Overcoming molehills and mountains implementing a new program

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agenda

- Purpose of Presentation
- Timeline of internal and external factors affecting Program Formulation & Implementation to showcase challenges
- Introduction to Science Mission Directorate and Lunar Quest Program (LQP)
- Hills climbed to reach current status
- Challenges, successes and status of LQP components
- Programmatic successes and challenges
- Conclusions

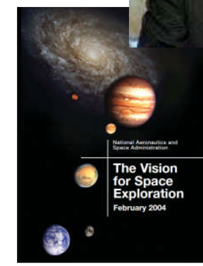
purpose of presentation

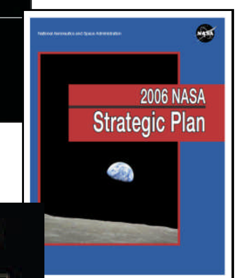
- *Share the challenges* that were encountered formulating a new program concurrent with formulating & implementing new spacecraft development projects
  - Immature mission concepts put on the fast track
  - Need to reconcile ambitious objectives with cost and budget reality
  - Changes of major stakeholders
  - Timing, timing, timing
  - Changing ground rules, assumptions, and risk tolerance
  - The role of centers

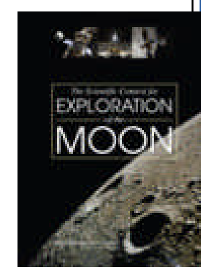
- *Share the successes* to date despite the challenges
- *Demonstrate how interdependencies* between the program, projects, NASA HQ environment, and external political forces *affect the process*, and how expectations must be managed while dealing with external factors and great change

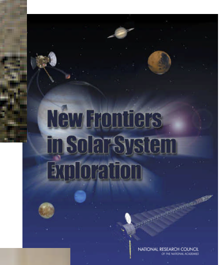
timeline of internal and external factors affecting program formulation & implementation

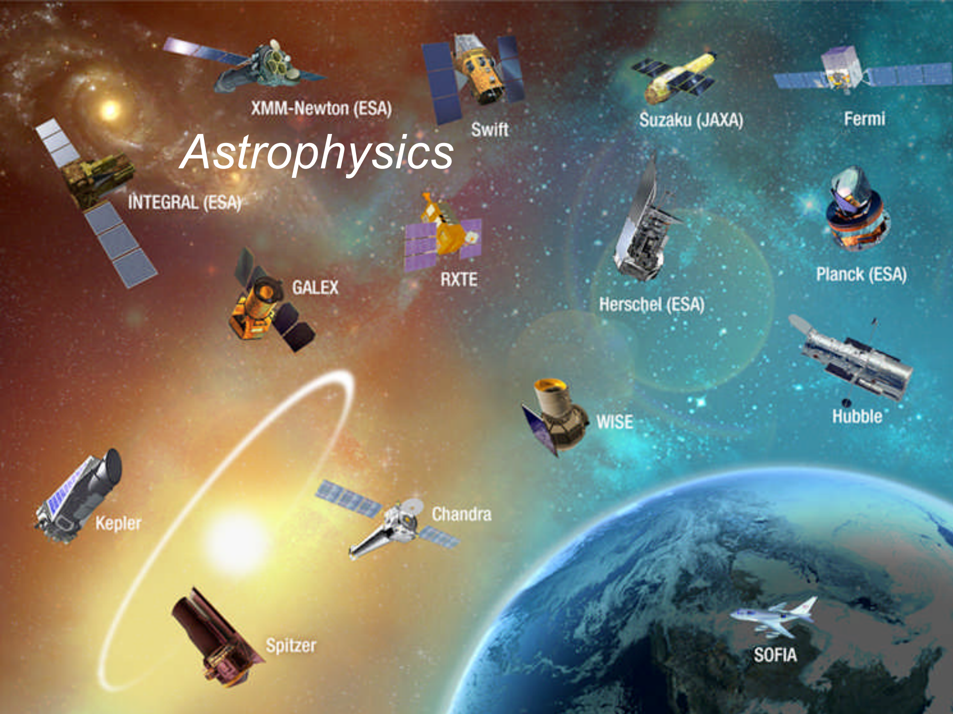
- February **2004:** The President's Vision for Space Exploration (VSE) sets the nation on a course to return to the moon
- **2005:** The NASA Authorization Act states that the VSE is the U.S. Space Policy and directs NASA to send robotic spacecraft to study the moon
- **2006:** NASA Strategic Plan established 6 strategic goals, calling for a balanced program of exploration and science and establishing a lunar return program
- **2007:** National Academies report, *The Scientific Context for Exploration of the Moon* (SCEM), supplements the 2003 Decadal Survey by focusing on scientific objectives which support the VSE.
- March **2008**: SMD AA address to the Subcommittee on Space & Aeronautics, U.S. House of Representatives
  - LADEE, ILN Anchor Nodes and Lunar R & A are included in the FY2009 NASA budget request
  - The Formulation of a Lunar Science Program (became the Lunar Quest Program) and management of the pre-formulation of the ILN mission was assigned to the MSFC Program Formulation team and the LADEE mission to the ARC pre-formulation team
- **2009**: LADEE passed KDP- A and KDP-B
- January **2010**: The Lunar Quest Program was approved by the Agency PMC
- February **2010**: the President redirected the agency away from the moon

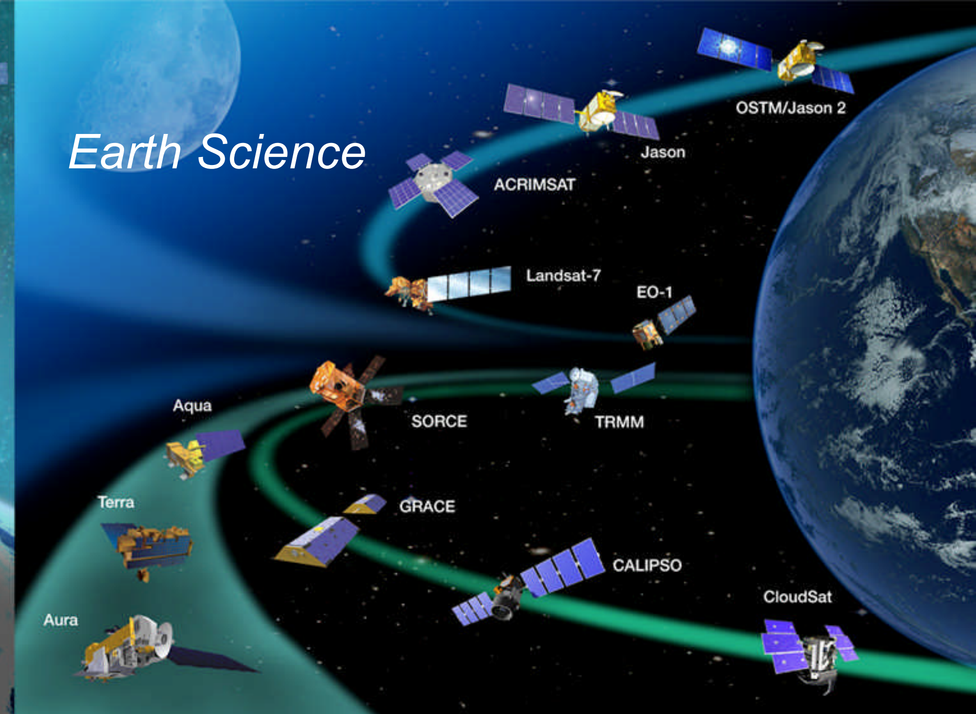



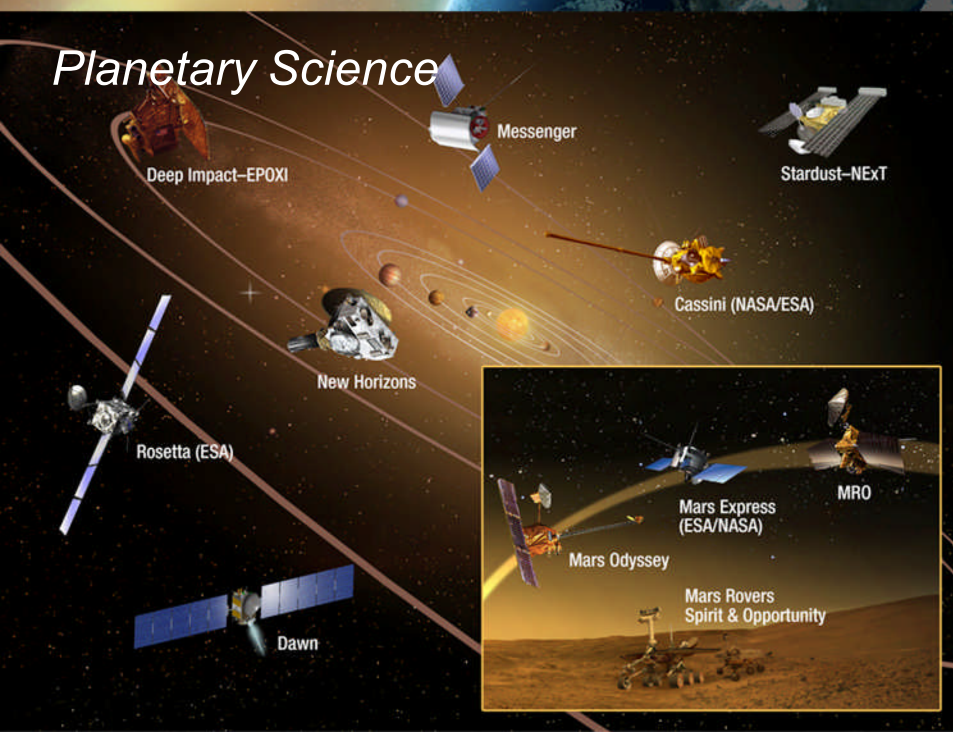


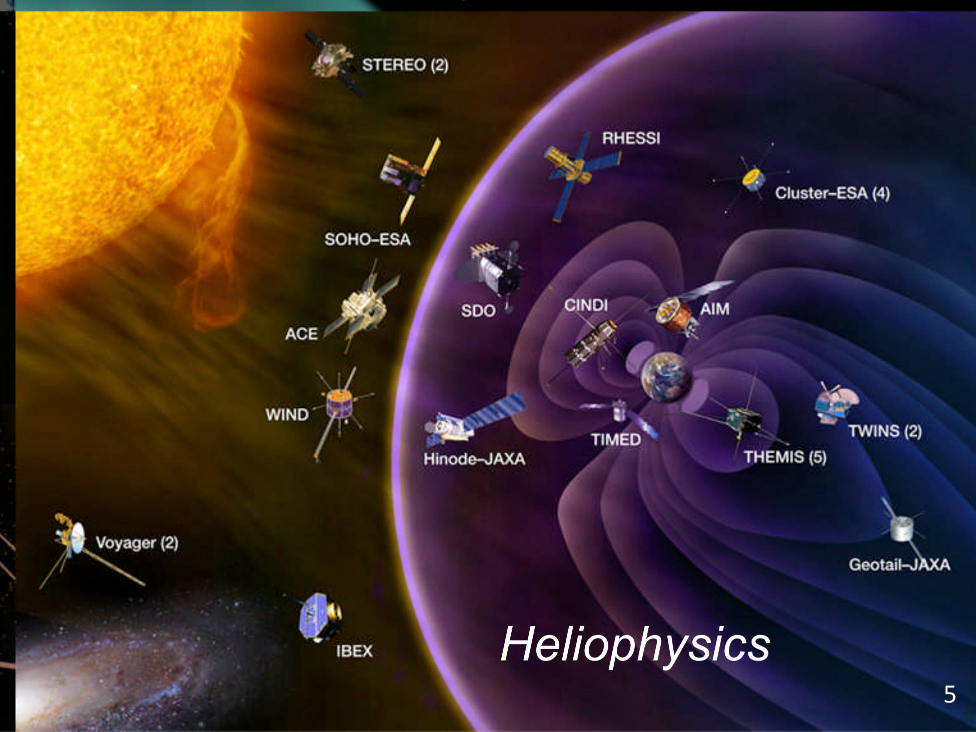





Astrophysics
XMM-Newton (ESA)
Swift
Suzaku (JAXA)
Fermi
INTEGRAL (ESA)
RXTE
GALEX
Herschel (ESA)
Planck (ESA)
WISE
Hubble
Kepler
Chandra
Spitzer
SOFIA


Earth Science
OSTM/Jason 2
Jason
ACRIMSAT
Landsat-7
EO-1
Aqua
SORCE
TRMM
Terra
GRACE
CALIPSO
CloudSat
Aura


Planetary Science
Messenger
Stardust-NExT
Deep Impact-EPOXI
Cassini (NASA/ESA)
New Horizons
Rosetta (ESA)
Dawn
MRO
Mars Express
(ESA/NASA)
Mars Odyssey
Mars Rovers
Spirit & Opportunity


STEREO (2)
RHESSI
Cluster-ESA (4)
SOHO-ESA
SDO
CINDI
AIM
ACE
WIND
Hinode-JAXA
TIMED
THEMIS (5)
TWINS (2)
Voyager (2)
Geotail-JAXA
IBEX
Heliophysics

SMD divisions, programs and projects

Planetary Science

Programs

Discovery
Mars Exploration
New Frontiers
Planetary Research
Lunar Quest

Projects

Formulation	Implementation	Operations (Primary)	Operations (Extended)
International Lunar Network	GRAIL	DAWN	ASPERA-3
TGO	Juno	EPCIXI	Classical
	LADEE	MESSENGER	LRD
	MAVEN	MRO	Mars Express
	MSL	New Horizons	Mars Odyssey
	STROFIO	Resets	MER
		Stardust	
		NEXT	

Earth Science

Programs

Earth System Science Pathfinder
Earth Systematic Missions
Earth Science Research

Projects

Formulation	Implementation	Operations (Primary)	Operations (Extended)
CLARRED	Aquarius	Calpao	Acrimaat
DESDyml	Glory	GOES O-P	Aqua
IceSat-2	GPM	CSTM	Aura
Jaxton-3	LDCM		Cloudast
SMAP	MPP		ECI-I
	OCO-2		GRACE
			Jaxon-I
			Source
			Tarra
			TRMM

Astrophysics

Programs

Physics of the Cosmos
Explorer (Astrophysics)
Hubble Space Telescope
James Webb Space Telescope
Exoplanet Exploration
Stratospheric Observatory for Infrared Astronomy
Astrophysics Research
Spitzer
Cosmic Origins

Projects

Formulation	Implementation	Operations (Primary)	Operations (Extended)
Euclid	Astro-H	Fermi	Chandra
DID	JWST	Herschel	Galex
JDEM	LBTI	Kack	HST Operations
LISA	NuSTAR	Kepler	Integral
SIM	SCMA Aircraft	Planck	RXTE
TPF	ST-7		Spitzer
WFIRST			Suraku (Astro-E2)
			SWIFT
			WISE
			WMAP
			XVM

Heliophysics

Programs

Explorer (Heliophysics)
Living with a Star
Solar Terrestrial Probes
NMP
Heliophysics Research

Projects

Formulation	Implementation	Operations (Primary)	Operations (Extended)
Solar Orbiter	IRIS	Hinod (Solar-B)	AIM
Solar Probe Plus	MMS	IBEX	CINDI
	RBSP	SOCI	CLUSTER-I
	SET		GBOTAIL
			RHESSI
			SOHO
			STEREO
			THEVIS
			TIMED
			TRACE
			TWINS
			Voyager
			WIND

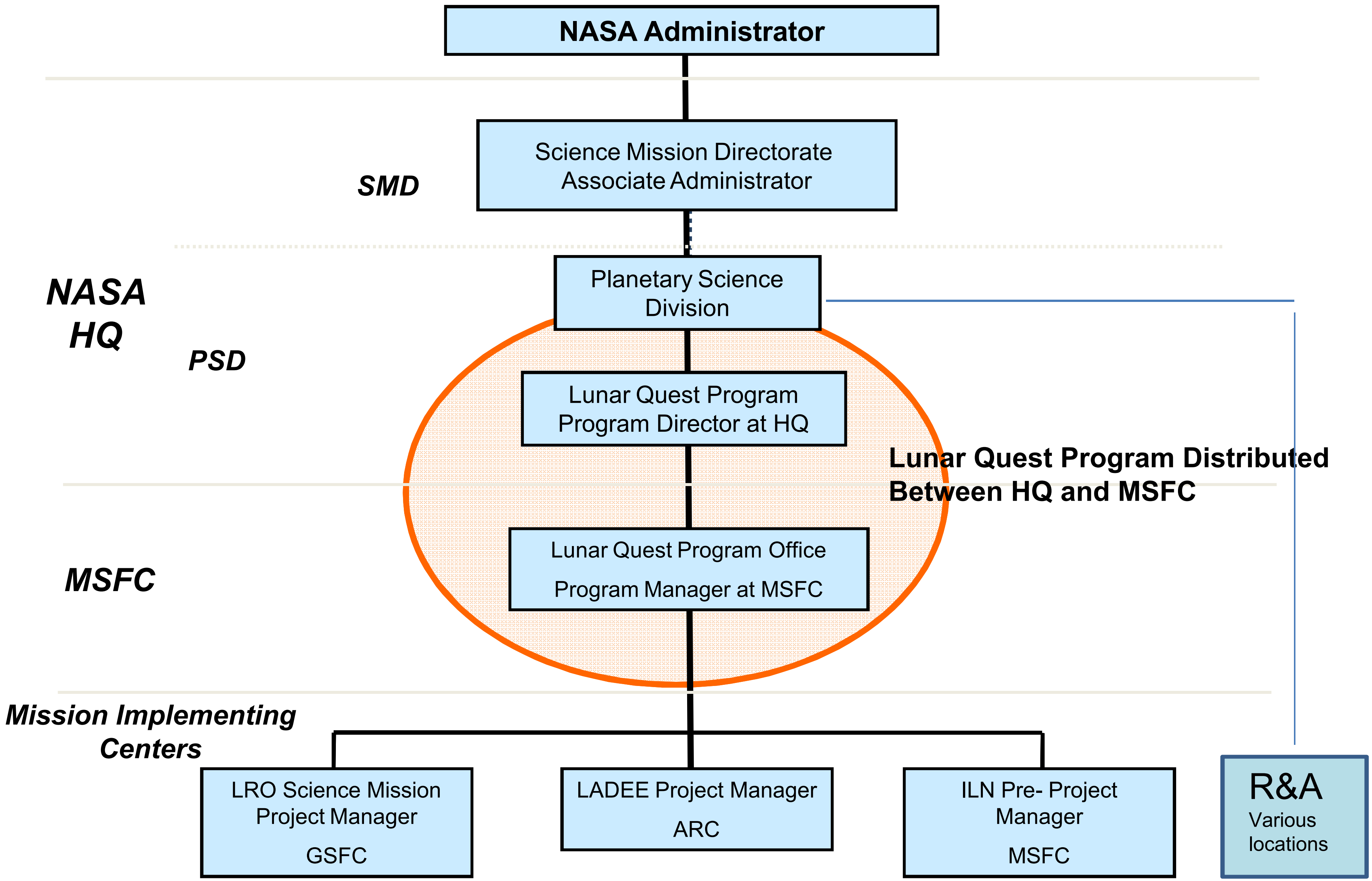
Joint Agency Satellites

Programs

Joint Polar Satellite Systems

Projects

Formulation	Implementation	Operations (Primary)	Operations (Extended)
JPSS-1			


NASA Administrator
SMD
Science Mission Directorate Associate Administrator
NASA HQ
PSD
Planetary Science Division
Lunar Quest Program
Program Director at HQ
Lunar Quest Program Distributed Between HQ and MSFC
MSFC
Lunar Quest Program Office
Program Manager at MSFC
Mission Implementing Centers
LRO Science Mission Project Manager
GSFC
LADEE Project Manager
ARC
ILN Pre- Project Manager
MSFC
R&A
Various locations

SMD established the need for a Lunar Focused Program

- SMD responded to the U.S. Space Exploration Policy to return to the Moon by
  - Accelerate scientific understanding of the Moon to inform exploration activities
  - Expedite the achievement of lunar science goals and objectives
  - Re-invigorate the lunar science community by increasing opportunities to participate in lunar missions and research
  - Focus and enhance numerous lunar R&A activities

- SMD identified two candidate missions
  - LADEE – Lunar orbiter common bus
  - ILN – Lunar geophysical network mission
- SMD created a program for lunar focused projects and R&A activities
  - No existing SMD Program was ideal for the new lunar-focused missions
  - Discovery/New Frontiers had lunar missions, but lunar would have to compete with other planetary interests
  - Successful mission proposals are often optimized to a specific mission without the ability to accommodate additional NASA strategic objectives which can be included in directed missions

The Lunar Quest Program

A strategic program performing community prioritized science through directed missions and competitively selected science investigations and R&A

LQP program level requirements

LQP-1: **The LQP shall conduct lunar science through the execution of robotic missions, Missions of Opportunity (MO), and Research and Analysis (R&A) within the available program budget.**

LQP-2: **The LQP elements shall address the prioritized lunar science community goals and objectives defined in current community reports and roadmaps such as the "Scientific Context for Exploration of the Moon" (SCEM, 2007), the Lunar Exploration Analysis Group (LEAG) Lunar Exploration Roadmap, and the Planetary Decadal Survey.**

LQP-3: **The LQP shall plan and implement a public engagement element covering formal and informal education and outreach activities.**

LQP-4: **The LQP shall support archival of new and existing lunar data and relevant mission data in the Planetary Data System (PDS).**

molehills and mountains

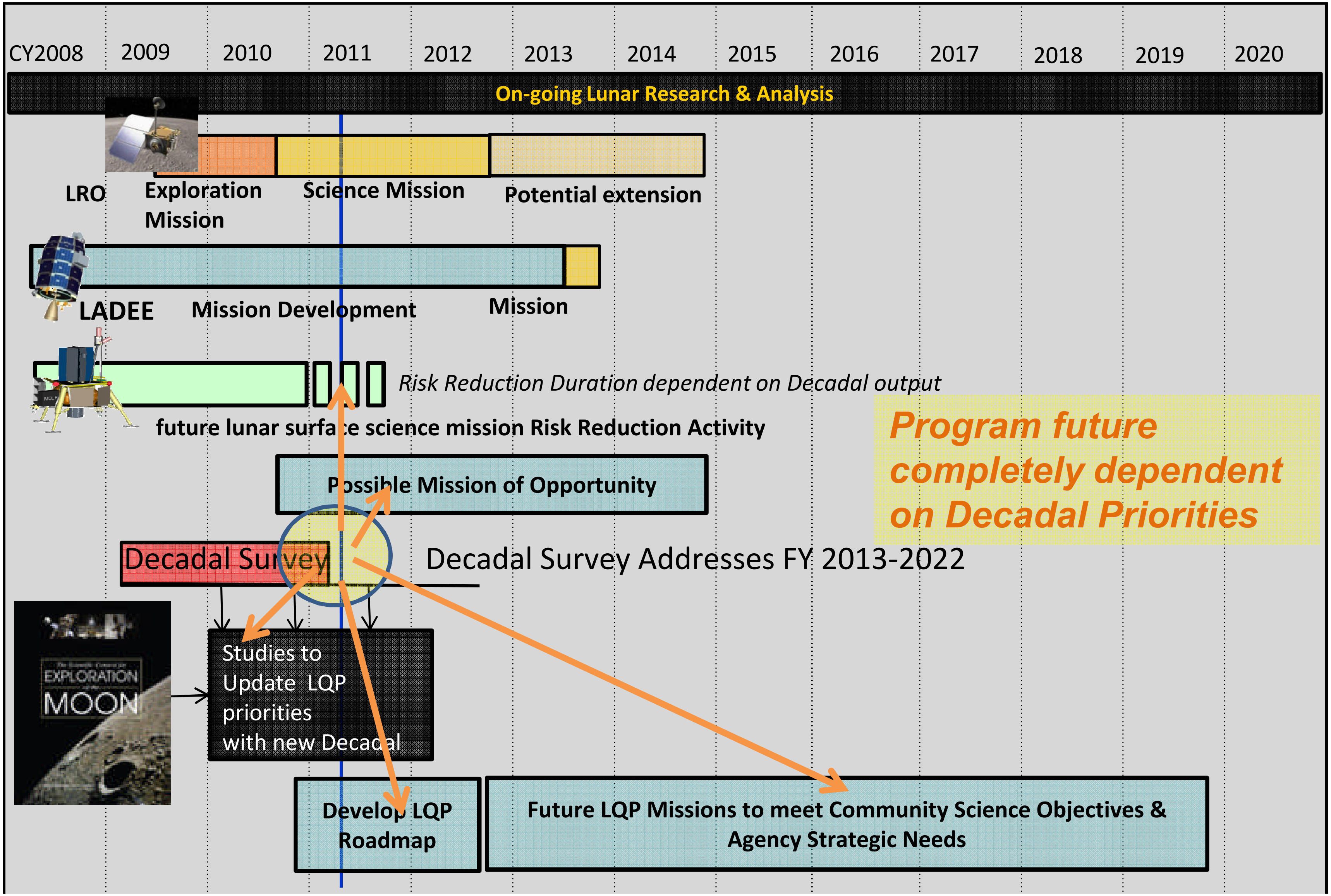
The two initial flight elements of the LQP, LADEE and ILN where directed in April 2008.

- LADEE was targeted for a LCC of $80M and initially planned to launch as a secondary payload on the GRAIL mission with two science instruments in 2010 or 2011. As the mission formulation progressed:
  - LADEE was manifested on a dedicated Launch Vehicle – Minotaur V
  - An additional science instrument was recommended by the SDT, and the Dust Detector was competed & awarded
  - A technology payload, the Lunar Laser Communication Demonstration was added, sponsored by another Mission Directorate (SOMD)
  - Other factors resulted in additional LCC increases. LADEE was confirmed for up to $262.5M, launching in 2013.
- The ILN was targeted to land two landers on the moon for $200M to form the Anchor Nodes of an International Lunar Geophysical Network. As the mission concept evolved:
  - A Science Definition Team developed rigorous science requirements: 4 nodes, 6 yrs continuous operations.
    - Two nodes from US and two international contributions?
  - In April 08 the new SMD AA changed the philosophy for the ILN Mission from a cost driven mission ($200M) to a science driven mission, providing Decadal class science
  - LCC increased to ~ $960M for the four node mission.
- In 2010 LQP inherited ESMD's Lunar Reconnaissance Orbiter to conduct a science mission leveraging on high value operational assets, spacecraft and science teams.

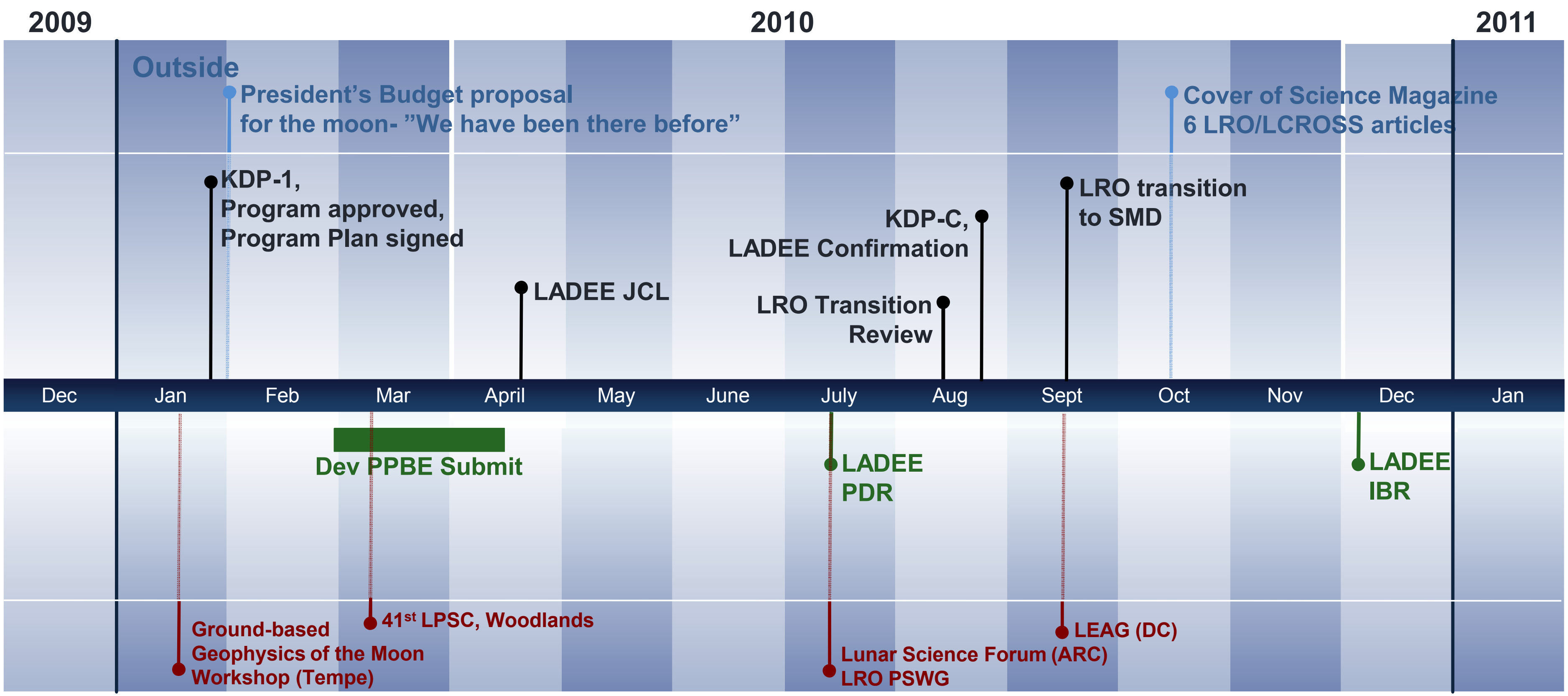
more hills

- Risk tolerance changes
  - Interest in increasing non-traditional centers for in-house spacecraft development
  - We will let you build it cheap and take a risk to learn to do business differently
  - You need to follow all standard practices, including new requirements as they come up
    - regardless of prior agreement and budget
- ILN: started under unrealistic parameters
  - 8 Space Agencies signed an MOU
  - Created unrealistic expectations
  - Anchor Nodes kept alive on fumes until Decadal is clear

plan for LQP current/future missions and research & analysis timeline



where we are now

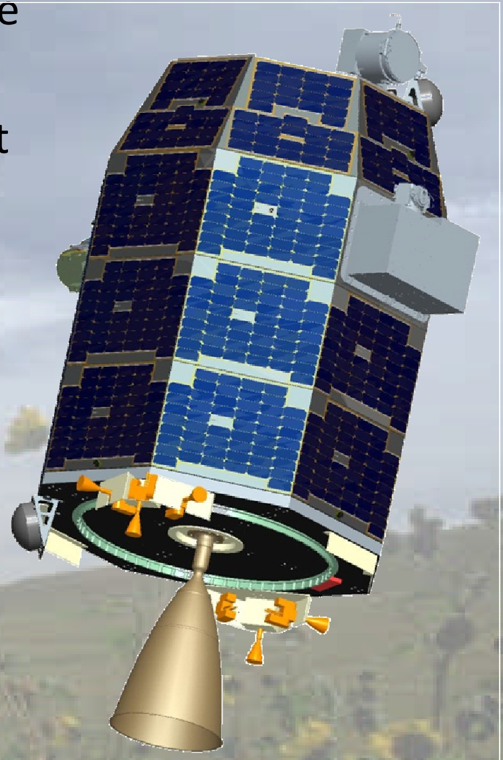


LADEE hills in the road

- ARC directed as Project Manager
  - GSFC added to 'help'
  - Very different cultures
    - Ames goal: show NASA how we can do this cheaper and quicker
    - GSFC strength: tons of in house experience and very structured to follow all of the highest, most programmatic, quality driven procedures (i.e. not cheap and quick)
    - Questioned approach from Day 1 – had to back track & bring team along together in design
- Budgeted for small project office
  - New requirements (JCL, Independent EVM analysis, weekly reporting, GAO audits,…) weren't anticipated
- Developed as Cat III (Phases A & B), Implemented as Cat II (Phase C)
- Green light schedule from Day 1 to meet Cost & Schedule challenge
- Technology Demo status
  - Can you really fly without it?
- First use of Minotaur V
  - Protested by Commercial company
  - Sec Def approval and process timing vs confirmation
  - Contamination requirements
  - Launch Loads unknown – analysis delayed

LADEE status today

- LADEE is the first Lunar Quest Mission and will characterize the lunar exosphere and measure exospheric dust
- LADEE is in Phase C, being developed by the ARC/GSFC project team
- To be Launched in 2013 as single payload on Minotaur V (first NASA use of this DoD launch vehicle) from WFF
- 100 day science mission – 3 science instruments
  - **Neutral Mass Spectrometer (NMS) - GSFC**
    - *In situ* measurement of exospheric species
  - **UV Spectrometer (UVS) – ARC**
    - remote detection of exospheric species
  - **Lunar Dust EXperiment (LDEX) – LASP**
    - in situ measurement of dust particles
- Technology Payload – Addresses Agency strategic needs by demonstration of Lunar Laser Communications for SOMD



Success:

NASA’s first dedicated use of Minotaur, first spacecraft in-house at Ames ever, great partnership between Ames/GSFC being developed, confirmed and on it’s way.

LADEE Instrument Payload

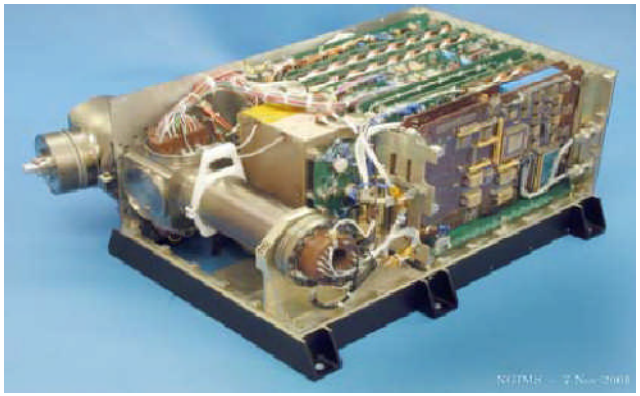
Neutral Mass Spectrometer (NMS)

MSL/SAM Heritage

SMD - directed instrument

In situ measurement of exospheric species

P. Mahaffy
NASA GSFC



150 Dalton range/unit mass resolution

UV Spectrometer (UVS)

LCROSS heritage

Dust and exosphere measurements

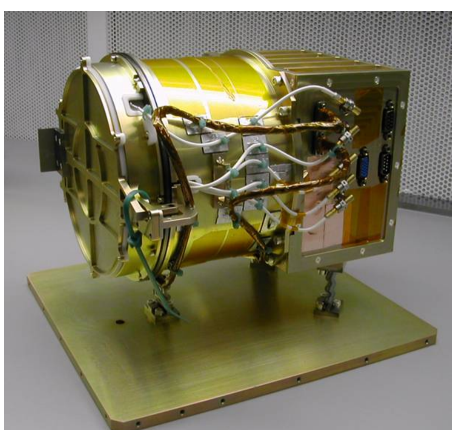
SMD - directed instrument

A. Colaprete
NASA ARC

Lunar Dust EXperiment (LDEX)

HEOS 2, Galileo, Ulysses and Cassini Heritage

SMD - Competed instrument



M. Horányi
LASP

Lunar Laser Com Demo (LLCD)

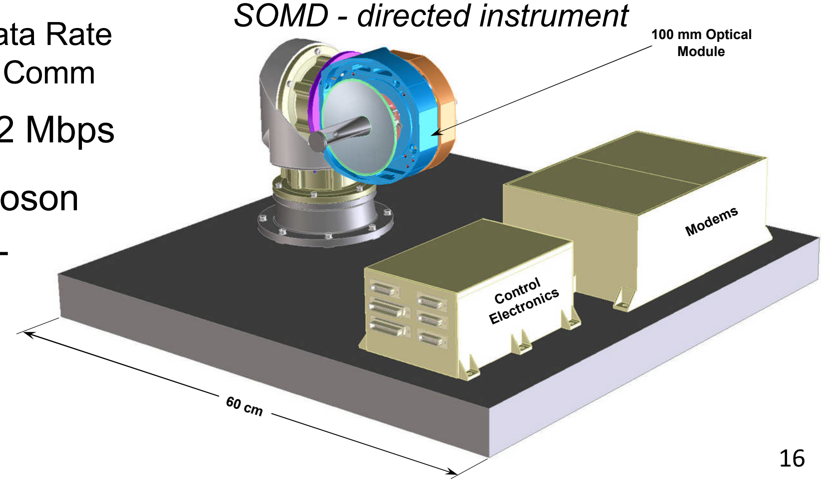
Technology demonstration

SOMD - directed instrument

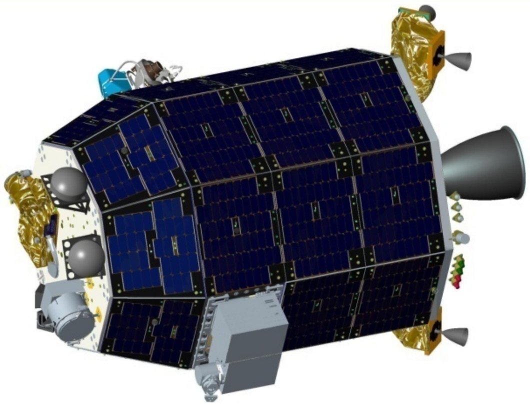
High Data Rate Optical Comm

51-622 Mbps

D. Boroson
MIT-LL



LADEE E/PO recent highlight

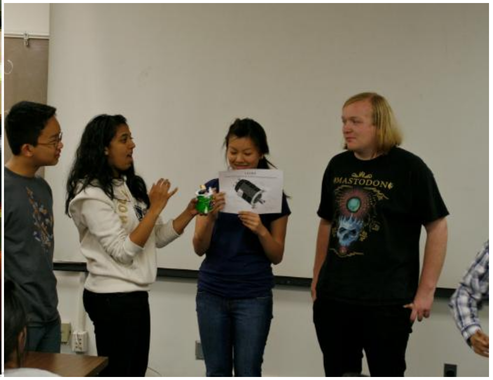


Candy Sats

Student teams designed a LADEE Spacecraft using a wide variety of edible materials but staying within a mass and cost constraint.

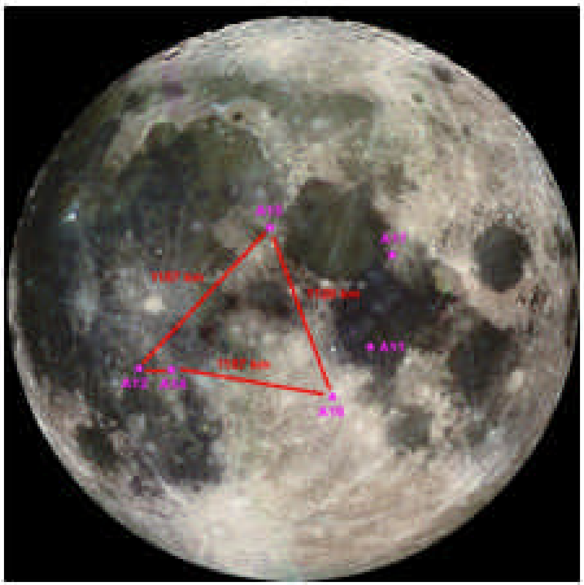
The team designs were tested against specific criteria to establish which team won the "contract".

Candy Sats Design Criteria
Cost
Weight
Teamwork
Structural Integrity
LADEE Design Match



the "big" ILN

- The International Lunar Network (ILN) is a cooperative effort designed to coordinate individual lunar landers in a geophysical network on the lunar surface.
  - The ILN accomplishes high priority science by coordinating landed stations from multiple space agencies.
  - 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 space agency.
  - Additional contributions could include orbiter support, tracking, communications, and closely related science.



- To guide the ILN concept, a non-binding "Statement of Intent" was signed on July 24, 2008, by Canada, France, Germany, India, Italy, Japan, Korea, the UK, and the U.S.

- ILN Working Groups where assigned for Core Instrumentation (WG1), Communications (WG2) Site Selection (WG3), and Enabling Technologies (WG4)

ILN hills in the road

- The LQP Program Office was challenged to implant two geophysical stations on the moon for a full LCC of $200M to form the Anchor Nodes for the International Lunar Network.
- A pre-project team (MSFC/APL) was directed to begin pre-formulation of the ILN Anchor Nodes Mission
- The ILN SDT was organized to provide Science Objectives for the lunar geophysical network
  - The result was mission objectives significantly different from original HQ/SMD guidance
    - Baseline science required 4-nodes, 6 year continuous operations at non-polar locations.
    - The approach of the US delivering 2-anchor nodes with the reliance of the international partners contributing the additional 2 nodes might not be valid
  - After multiple iterations, two Design Reference Missions where selected for maturation:
    - 4-Node ASRG Lander Mission
      - NASA would provide the complete ILN Anchor Node complement
    - 2-Node Solar/Battery Mission
      - NASA would either:

        a. Rely on International Partners to provide remaining 2 Anchor Nodes or

        b. Deliver the full 4-Node complement on two separate missions
- The LQP Budget for the ILN Anchor Nodes was inadequate to support any of the 2 and 4 node science driven mission concepts
- As ILN Anchor Nodes Mission concepts evolved, the SMD philosophy for the Mission changed from a cost driven mission to a science driven mission (Decadal class science)

ILN status today

- ILN Mission activities are on hold pending direction from HQ in response to the outcome of the Planetary Decadal Survey
- Robotic Lunar Lander Project Team currently:
  - Examining ILN Class lander bus applications to other lunar surface science missions
  - Executing risks reduction activities for delivering and sustaining a broad-range of science payloads to the Lunar Surface.
    - Activities including maturating high thrust, low mass thrusters, developing deep depth-of-discharge batteries and developing a Warm Gas Lander Test Bed for final decent and landing hardware and control algorithms development and validation.

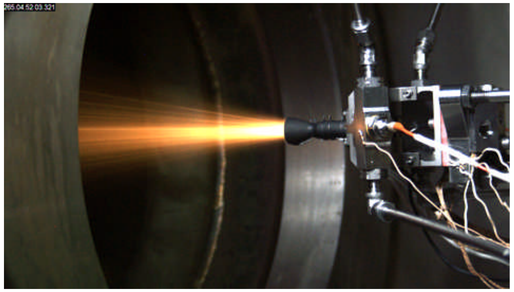
Success:

Mature Lunar Lander concepts developed to meet ILN and other science objectives. Useful capabilities for Lunar Lander and many other missions are matured as part of risk reduction phase.

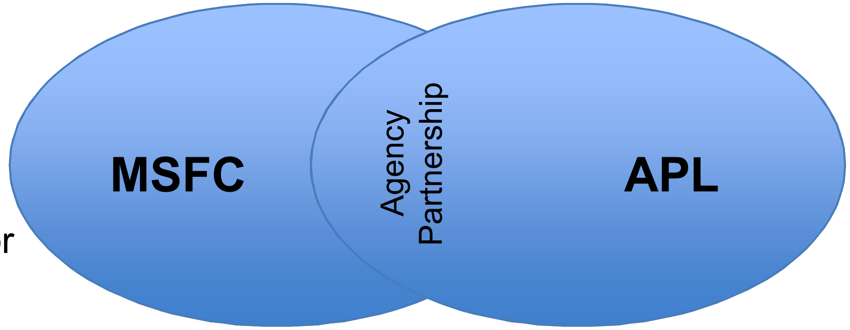
ILN risk reduction activities currently on-going

1. Lunar Lander Test Bed: Hardware in the Loop (HWIL) testing with landing algorithms and thruster positions
2. Propulsion: thruster testing in relevant environment, pressure regulator valve
3. Power: battery testing
4. Thermal: Warm Electronics Box and Radiator analysis
5. Structures: composite coupon testing, lander stability testing
6. Avionics: reduced mass and power avionics box with LEON3 processor
7. GN&C: landing algorithms
8. Mole testing @ JPL: test mole in lunar regolith simulant
9. Seismograph task: analysis to inform the requirement for the number and location of sites

Flight-like subsystems in a early test article.



Advancing Technology for Lunar Missions



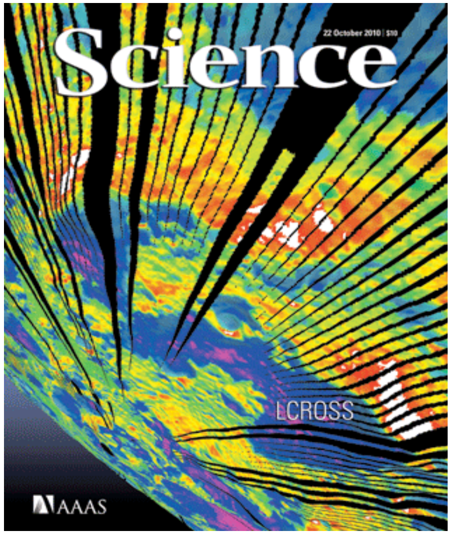
LRO is smooth sailing

- Having successfully completed the one year ESMD mission, the project was approved to transition to a two year Science focused mission with five objectives:
  - the bombardment history of the Moon
  - lunar geologic processes and their role in the evolution of the lunar crust and shallow lithosphere
  - the processes that have shaped the global lunar regolith
  - the types, sources, sinks, and transfer mechanisms associated with volatiles on the Moon
  - how the space environment interacts with the lunar surface.
- The S/C, sub-systems and instruments are in excellent health and are expected to meet Level-1 Science requirements
- Only Issue is a potential conflict with LADEE as they both via for WS1 S-band data receiving capability

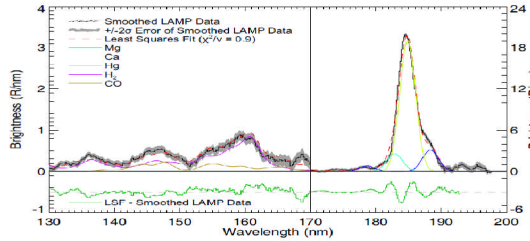
Success:

Re-Use of an operating spacecraft that had completed
it's primary exploration objectives to meet science objectives

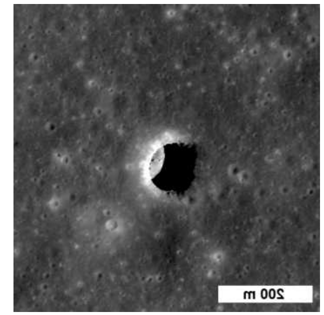
LRO results



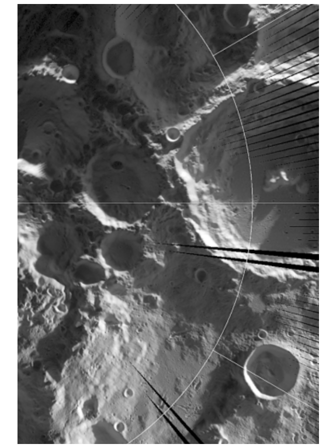
Cover of Science Oct 2010- 6 LRO / 2 LCROSS reports



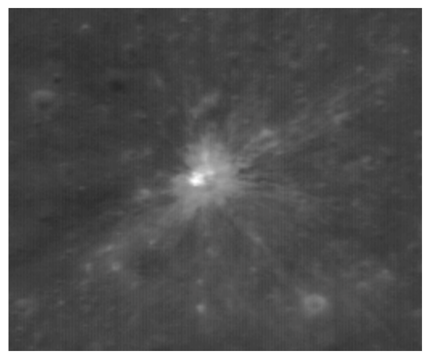
LAMP Observation of LCROSS Impact – Identifies H_2, Mg, Ca, Hg, CO



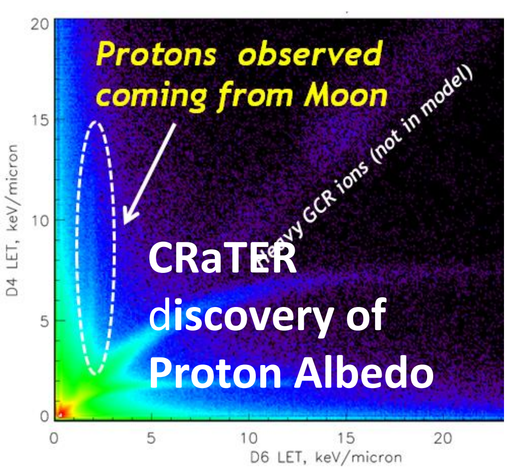
Mare Pit Craters

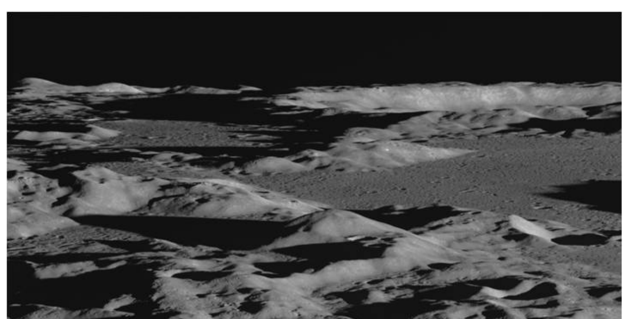


Diviner thermal image- South Pole

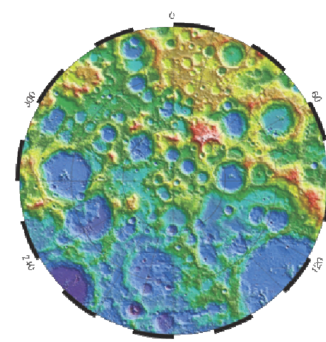


New crater ~10 m diameter

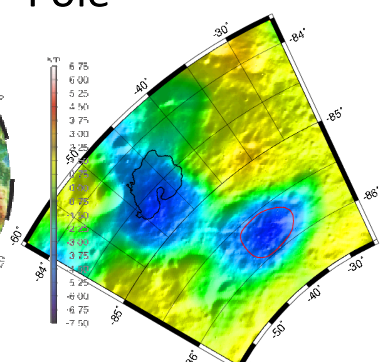




LROC – North Polar Oblique



LOLA South Pole **Topography**



LEND maps of **Neutron Suppression** Regions near the South Pole

research activities progressing

NASA Lunar Science Institute (NLSI)

- **Brings together leading lunar scientists from around the world for high priority research focused on lunar science- investigations of the Moon, from the Moon, and on the Moon**
- **Seven initial member research teams funding 198 researchers**
- **Six additional international teams (Canada, Korea, UK, Saudi Arabia, Israel, Netherlands)**

Lunar Advanced Science and Exploration Research (LASER)

- **Investigations to increase knowledge of the moon**
- **Over 135 high-priority research investigations funded**
- **Broaden the participation in the analysis of mission data sets**

what worked well programmatically

- Moved forward in the face of uncertainty
- Great partnerships established: HQ/MSFC, ARC/GSFC, MSFC/APL
- Got LADEE on its way while window was open
  - Use of Minotaur launched from Wallops
  - Reusable bus design
  - Potential future for ARC space craft development
- Despite lack of initial realism, developed a range of mature Lunar Lander concepts to meet ILN and other science mission objectives
- Advanced useful capabilities for future lunar lander and other robotic spacecraft

what didn't work well programmatically

- Accepted huge challenges in order to play in game. Now in game but can't finish
- Did not reconcile the ILN budget needs with the stakeholders before the window of opportunity closed
- Did not find a scientifically valuable mission for ILN that could fit in budget
- Given lunar discoveries, did not foresee impact of Presidential redirection for Agency
- A narrowly focused program can be on thin ice when the focus is no longer a high priority

conclusions

- Concurrently formulating a NASA Program and projects creates unique challenges
- If Projects are initiated with what is found to be unreasonable objectives, constraints, cost estimates and schedules
  - Sets expectations that the project will go forward
  - Unmet expectations from multiple stakeholders if project doesn't go forward
  - Or the $$ has to come from somewhere else – creating shortfalls and frustration elsewhere
  - reconcile and face reality as soon as possible
- Projects in pre-formulation should anticipate many concepts studies targeting various criteria, especially Life Cycle Cost
- It is important that project be shielded from the chaos at HQ, but be informed of the reality as much as possible