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

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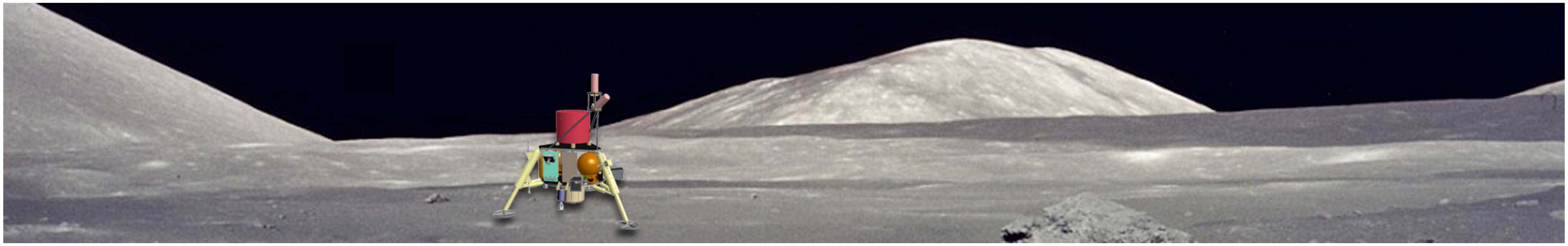
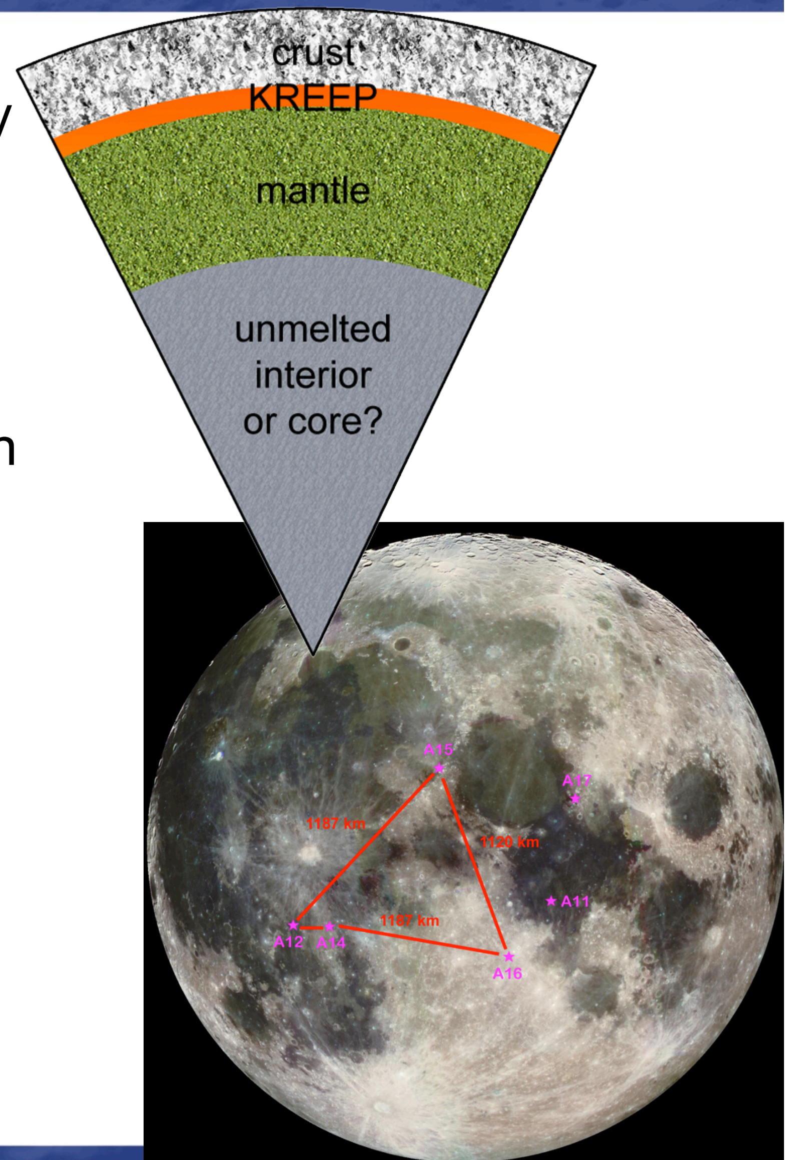


The ILN and the US Anchor Nodes

- 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 – Canada, France, Germany, India, Italy, Japan, Korea, United Kingdom
  - Ongoing: ILN Working Groups: Enabling Technologies, Landing Site, Communications, and Core Instrument Definition Working Groups.
- NASA is examining the provision of two-four ILN Anchor Nodes in the 2015-2018 timeframe.
  - Anchor Nodes Science Definition Team completed Final Report Jan 2009, available on NSLI website
  - Engineering Pre-Phase A activities

A Lunar Geophysical Network

- 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 our current knowledge
  - wider geographical placement
  - more sensitive instrumentation
  - longer baseline of observations



Anchor Node Science Objectives & Baseline Instruments (from Science Definition Team (SDT) Jan 2009 report)

Objective	Instrument
1. Understand the current seismic state and determine the internal structure of the Moon	Three axis broadband seismometer
2. Measure heat flow to characterize the temperature structure of the lunar interior	Temperature and thermal conductivity measurements to depths > 3 m
3. Use electromagnetic sounding to measure the conductivity structure of the lunar interior	Electromagnetic Sounding Experiment
4. Determine deep lunar structure by installing next-generation laser ranging capability	Laser ranging experiment

- Seismometers must simultaneously and continuously operate for 6 years (to capture lunar tidal cycle); others may operate for less time
- 4 nodes minimum to accurately locate a shallow moonquake anywhere on the lunar surface; 2 minimum to investigate lunar core only
- Strong science desire for far-side placement to investigate global properties (heat flow in highlands and SPA terrains, crustal thickness, etc.)

Notional Instrument Payload Used for Lander Trades

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Configuration	Measurement	Instrument *	Mass (kg)	Data (Mb/day)	Power (W)	Accommodation
Floor and Baseline	Seismometry	Seismometer (ExoMars)	5	100	2.6	Good surface contact Vibration isolation Thermal isolation
Baseline Only	Heat Flux	HP3 mole (ExoMars)	1.5	10	5.7 pk 0 nonop	Regolith contact to 3 m Initial vertical alignment Minimize thermal variations
	EM Sounding	Electrometer, magnetometer, langmuir probe (excl booms)	2.6	25	6.1 op 2 nonop	EM cleanliness Instrument separation from spacecraft
	Laser Ranging	Retroreflector (LRO)	0.46	0	0	+/– 15 deg alignment to Earth

*** Representative instrument concepts used to develop lander concepts. Actual instruments are expected to be competed**

Note: Values in tables represent current best estimates and do not carry margins

Some synergy may exist among SMD, ESMD (surface plasma environment, hazard avoidance), and SOMD (comm sat, laser comm testing, etc.)

ILN Anchor Node Lander Concept Evolution

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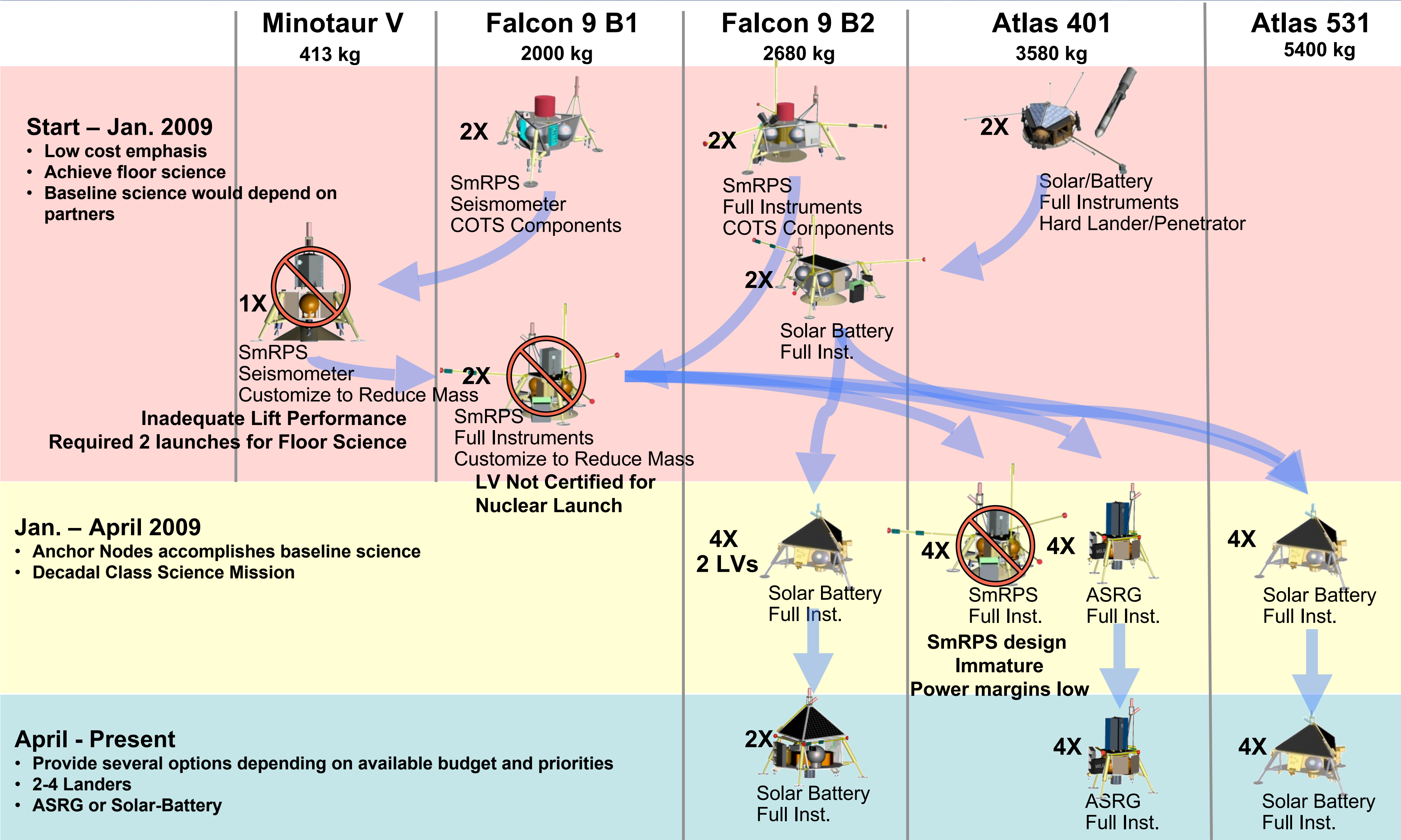
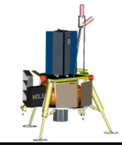


Anchor Nodes Major Trades Summary

- Power: Solar Arrays vs Radioisotope Power System (RPS)
  - Alternative concept studies indicate RPS may be required to meet continuous operation requirement within target lander size class
- Instrument Accommodation
  - Instruments appear to require soft lander approach
  - Vibration isolation is challenging but can be solved (Stirling Engine, lander structure and lunar surface thermal disturbances)
- Launch Vehicle Accommodations
  - Given RPS then only Atlas V can accommodate (at this time)
- Number of Nodes
  - How many vehicles fit on single launch vehicle
  - Operations issues
  - Budget issues
- Communications
  - Far side nodes strongly desired by science
  - Communications satellite needs to be provided

Resulting Lander Options

Note: All mass and power figures include 30% growth margin	Lander Option	
	Solar/Battery 	ASRG 
Wet Mass (Cruise/Lander) (kg)	1164/422	796/260
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	• 1 on Taurus II Falcon 9 B1 • *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**

Mission Concept of Operations

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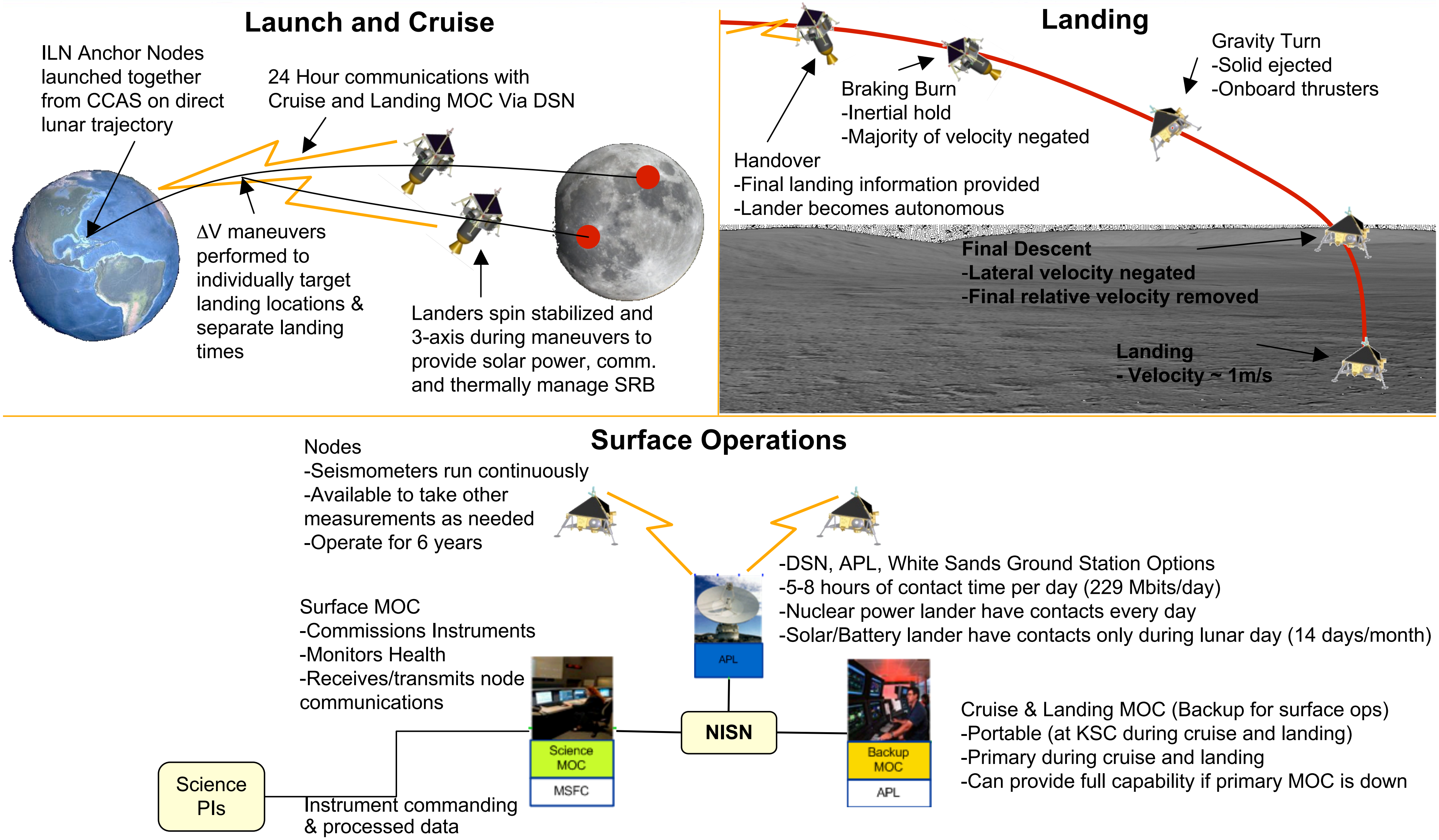
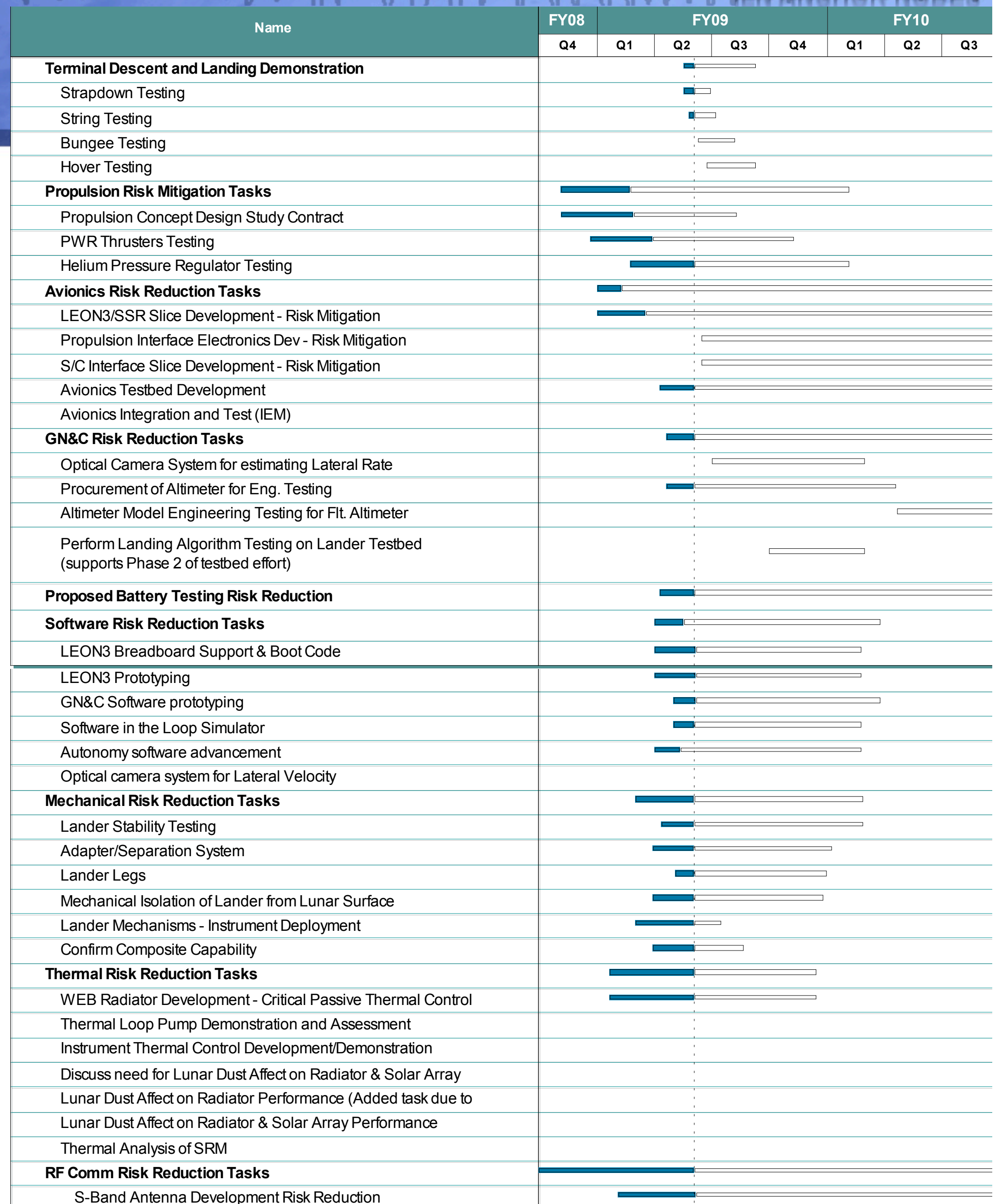


ILN Recent Accomplishments

- MSFC and APL completed and presented eight different mission concept design studies to HQ/SMD
  - Detailed concept engineering analysis and parametric cost estimates were provided
  - Variations of nuclear powered landers on multiple launch vehicles
  - Variations of solar array/battery powered landers on multiple launch vehicles
- PA&E Review June 23 & 24 – to understand evolution and maturity of mission concepts. Several key points were successfully established:
    - Perception of cost growth from "$200M mission to $800M mission" was due to evolution of SMD direction from "cost driven mission" to "science driven mission"
    - ILN mission concept design and analysis is well beyond pre-phase A maturity and cost estimates are complete
    - The MSFC/APL team is well integrated and functioning as an effective partnership
  - PA&E team briefed findings to SMD AA 7/17
  - PA&E report to OMB due in August
- Now working on risk reduction tests and activities to support development of the ILN lander
  - Includes activities for each subsystem
  - MSFC, APL, Ames, JPL, GRC and the local contractor base all providing various tasks

Risk Reduction Schedule

- Integrated schedule includes all high priority risk reduction activities
- Project is managing each risk reduction activity with schedules and budget allocations
- Significant funds being applied to reduce risk and validate design concepts



MSFC Lunar Lander Test Bed

- NASA contributed $4M to develop a Lunar Lander testbed capability at MSFC
- Phase 1 – prove out MSFC test facility
  - Ames lent their hover lander
  - Successfully completed 12/17/08
- Phase 2 – implement MSFC “ILN-Like” test vehicle
  - Cold gas propulsion system
  - Primarily supports demonstration of GN&C algorithms
  - Demonstrations by May 2008
- Phase 3 – integrate flight-like components for risk reduction tests
  - Landing sensors (cameras, altimeters), Instruments, Structure features (legs)
  - Alternative prop systems for descent and landing tests

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
- Lander design is being matured through risk reduction activities
- ILN Working Groups are ongoing and will provide guidance to mission payload and schedule