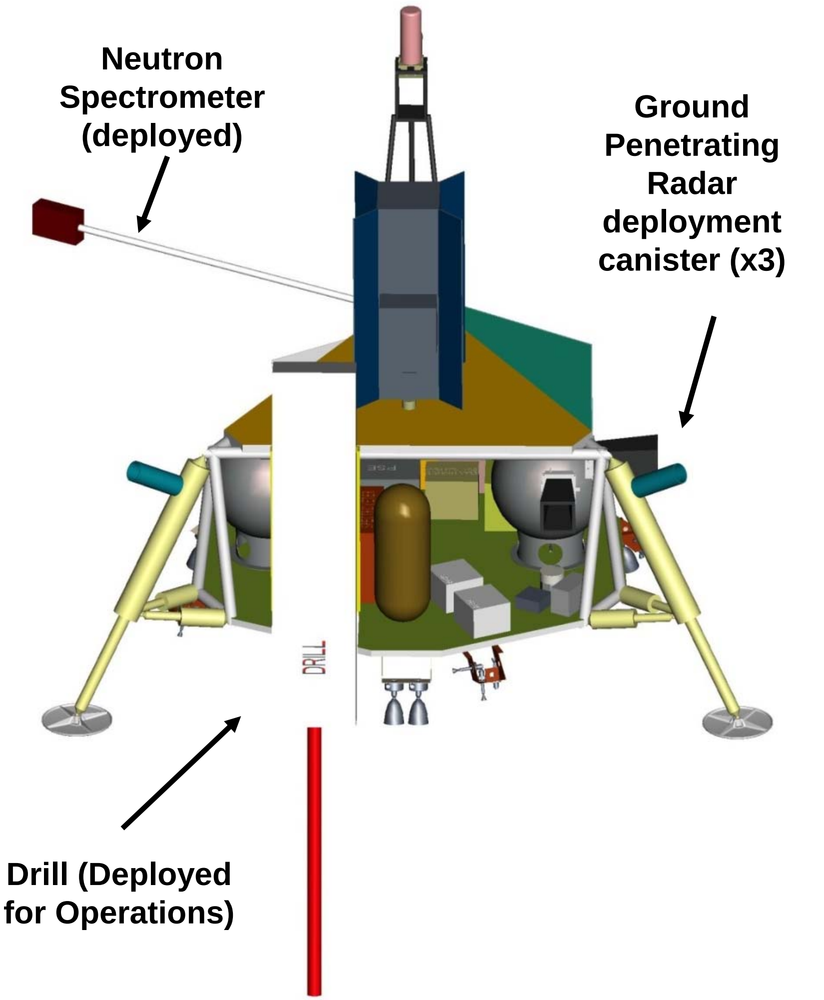
- Mission Goals: detailed inventory of volatile species and constrain the sources of polar volatiles and their nature
- Single stationary polar lander to permanently shadowed lunar crater
  - ASRG powered and launched via Atlas V EELV (Co-manifest compatible)
  - Land at a predetermined obstacle free site with 200m accuracy using TRN, no HDA
  - Site selected to provide seven days / month DTE communication
- Detailed analysis of volatile compounds at single site
  - Payload includes drill (to 1-m in lunar surface) and sample analysis, neutron spectrometer, ground penetrating radar and EM sounding
  - Also provide seismometer to act as a single node of an ILN seismometry network.
  - Mission life provides 3 months of active drilling and 6 years seismometry



Surface Configuration

Lunar Polar Volatiles Mobile (study for Planetary Decadal Survey)

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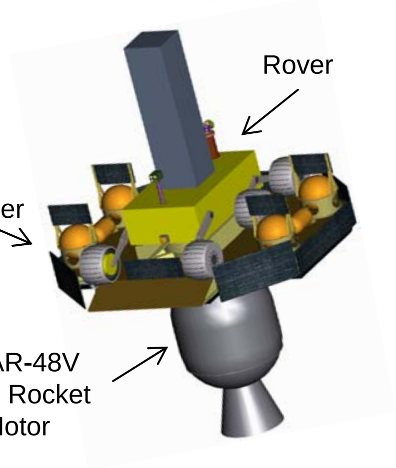
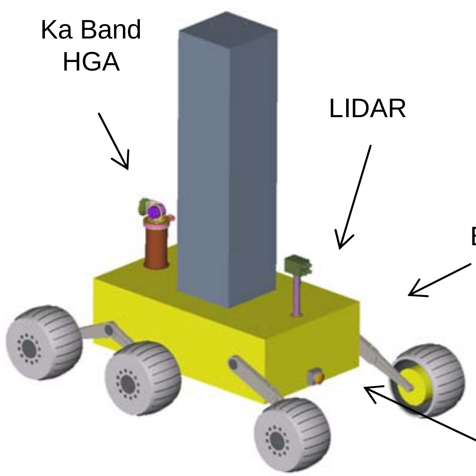
- Single polar lander with mobility to permanently shadowed lunar crater
  - ASRG or battery powered and launched via Atlas V EELV (Co-manifest compatible)
  - Land at a predetermined obstacle free site with 200m accuracy using TRN, no HDA
  - Site selected to provide seven days per month communication direct to earth
- Mobility enables polar volatiles objectives plus information about spatial distribution of volatiles
  - Payload may include drill (to 1-m in lunar surface) and sample analysis, neutron spectrometer, ground penetrating radar and EM sounding
  - May also provide seismometer to act as a single node of an ILN seismometry network (ASRG version only)
- An RLEP 2 concept (developed by this team) with updated knowledge gained by this team from the small lander efforts.

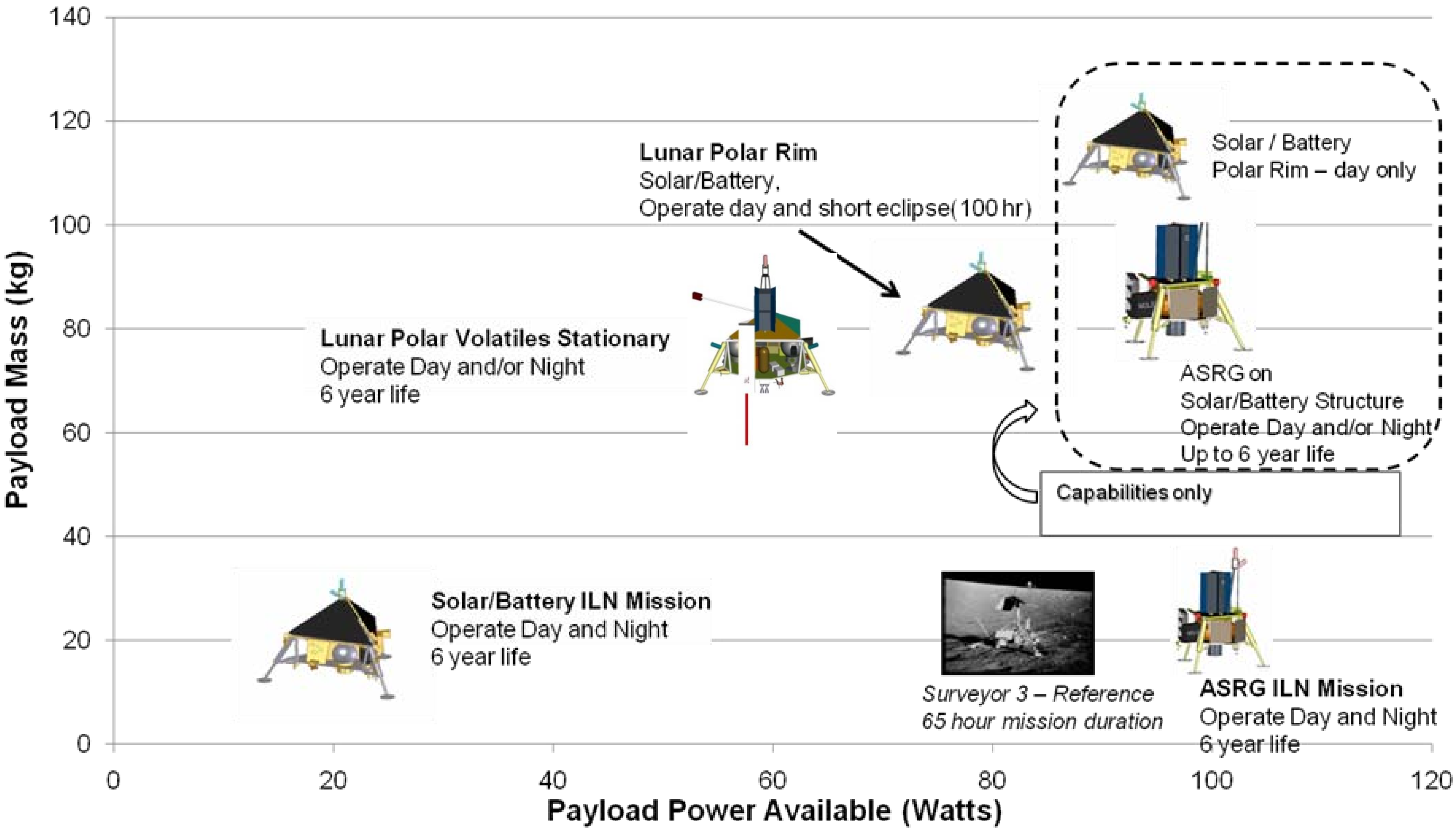


Integrated Flight System



Battery Rover (could also accommodate ASRG)

Small Robotic Lunar Lander Summary (2008-10)



Robotic Lander Testbed Phase 1

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- **Cold Gas Test Article (Operational)**
  - Completed in 9 months
  - Demonstrates autonomous, controlled descent and landing on airless bodies
  - Incorporates flight algorithms, software environment, heritage avionics, and sensors
  - Gravity cancelling thruster for reduced gravity operations that can vary with throttling
  - Flight time of 10 seconds; descent from 3 meters altitude
  - Utilizes 3000psi compressed air for safety, operational simplicity, and multiple tests per day
  - 3 primary and 6 ACS thrusters

Accomplishments

Fully Functional, Flown >200 times

Upgraded with flight-like algorithms

Robotic Lander Testbed Phase 2

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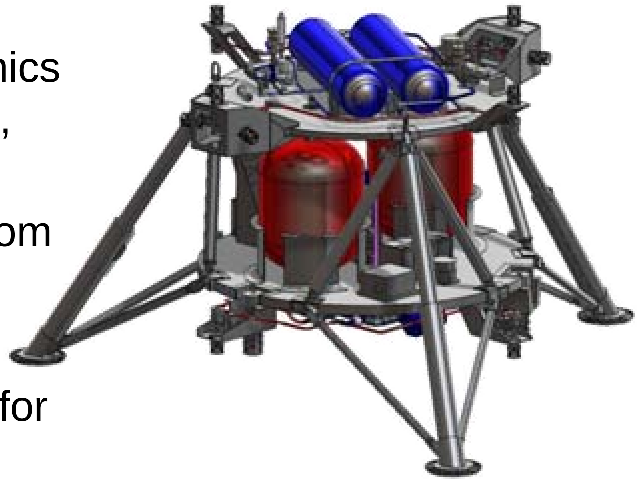
- **Warm Gas Test Article** (Winter 2010) adds to Cold Gas Test Article Functionality:
  - Demonstrates terminal descent phase autonomous controlled
  - Began WGTA September 2009 ; Critical Design Review March 2010
  - Flight-design sensor suite, software environment, avionics processors, GN&C algorithms, ground control software, composite decks and landing legs
  - Longer flight duration (approx. 1 min) and descends from 30 meters to support more complex testing
  - Can accommodate 3U or 6U size processor boards.
  - Incorporates Core Flight Executive (cFE) which allows for modular software applications
  - 12 thruster ACS configuration. Option to only fire 6 ACS thrusters. Provides capability to support testing of hazard avoidance or precision landing algorithms. Emulates pulse or throttle system.
  - G-thruster can be set between 0-1 g for descent



Summary

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- ILN Anchor Node mission is on hold awaiting Decadal Survey results, but International Lunar Network activities continue
- Robotic Lunar Lander Project has refined lander bus design to be suitable for multiple mission scenarios
- Opportunities may arise in both SMD and ESMD for lunar landers that provide additional measurements but may still fulfill a US contribution to ILN collaboration
- Equally important, the RLLD team's demonstration and qualification of robotic lander technologies have extended application to future robotic missions to airless bodies