Space Exploration Plan

- **Low Earth Orbit**
  - Return humans to the Moon as early as 2015 to enable sustained exploration of the Moon, including a robust precursor program to develop a sustained human presence on the Moon.
  - Develop and fly the Crew Exploration Vehicle (Orion) no later than 2014.
  - 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.

- **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.
  - Tackles the mission 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.”

---

Components of Program Constellation

- **Area V - Heavy Lift Launch Vehicle**
- **Area I - Crew Launch Vehicle**
- **Orión - Crew Exploration Vehicle**
- **Earth Departure Stage**

Building on a Foundation of Proven Technologies:

- **Launch Vehicle Comparisons**

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 develop a sustained human presence on the Moon, including a robust precursor program to develop a sustained human presence on the Moon, including a robust precursor program to develop a sustained human presence on the Moon, including a robust precursor program to develop a sustained human presence on the Moon, including a robust precursor program to develop a sustained human presence on the Moon, including a robust precursor program to develop a sustained human presence on the Moon, including a robust precursor program to develop a sustained human presence on the Moon, including a robust precursor program to develop a sustained human presence on the Moon.
### Constellation Program

**Headquarters**
- Special Assistant to the Associate Administrator
- Exploration Systems Mission Directorate

**Mission Operations**
- Exploration Systems Mission Directorate

**Human Exploration**
- Exploration Systems Mission Directorate

**Vehicle Project**
- Exploration Systems Mission Directorate

**Science**
- Exploration Systems Mission Directorate

**Technology**
- Exploration Systems Mission Directorate

**Launch Projects**
- Exploration Systems Mission Directorate

**Crew Exploration Defined**
- Exploration Systems Mission Directorate

**Mission Operations Defined**
- Exploration Systems Mission Directorate

**Launch Projects Defined**
- Exploration Systems Mission Directorate

**Crew Exploration Driven By A Strategy**
- Exploration Systems Mission Directorate

**Mission Operations Driven By A Strategy**
- Exploration Systems Mission Directorate

**Launch Projects Driven By A Strategy**
- Exploration Systems Mission Directorate

**Architecture Development Driven By A Strategy**
- Exploration Systems Mission Directorate

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### 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

### 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**

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

**Lunar Robotic Missions**

- Lunar Outpost Buildup
- Commercial Crew/Cargo for ISS
- Ares I Development
- Lunar Lander Development
- Surface Systems Development
- Ares V & Earth Departure Stage

**Exploration Roadmap**

- SSP Transition
- Orion Development
- Orion Production and Operation
- Space Shuttle Operations
- Initial Capability: Orion (CEV)

**The Moon Presents Compelling Science Opportunities**

- 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.
- Testing Planetary Protection protocols.

**Outline**

- 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

**Lunar Architecture Team Science Capability Focus Element Work Flow**

- PRIORITY from Tempe Workshop
- Top Objectives Examples: Planetary Science Subcommittee Findings

**Top Objectives Examples: Planetary Science Subcommittee Findings**

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

Site Lat. Long.

A  South Pole  89.9° S  180° W
B  Aitken Basin  54° S  162° W
C  Orientale Basin  19° S  88° W
D  Oceanus Procellarum  3° S  43° W
E  Mare Smythii  2.5° N  86.5° E

Site Lat. Long.

F  Mare Tranquillitatis  8° N  21° E
G  Rima Bode  13° N  3.9° W
H  Aristarchus Plateau  26° N  49° W
I  Central Far Side Highlands  26° N  178° E
J  North Pole  89.5° N  91° E


• 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 volatiles component of lunar interior volatile
• Determine the extent and composition of the volatile ocean 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 possible 500-km discontinuity and the composition of the lower mantle
• Determine the global density, composition, and time variability of the fragile lunar atmosphere
• Determine the size, charge, and spatial distribution of electrostatically transported dust grains and assess their likely effects on lunar exploration and human-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

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)

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 best approach
• 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

Permanent Sunlight?
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).

Note: ‘Red Zone’ = 750 m x 5 km (personal communication with Paul Spudis).