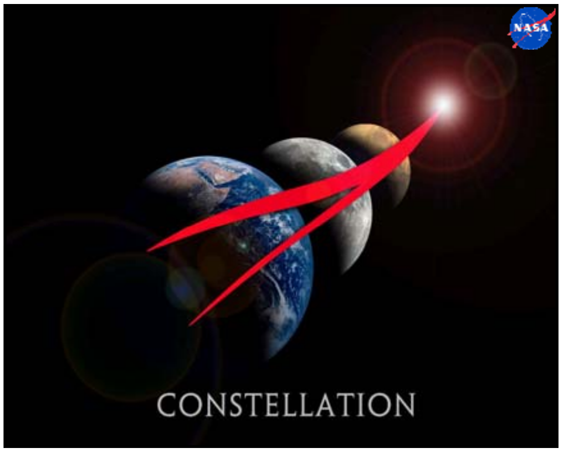


A Bold Vision for Space Exploration, Authorized by Congress

- Complete the International Space Station
- Safely fly the Space Shuttle until 2010
- Develop and fly the Crew Exploration Vehicle (Orion) no later than 2014
- Return to the Moon no later than 2020
- Extend human presence across the solar system and beyond
- Implement a sustained and affordable human and robotic program
- Develop supporting innovative technologies, knowledge, and infrastructures
- Promote international and commercial participation in exploration

NASA Authorization Act of 2005

The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.

Space Exploration Plan

- Low Earth Orbit
  - Retire the Shuttle after Space Station assembly is completed, planned for the end of this decade
  - Focus U.S. research on the Station on understanding the effects of the space environment on astronaut health
- Beyond Low Earth Orbit
  - Develop a new crew exploration vehicle to provide crew transportation for missions beyond low Earth orbit
  - Return humans to the Moon as early as 2015 to enable sustained exploration of Mars and more distant destinations
  - Continue robotic exploration of Mars to search for evidence of life and prepare for future human exploration
  - Conduct robotic exploration across the solar system for scientific purposes and to support human exploration

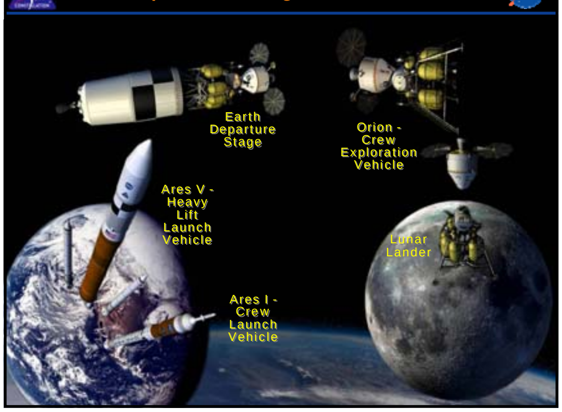
A Sustained Commitment

- Why a new vision was necessary:
  - Future infrastructure and research investment decisions require an overarching context
  - Lack of direction cited by Columbia Accident Investigation Board:
    - "The U.S. civilian space effort has moved forward for more than 30 years without a guiding vision..."
- Renewed vision provides a sustained commitment
  - A long-term plan for exploration throughout the solar system
  - Paced by experience, available resources, and scientific discovery
  - Does not require significant new funding, but re-focuses NASA

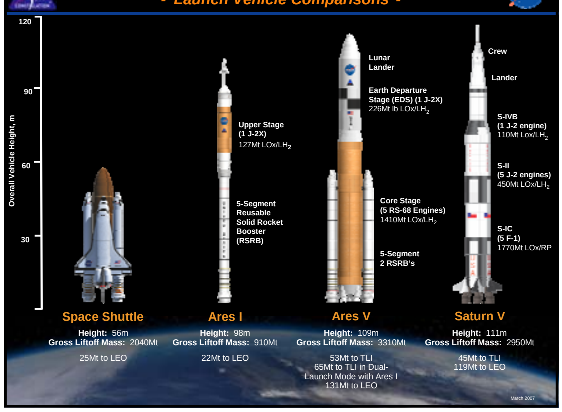
"The vision I outline today is a journey, not a race, and I call on other nations to join us on this journey, in a spirit of cooperation and friendship."

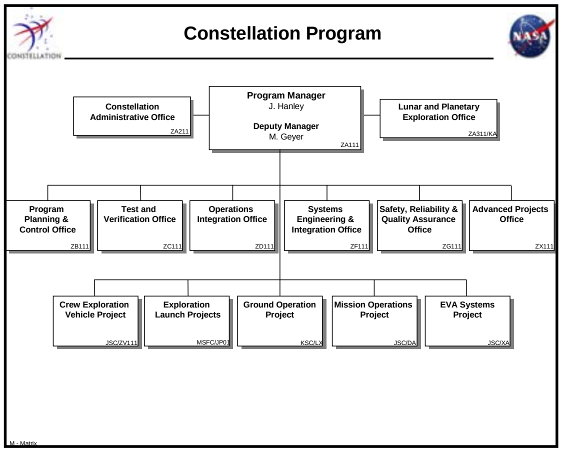
-- President George W. Bush
January 14, 2004

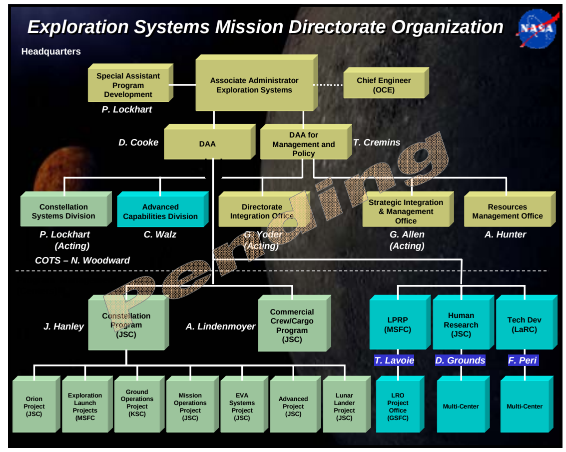
Components of Program Constellation



Building on a Foundation of Proven Technologies
- Launch Vehicle Comparisons -

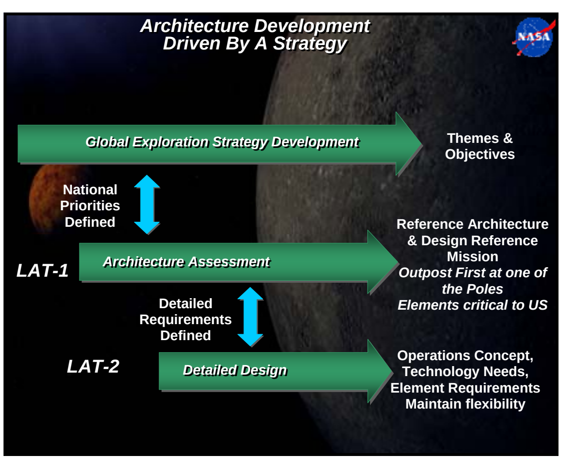



Constellation Program
CONSTELLATION
Program Manager
J. Hanley
Deputy Manager
M. Geyer
ZA111
Constellation Administrative Office
ZA211
Lunar and Planetary Exploration Office
ZA311/KA
Program Planning & Control Office
ZB111
Test and Verification Office
ZC111
Operations Integration Office
ZD111
Systems Engineering & Integration Office
ZF111
Safety, Reliability & Quality Assurance Office
ZG111
Advanced Projects Office
ZX111
Crew Exploration Vehicle Project
JSC/ZV111
Exploration Launch Projects
MSFC/JP01
Ground Operation Project
KSC/LX
Mission Operations Project
JSC/DA
EVA Systems Project
JSC/XA
M - Matrix

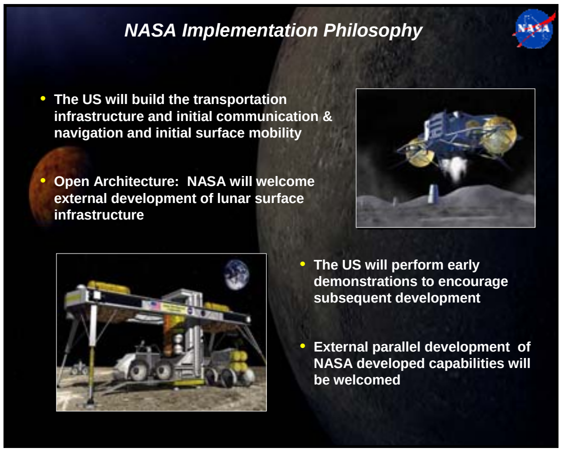

Exploration Systems Mission Directorate Organization
Headquarters
Special Assistant Program Development
P. Lockhart
Associate Administrator Exploration Systems
Chief Engineer (OCE)
D. Cooke
DAA
DAA for Management and Policy
T. Cremins
Constellation Systems Division
P. Lockhart (Acting)
COTS – N. Woodward
Advanced Capabilities Division
C. Walz
Directorate Integration Office
G. Yoder (Acting)
Strategic Integration & Management Office
G. Allen (Acting)
Resources Management Office
A. Hunter
Pending
J. Hanley
Constellation Program (JSC)
A. Lindenmoyer
Commercial Crew/Cargo Program (JSC)
LPRP (MSFC)
T. Lavoie
Human Research (JSC)
D. Grounds
Tech Dev (LaRC)
F. Peri
Orion Project (JSC)
Exploration Launch Projects (MSFC
Ground Operations Project (KSC)
Mission Operations Project (JSC)
EVA Systems Project (JSC)
Advanced Project (JSC)
Lunar Lander Project (JSC)
LRO Project Office (GSFC)
Multi-Center
Multi-Center

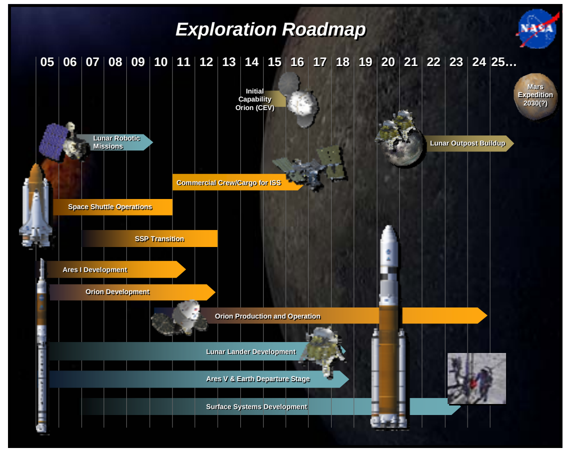

NASA Exploration Lunar Activities addressing Themes
Human Civilization
Global Partnerships
Scientific Knowledge
Economic Expansion
Exploration Preparation
Public Engagement

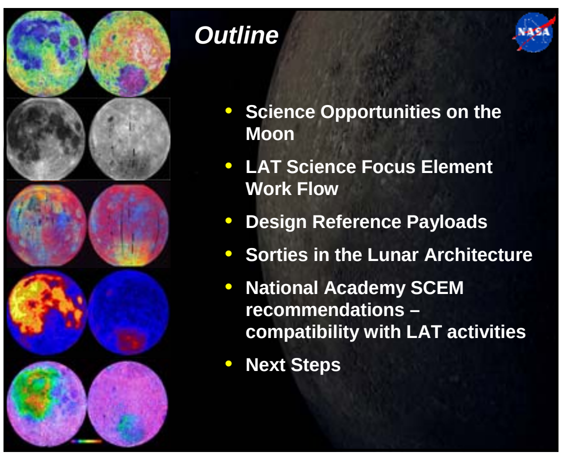

Global Exploration Strategy
Use the Moon to prepare for future human and robotic missions to Mars and other destinations
Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them
Extend sustained human presence to the moon to enable eventual settlement
Expand Earth's economic sphere to encompass the Moon and pursue lunar activities with direct benefits to life on Earth
Strengthen existing and create new global partnerships
Engage, inspire, and educate the public
March 2007

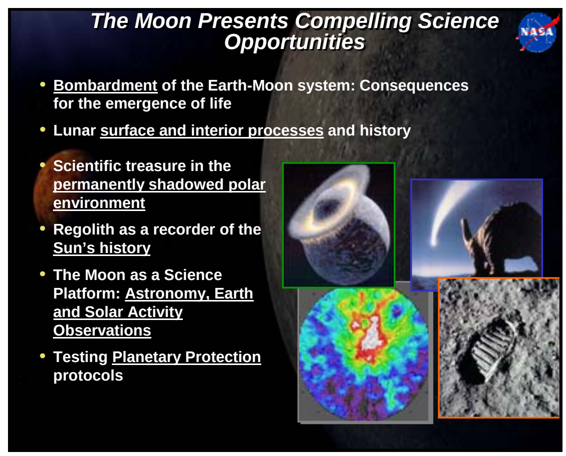

Architecture Development Driven By A Strategy
Global Exploration Strategy Development
Themes & Objectives
National Priorities Defined
LAT-1
Architecture Assessment
Reference Architecture & Design Reference Mission
Outpost First at one of the Poles
Elements critical to US
Detailed Requirements Defined
LAT-2
Detailed Design
Operations Concept, Technology Needs, Element Requirements
Maintain flexibility

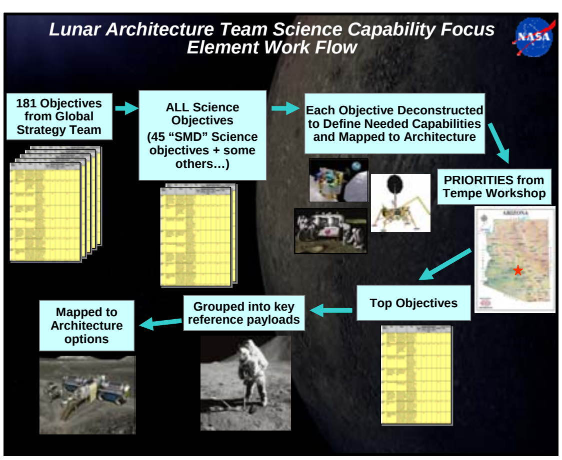

Lunar Architecture Framework —
Point of Departure- December 2006
Human lunar missions will be used to build an outpost initially at a polar site
The ability to fly human sorties and cargo missions with the human lander will be preserved
Initial power architecture will be solar with the potential augmentation of nuclear power at a later time
Robotic missions will be used to:
– Characterize critical environmental parameters and lunar resources
– Test technical capabilities as needed
The ability to fly robotic missions from the outpost or from Earth will be a possible augmentation

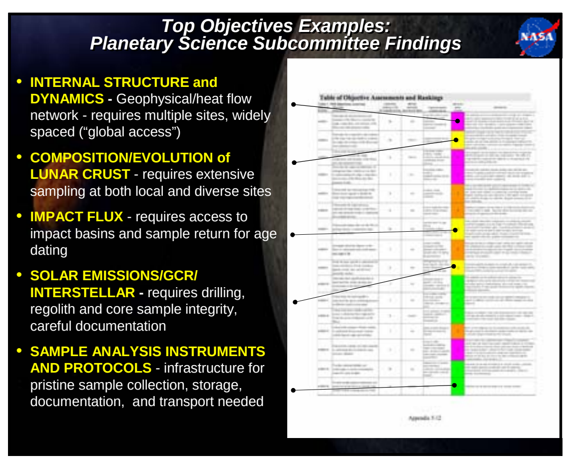

NASA Implementation Philosophy
NASA
The US will build the transportation infrastructure and initial communication & navigation and initial surface mobility
Open Architecture: NASA will welcome external development of lunar surface infrastructure
The US will perform early demonstrations to encourage subsequent development
External parallel development of NASA developed capabilities will be welcomed


Exploration Roadmap
NASA
05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25…
Initial Capability Orion (CEV)
Mars Expedition 2030(?)
Lunar Robotic Missions
Lunar Outpost Buildup
Commercial Crew/Cargo for ISS
Space Shuttle Operations
SSP Transition
Ares I Development
Orion Development
Orion Production and Operation
Lunar Lander Development
Ares V & Earth Departure Stage
Surface Systems Development

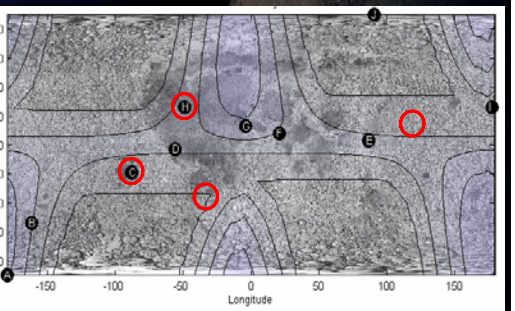

Outline
NASA
Science Opportunities on the Moon
LAT Science Focus Element Work Flow
Design Reference Payloads
Sorties in the Lunar Architecture
National Academy SCEM recommendations – compatibility with LAT activities
Next Steps


The Moon Presents Compelling Science Opportunities
NASA
Bombardment of the Earth-Moon system: Consequences for the emergence of life
Lunar surface and interior processes and history
Scientific treasure in the permanently shadowed polar environment
Regolith as a recorder of the Sun's history
The Moon as a Science Platform: Astronomy, Earth and Solar Activity Observations
Testing Planetary Protection protocols


Lunar Architecture Team Science Capability Focus Element Work Flow
NASA
181 Objectives from Global Strategy Team
ALL Science Objectives (45 "SMD" Science objectives + some others…)
Each Objective Deconstructed to Define Needed Capabilities and Mapped to Architecture
PRIORITIES from Tempe Workshop
Top Objectives
Grouped into key reference payloads
Mapped to Architecture options


Top Objectives Examples:
Planetary Science Subcommittee Findings
NASA
INTERNAL STRUCTURE and DYNAMICS - Geophysical/heat flow network - requires multiple sites, widely spaced ("global access")
COMPOSITION/EVOLUTION of LUNAR CRUST - requires extensive sampling at both local and diverse sites
IMPACT FLUX - requires access to impact basins and sample return for age dating
SOLAR EMISSIONS/GCR/ INTERSTELLAR - requires drilling, regolith and core sample integrity, careful documentation
SAMPLE ANALYSIS INSTRUMENTS AND PROTOCOLS - infrastructure for pristine sample collection, storage, documentation, and transport needed
Table of Objective Assessments and Rankings
Appendix 5-12

The Architecture Maintains Sortie Capability: Possible Sortie Locations to Optimize for Geophysics



	Site	Lat.	Long.		Site	Lat.	Long.
A	South Pole	89.9° S	180° W	F	Mare Tranquillitatis	8° N	21° E
B	Aitken Basin	54° S	162° W	G	Rima Bode	13° N	3.9° W
C	Orientale Basin	19 S	88° W	H	Aristarchus Plateau	26° N	49° W
D	Oceanus Procellarum	3° S	43° W	I	Central Far Side Highlands	26° N	178° E
E	Mare Smythii	2.5° N	86.5° E	J	North Pole	89.5° N	91° E

National Research Council Report: " Scientific Context for Exploration of the Moon"

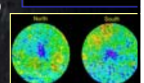
- Asked by NASA SMD to provide guidance on the ***scientific challenges and opportunities enabled by a sustained program of robotic and human exploration*** of the Moon during the period 2008-2023 and beyond

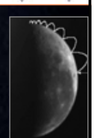
Key Science Findings:

- ***Enabling activities*** are critical in the near term
- Strong ties with ***international programs*** are essential
- Exploration of the ***South Pole-Aitken Basin*** remains a priority
- ***Diversity of lunar samples*** is required for major advances
- The Moon may provide a ***unique location for observation and study of Earth, near-Earth space, and the universe***

Scientific Context for Exploration of the Moon: Highest Priority Science Objectives

- *Test the cataclysm hypothesis by determining the* ***spacing in time of the creation of the lunar basins****.*
- *Anchor the early Earth-Moon impact flux curve by determining the* ***age of the oldest lunar basin*** *(South Pole-Aitken Basin).*
- *Establish a* ***precise absolute chronology****.*
- *Determine the compositional state (elemental, isotopic, mineralogic) and compositional distribution (lateral and depth) of the* ***volatile component in lunar polar regions****.*
- *Determine the extent and composition of the … feldspathic crust, KREEP layer, and other* ***products of planetary differentiation****.*
- *Determine the* ***thickness of the lunar crust*** *(upper and lower) and characterize its lateral variability on regional and global scales.*
- *Characterize the* ***chemical/physical stratification in the mantle****, particularly the nature of the putative 500-km discontinuity and the composition of the lower mantle.*
- *Determine the global density, composition, and time variability of the fragile* ***lunar atmosphere*** *before it is perturbed by … human activity.*
- *Determine the size, composition, and state (solid/liquid) of the* ***core of the Moon****.*
- *Inventory the variety, age, distribution, and origin of* ***lunar rock types****.*
- *Determine the size, charge, and spatial distribution of* ***electrostatically transported dust grains*** *and assess their likely effects on lunar exploration and lunar-based astronomy.*

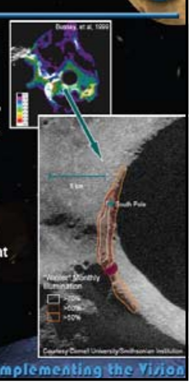


Summary and Future Work

- Science was an integral part of LAT 2 discussions
- The Lunar Architecture provides many opportunities for science
- Future studies will continue to our productive work with NASA's architecture process and the science community:
  - Refine reference payload designs, deployment and power strategies in particular -- also look more seriously at deployment of small orbiters
  - Evaluate alternate sortie locations/science strategies
  - Work with surface and mobility teams on mobility options with and without crew
  - Help plan future workshops, e.g., Optimizing the human-robotic partnership in (1) traverses, (2) near-outpost environment and (3) when humans aren't there
- NASA HQ is forming a joint SMD-ESMD Outpost Science and Exploration Working Group (OSEWG) that will consider these and other science issues within the evolving architecture

Key Decisions: Sortie vs. Outpost

- First: What is the fundamental lunar approach?
- LAT concluded outpost first is best approach
- Top 2 Themes – "Exploration Preparation" and "Human Civilization" drive to outpost
- Enables global partnerships
- Allows development and maturation of ISRU
- Results in quickest path toward other destinations
- Many science objectives can be satisfied at an outpost



Implementing the Vision

Permanent Sunlight?

South Pole: Three areas identified with sunlight for more than 50% of lunar day

One zone receives 70% illumination during dead of southern winter

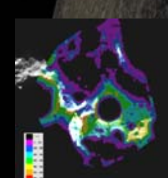
Lit areas in close proximity to permanent darkness (rim of Shackleton)

North Pole: Three areas identified with 100% sunlight

Two zones are proximate to craters in permanent shadow

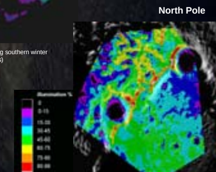
Data taken during northern summer (maximum sunlight)

South Pole

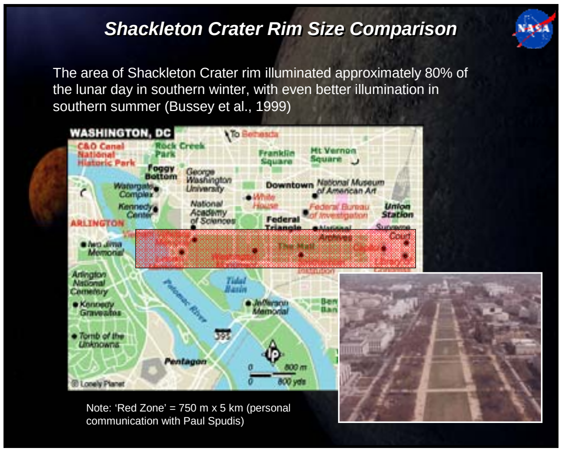


Data obtained during southern winter (maximum darkness)

North Pole



Data obtained during northern summer (maximum sunlight)


Shackleton Crater Rim Size Comparison
The area of Shackleton Crater rim illuminated approximately 80% of the lunar day in southern winter, with even better illumination in southern summer (Bussey et al., 1999)
WASHINGTON, DC
To Bethesda
C&O Canal National Historic Park
Rock Creek Park
Franklin Square
Mt Vernon Square
Foggy Bottom
George Washington University
Downtown
National Museum of American Art
Watergate Complex
Kennedy Center
National Academy of Sciences
White House
Federal Bureau of Investigation
Union Station
ARLINGTON
Federal Triangle
Iwo Jima Memorial
The Mall
Arlington National Cemetery
Kennedy Gravesites
Tomb of the Unknowns
Tidal Basin
Potomac River
Jefferson Memorial
Pentagon
800 m
800 yds
© Lonely Planet
Note: 'Red Zone' = 750 m x 5 km (personal communication with Paul Spudis)


The Moon as seen from the Earth ~4.2 billion years ago
The Earth as seen from the Moon ~15 years from now
After Pieters & Paulikas, SCEM Presentation