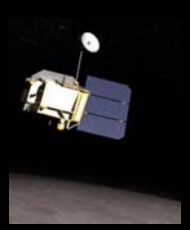
Lunar Exploration :

Opportunities for GSFC…



Dr. Jim Garvin

Chief Scientist

NASA's Goddard Space Flight Center

LESWG Meeting

Aug. 25, 2006

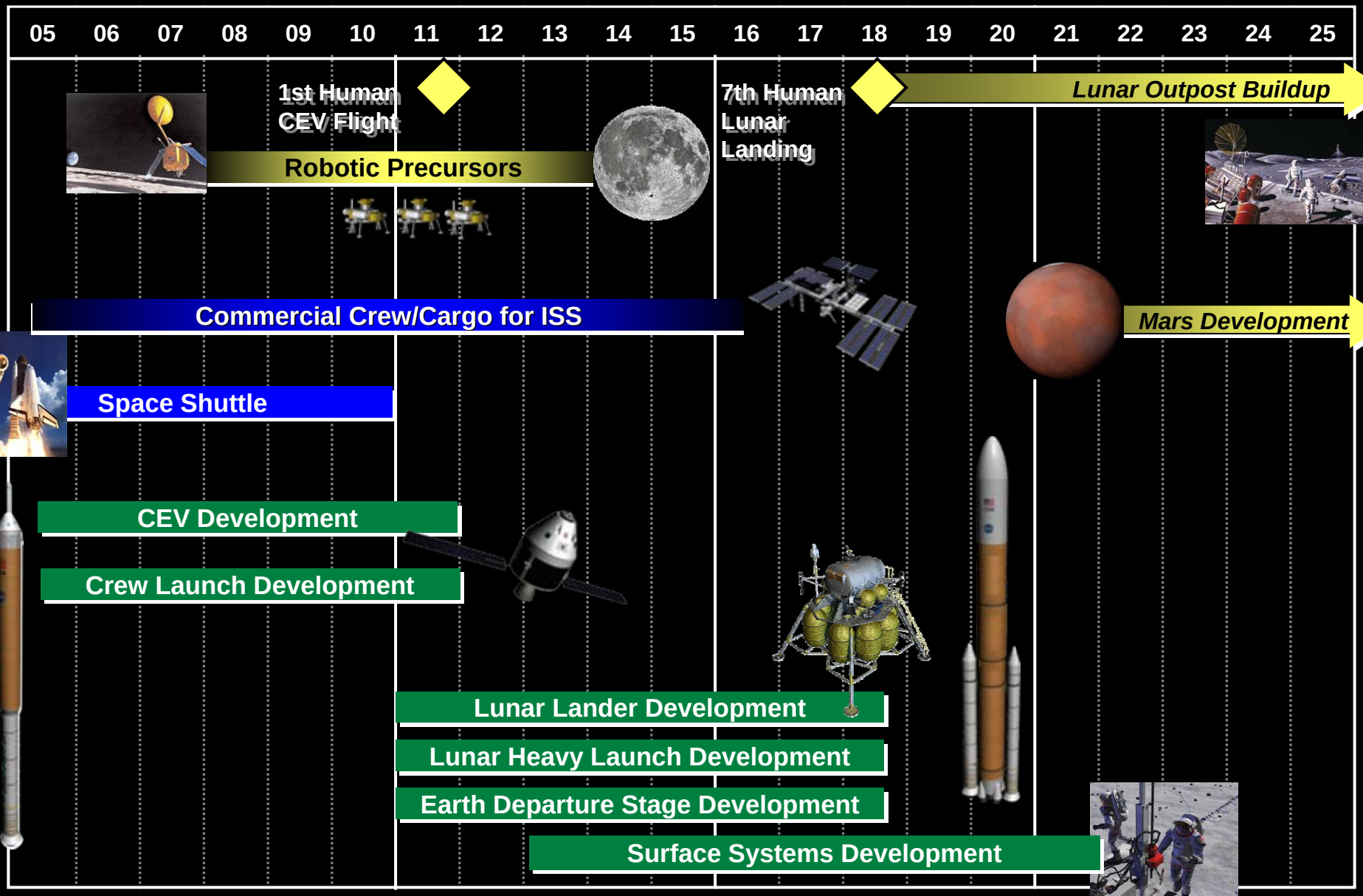
Vision Destinations…Moon first…then *Mars*…!

SCIENCE ROLES…

Exploration as a new "context"

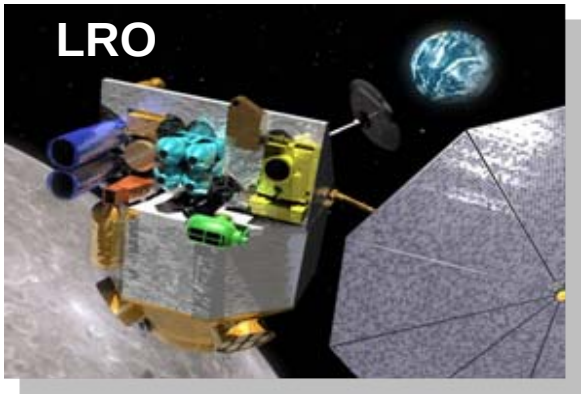
Human Spaceflight to the Moon "must" catalyze new partnerships

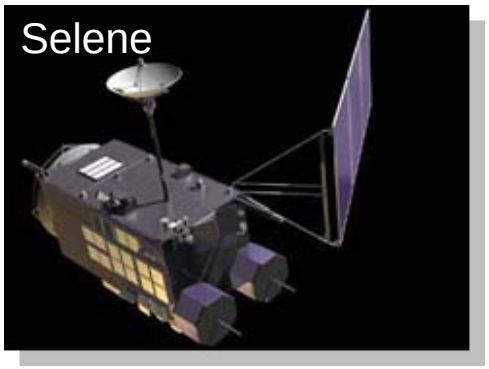
The Exploration Roadmap

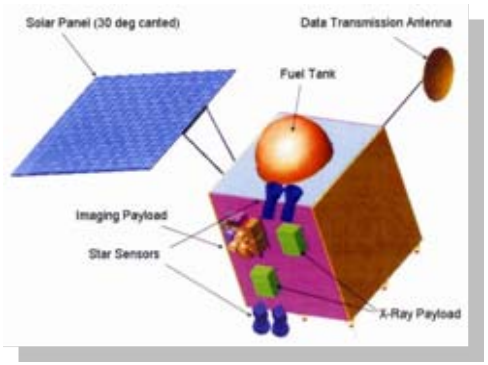


Lunar Armada

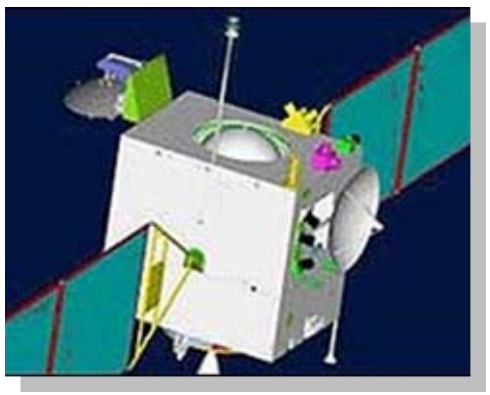
<u>Lunar Reconnaissance Orbiter</u> and Int'l missions are anticipated to provide key data for future robotic and human landings...







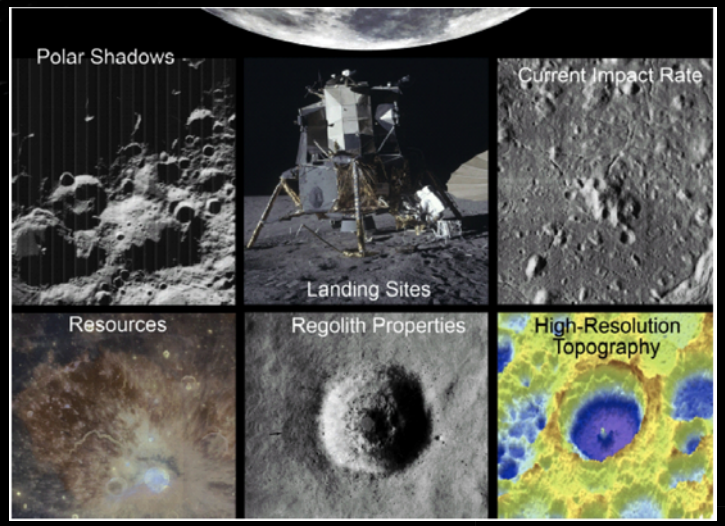
Chandrayaan-1

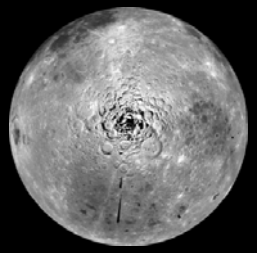


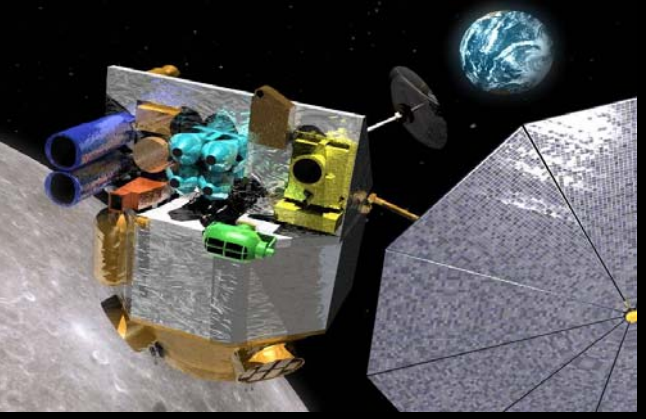
Chang'e

Lunar A

A First Step in Exploration : 2008 Lunar Reconnaissance Orbiter

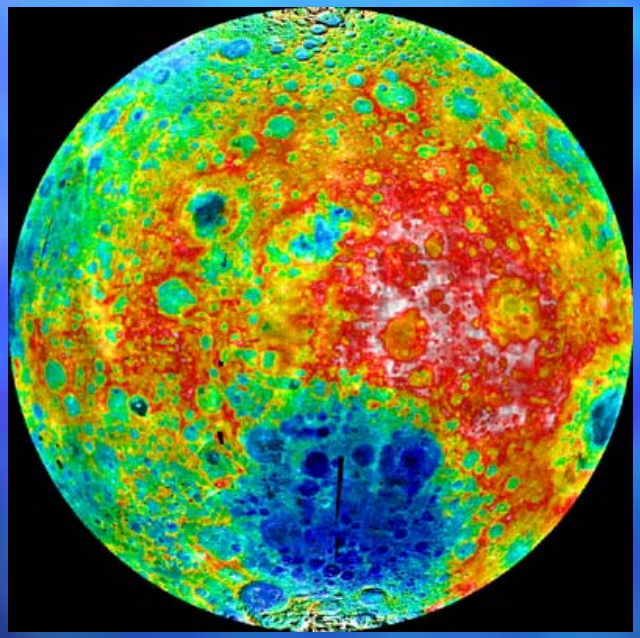




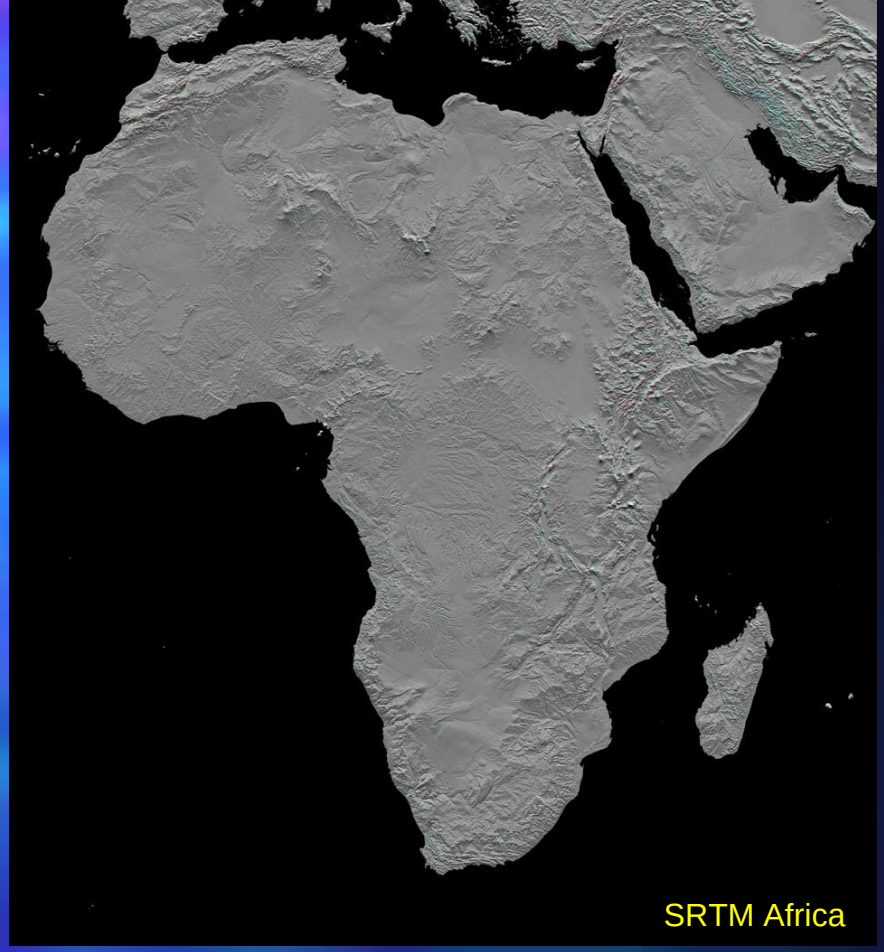


LRO: **GSFC's LOLA + LEND + …**

The Moon: *Africa-sized*

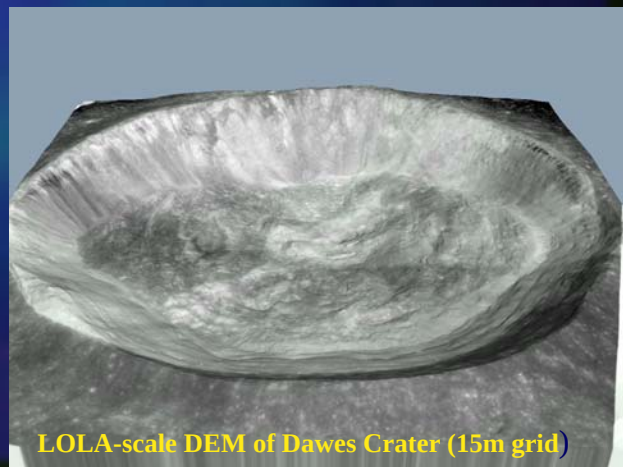


Clementine
Lidar (1994)



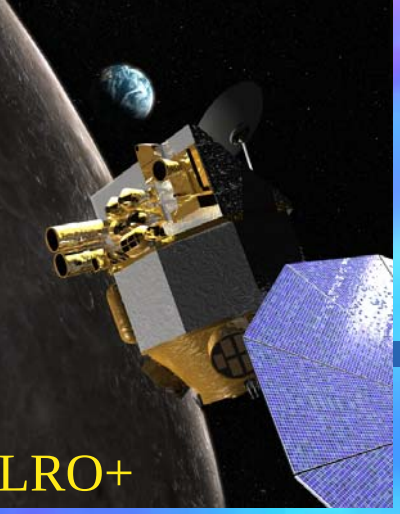
SRTM Africa

LRO



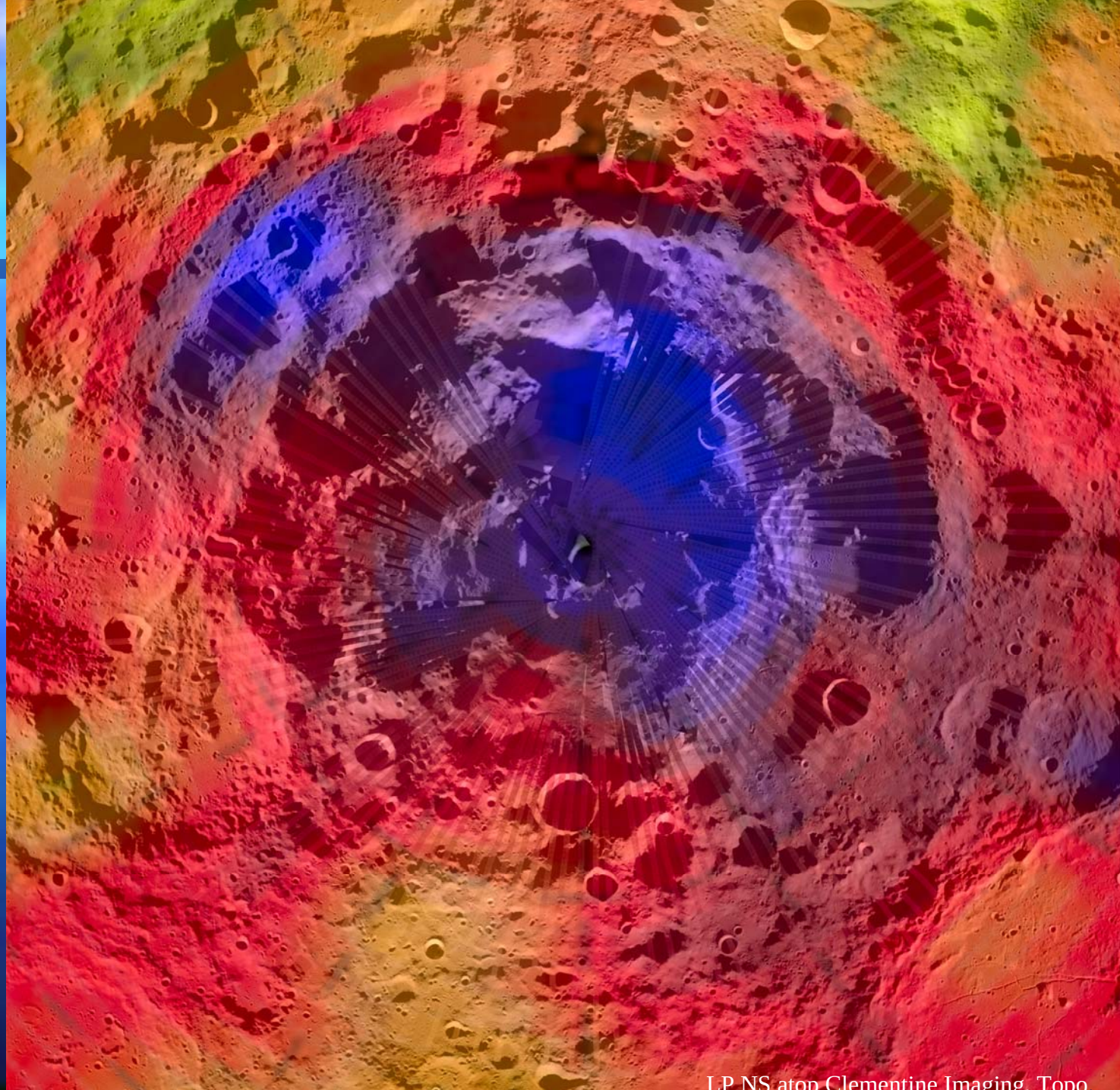
LOLA-scale DEM of Dawes Crater (15m grid)

<u>GSFC already is playing a key role</u>:
LRO's LOLA and geodetic topography…

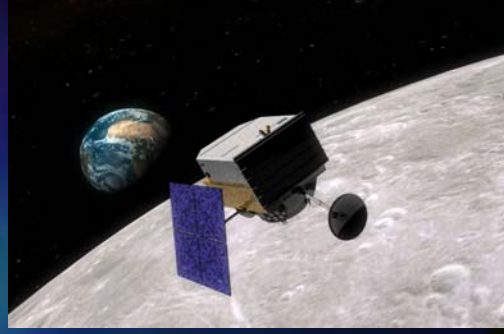


Lunar South Polar Region:

Large Discovery Potential awaits (volatiles, T, geochem, topo)



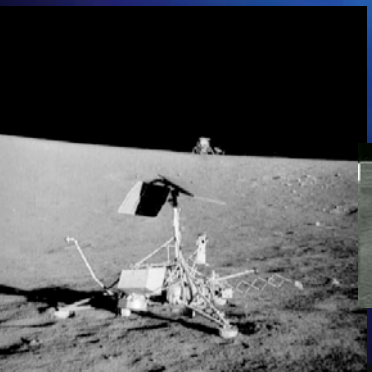
From Earth to the Moon:
finding the right places:
Integrating LRO, Selene, Chandrayaan, plus TBD



2008 LRO: the 1st step
...paving the way...
to the surface…
Integrating data analysis

Characterizing where we must go (at engin. scales),
for Resources, Safety, …

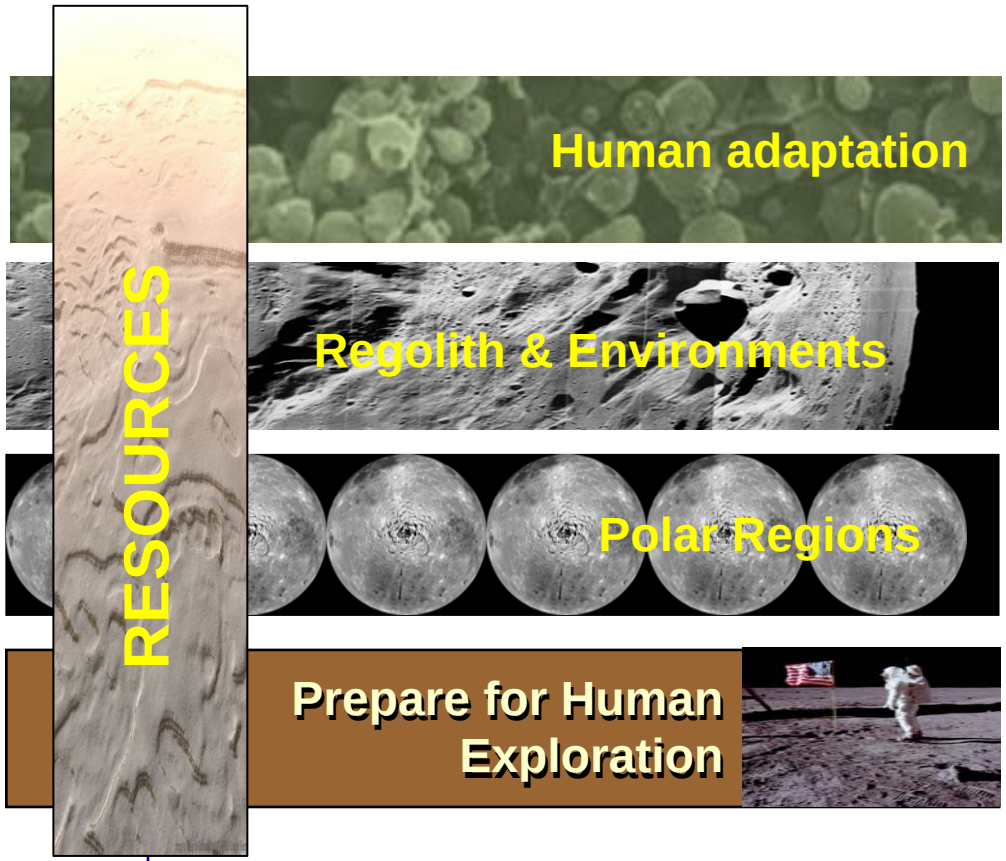
Finding the right stuff :
sampling, handling, analysis...
(in situ vs on Earth – key area)



Landed Systems: Next steps, before Humans

Lunar Exploration (*Science*) Objectives: ???

One Viewpoint we can debate



When • Where • Form • Amount

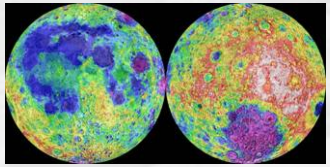
Focused Objectives

Biological adaptation to lunar environment ***(radiation, dust, delta-g,...)***

Understand the current state and evolution of volatiles and other resources in local context

Develop an understanding of the Moon in support of human exploration ***(hazards, topography, navigation, temperatures, environs, dust, Space Weather, electrical)***

Lunar Science of all flavors...



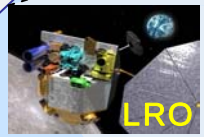
Classical Science

LSSO studies (2007)
Discovery (2008)
New Frontiers (2008-2009)

Robotic Precursors, human missions

Hypothesis driven (SMD)

Flight Demos etc.



LRO

& LPRP

Measurement driven (ESMD,SMD)

Engineering Capability driven (ESMD,SOMD)

Applied Science Research

Engin./ Tech. Demo's

Human on-site Activities

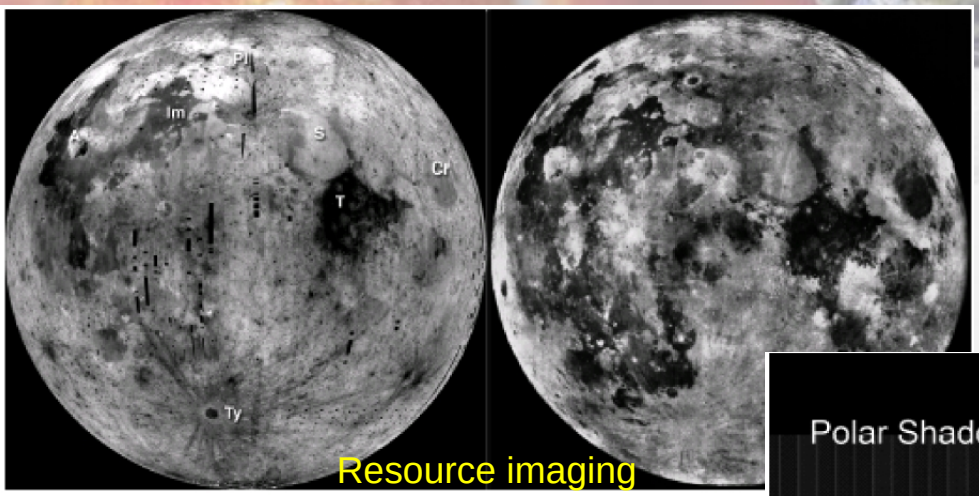
LRO (and LPRP) should support all 3 aspects of integrated Exploration

Partner with ARC?
Post-LRO mission
New Program?

ARC small missions
LPRP (MSFC/APL?)
Other?

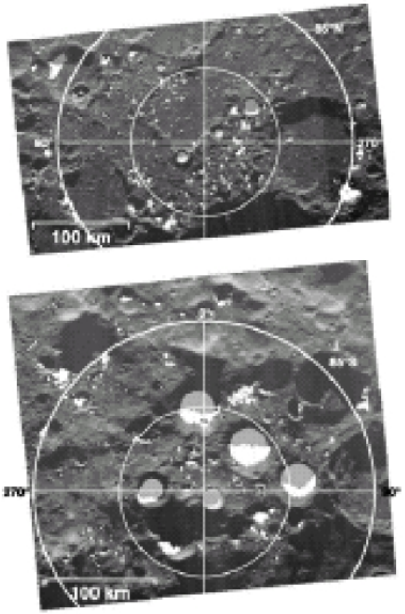
New data assimilation/modelling needed:

LRO + Selene + Chandrayaan + [prior missions]

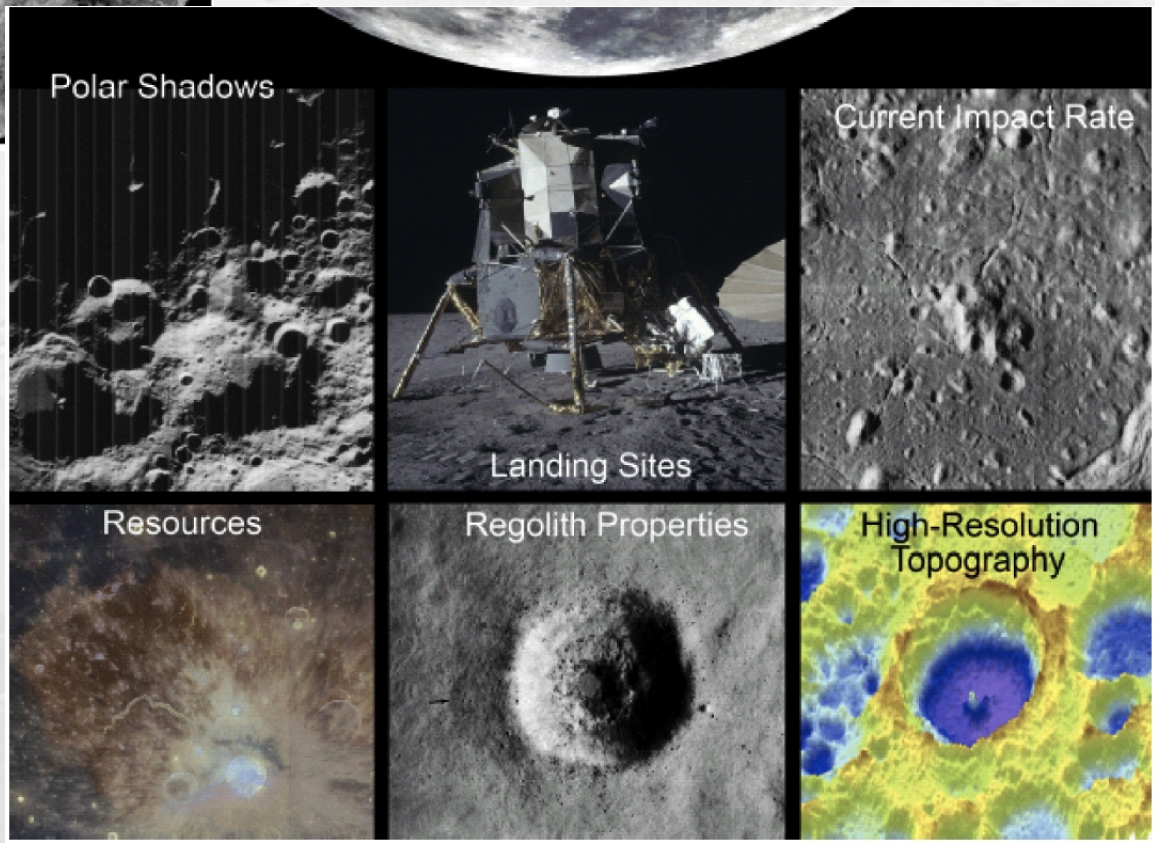


Resource imaging

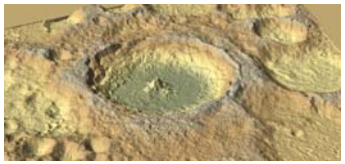
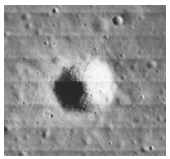
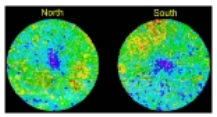
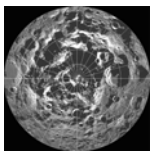
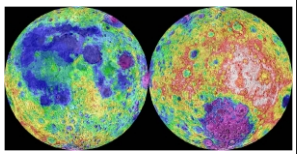
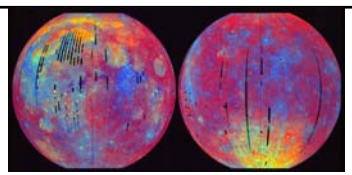
Temperature mapping (find cold traps)



Polar Topography/shadow mapping

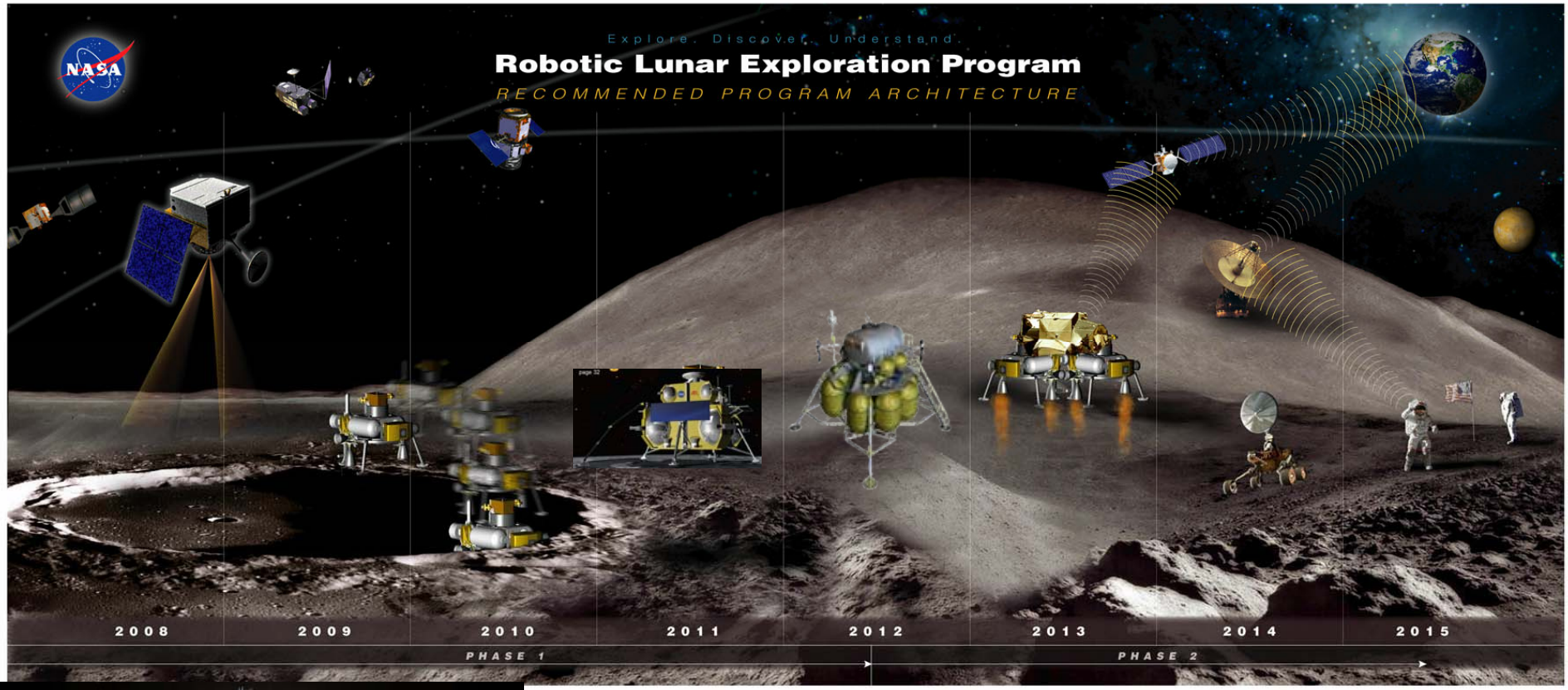


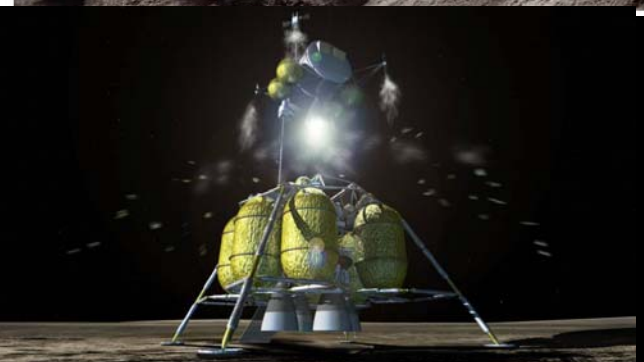
National Academy of Sciences *NRC Decadal (2003)* lists priorities for the MOON *(all mission classes thru 2013)* :

NRC Priority Investigation				*NRC approach*	Example Measurements (LRO etc.)
Geodetic Topography (*crustal evolution*)				**Altimetry from orbit (with precision orbits)**	***Global geodetic topography at ~50m scales (< 1 m rms)***
Local Geologic Studies In 3D (*geol. Evolution*)				**Imaging, topography (at m scales)**	***Sub-meter scale imaging with derived local topography***
Polar Volatile Inventory				**Spectroscopy and mapping from orbit**	***Neutron and VNIR spectroscopy in 3D context + UV (frosts)***
Geophysical Network (*interior evolution*)				***In situ* landed stations with seismometers**	***Crustal structure to optimize siting and landing safety (from geodetic topo+ gravity)***
Global Mineralogical Mapping (*crustal evolution*)				**Orbital hyperspectral mapping**	***100m scale multispectral and 5km scale H mapping***
Targeted Studies to Calibrate Impact Flux (*chronology*)				**Imaging and in situ geochronology**	***Sub-meter imaging of Apollo sites for flux validation and siting***

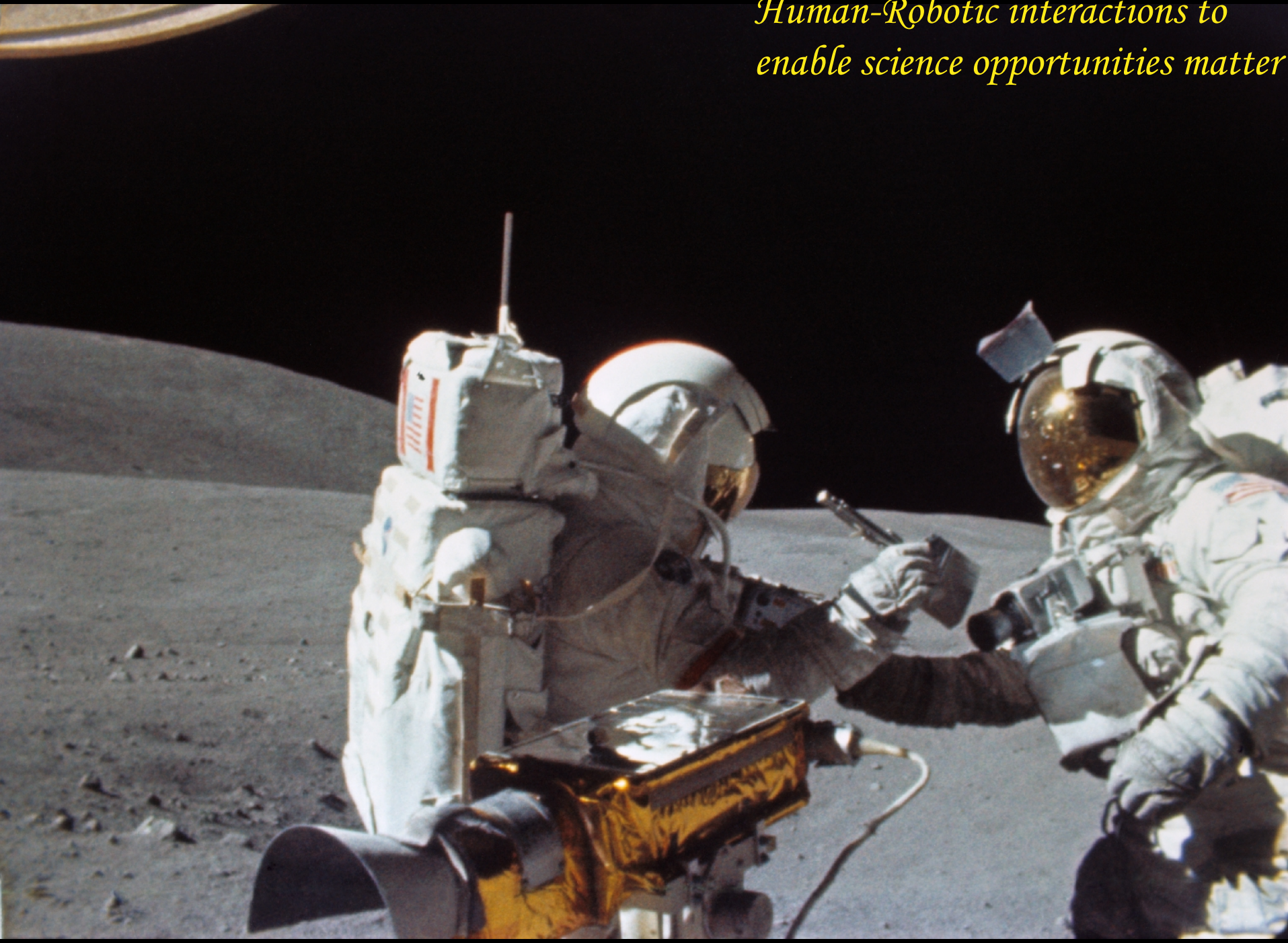
From Garvin (2005): Presentation to Congress

Architectures evolve, change, and are re-structured… but LRO is 1st!





Human-Robotic interactions to enable science opportunities matter



So what can we do?

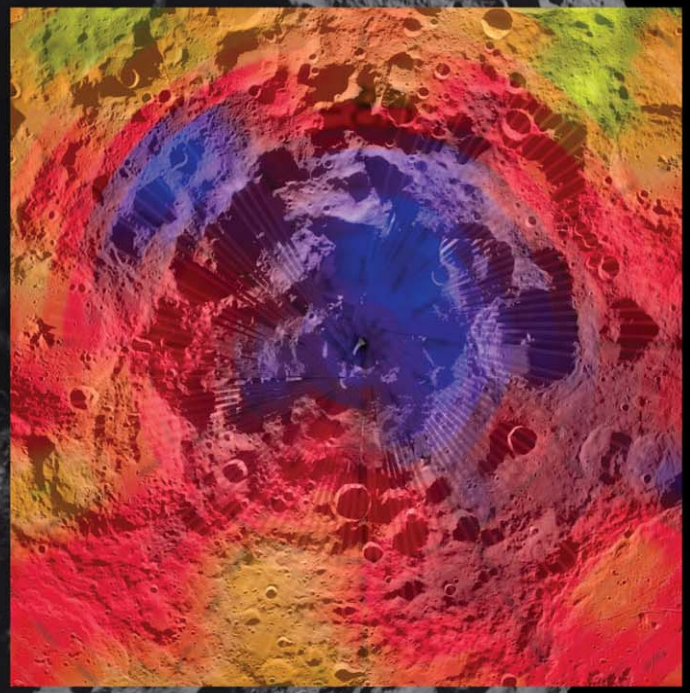
- Deliver on LRO, beyond ESMD expectations (just as MGS has done for Mars) – help provided integrated data assimilation solutions
  - LRO's success will sustain lunar exploration and provide science (beyond 2009)
  - Help ARC with LCROSS (measurements, impact site, observations, analysis)
- Leverage strengths in space weather as applied to the Moon
- Promote and develop new measurement approaches aligned with lunar issues (dust, electrical properties, water ice, gravity, local terrain)
- Be creative and adaptive, given new results soon to come from LRO, Selene, Chandrayaan etc.
  - Avoid "pet projects" – keep linkage to NRC/Decadal priorities for the Moon (Inner Planets)
  - Relate NRC Lunar priorities to emerging ESMD "knowledge" goals
- Help HQ (SMD) foster a niche for priority lunar science (in context)
  - We need a Lunar Fundamental Research Program (LFR) and an LRO Guest Science Observer Program (LRO-GSO)
- Leverage what we have done in the past year (LRO, LEx, RLEP2, lunar Discovery missions, HST/Moon, IRADs, ECANs, etc.)
- DISCUSS, ANALYZE, PROPOSE!
  - Use SMD ROSES opportunities well (LSSO, PIDDP, PGG, Planetary Astronomy, etc.)
- Lets use LESWG forum to build a lunar science future for all of us…
  - Suggest formation of GSFC Internal "Lunar Special Action Teams" for key issue areas

POSTSCRIPT: What we did January-March 2005 (GSFC's 1st Lander proposal)

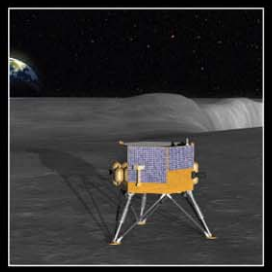
National Aeronautics and Space Administration

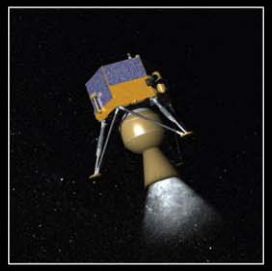
LEx
Lunar Explorer

Dr. Jim Garvin
Joe Burt
Jim Adams
(with Ed Weiler, Dolly Perkins, Kris Brown, Mike Amato, Gary Sneiderman, Geoff Hartman, Mary-Pat Hrbeck-Keith)



Presented : March 29, 2006

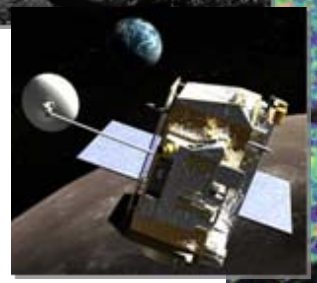


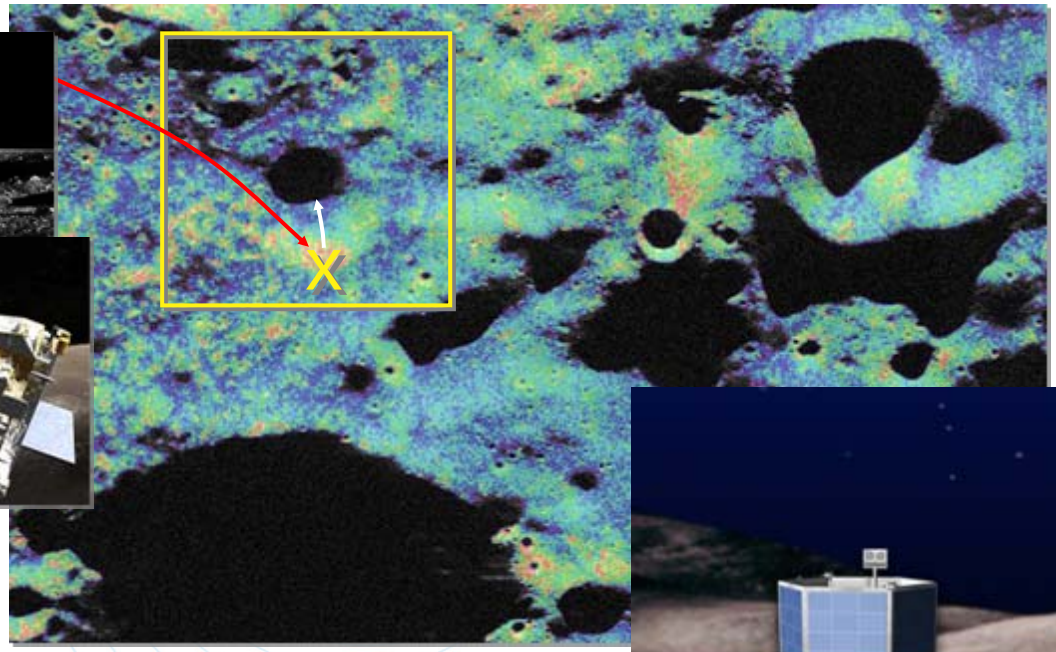


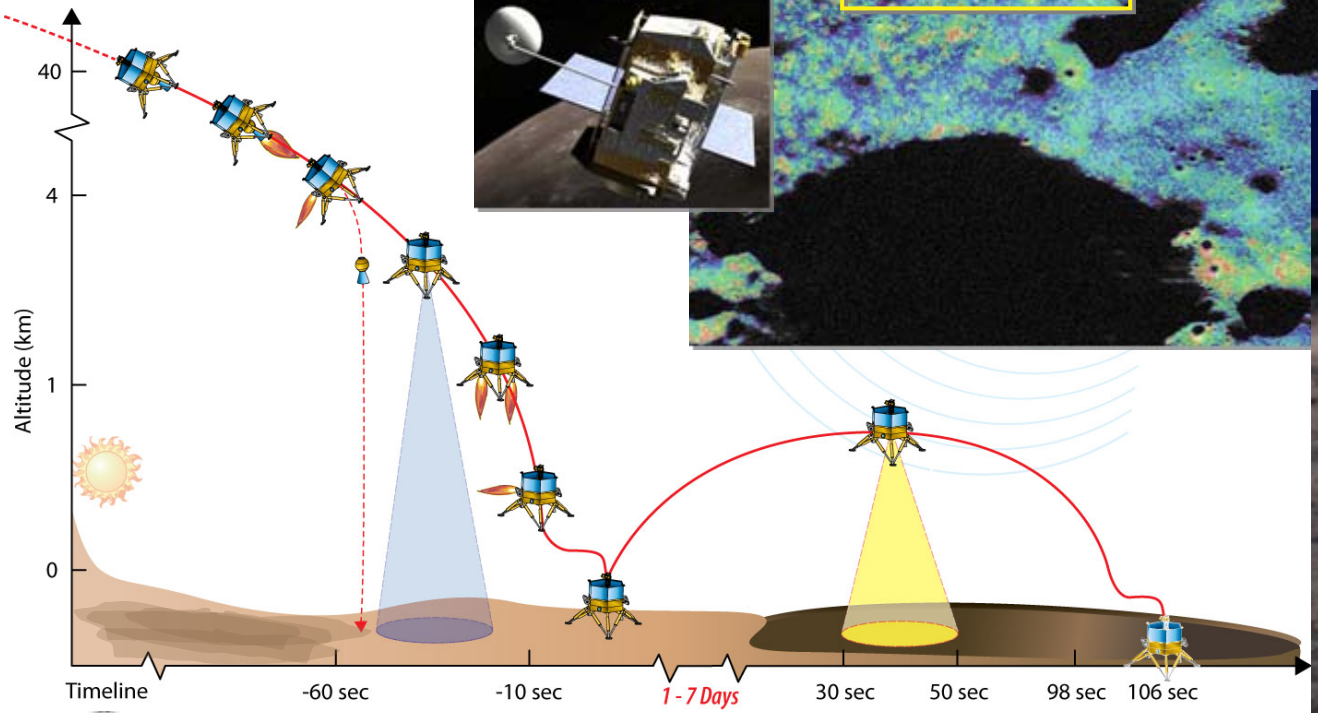
NASA GODDARD SPACE FLIGHT CENTER • RAYTHEON • MSSS • IKI • DRAPER • AEROJET

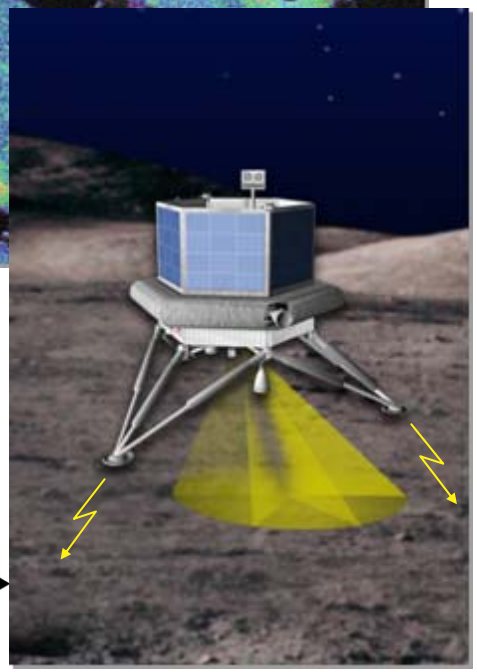
Proprietary Information • Do Not Distribute

LEx Returns the U.S. to the Moon for Exploration in 2008

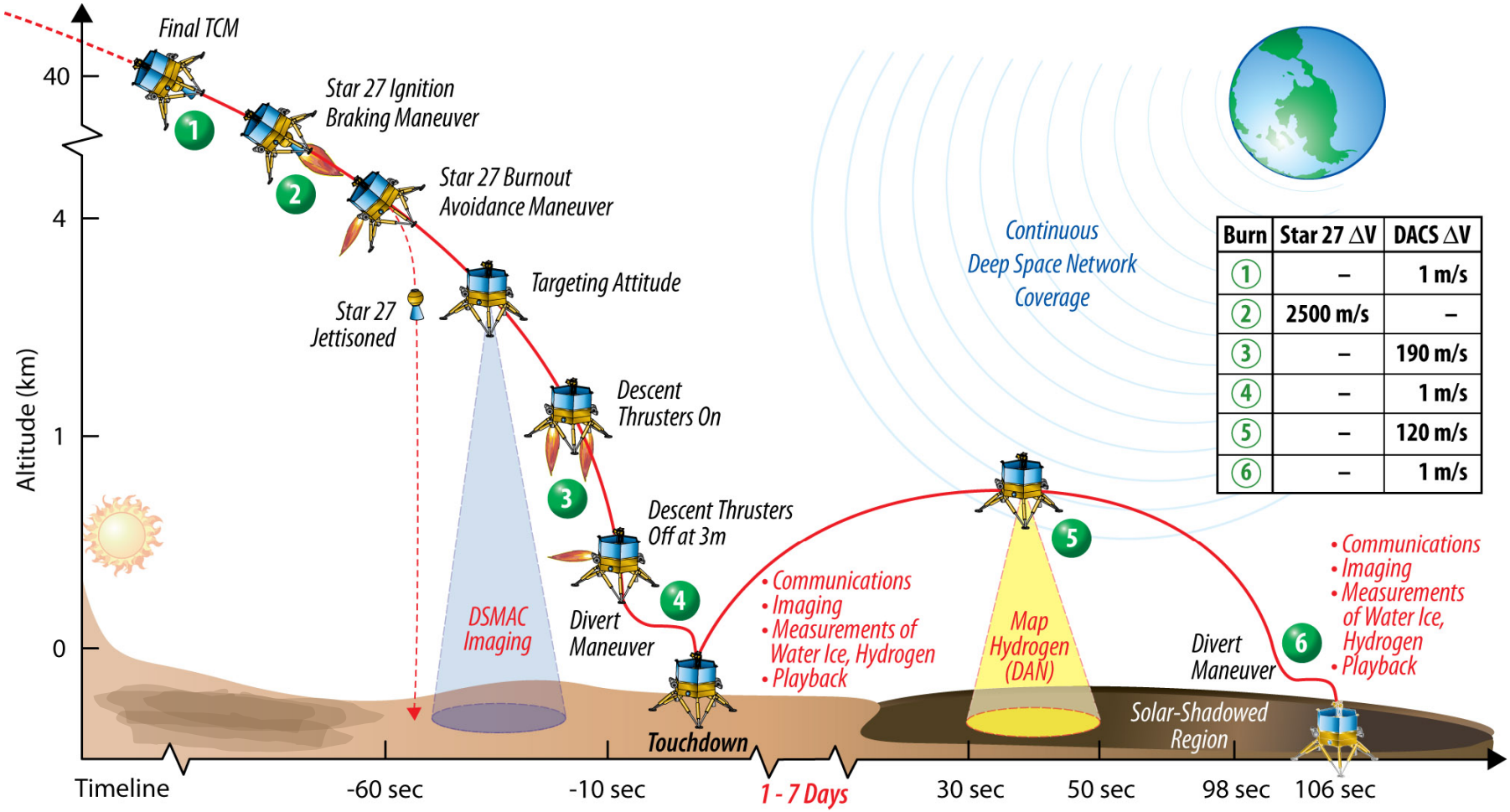








LEx Scenario



Burn	Star 27 ΔV	DACS ΔV
1	–	1 m/s
2	2500 m/s	–
3	–	190 m/s
4	–	1 m/s
5	–	120 m/s
6	–	1 m/s

WHAT HAVE WE DONE in the past year…

- **Aug. 2005**: proposed GSFC-Raytheon "Hopper" with APL for RLEP2
  - Selected as part of MSFC/GSFC/APL team (really 2 teams merged)
  - Operated RLEP2 activity from Oct. 2005 thru May 2006 under J. Loiacano of Code 400 with science support (hopper element)
  - GSFC science support of RLEP2 Measurement Team (Nov.-April)
- **Aug. 2005**: used HST's ACS to observe the Moon for resource analysis using UV imaging at 50m scales (GSFC-STSci) under GSFC leadership (w/ASU, Cornell, UPitts.)
  - Results presented at LEAG, LPSC, and in NASA Press Conference
- **Fall 2005**: Analyzed measurement systems for the Moon to support RLEP (investments via IRAD in some)
- **Fall-Winter 2005-2006**: GSFC roles in Lunar *Discovery* Proposals (GRAIL, Copernicus) – submitted April 2006, with selection decision by SMD by late Sept. 2006
- **Oct-Jan. 2006**: Developed concept of LEx as < $100M lander/flyer pathfinder for precision lunar access
  - Science partnership with MSSS, IKI, Cornell, Brown, Draper labs
- **Jan-Feb. 2006**: Proposed LEx to LRO Co-manifest Competition (ESMD)
  - Selected for Step 2 funded analysis as one of four finalists (Feb. 2006)
- **Feb.-March 2006**: Proposed LEx to Step 2 LRO co-manifest competition
  - April 2006: Not Selected (LCROSS), but received high marks
  - Analyzed LEx-lite as possibility for launch out of WFF on Minotaur LV
- **Now**: Exploring partnerships with ARC for small (< $50M) lunar exploration missions
- Continuing work on lunar communications architectures, plus other activities…

Plus ESMD Exploration Workshop and other activities…