Exploration and Science: The Role of the Moon

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1st Space Exploration Conference

Continuing the Voyage of Discovery

February 1, 2005

What's the value of exploration?

- *Humans explore because it conveys an evolutionary advantage*
  - exploration broadens experience and imagination, permitting better prediction of the future, ensuring better odds for survival
  - curiosity and its satisfaction is intellectually and emotionally satisfying
- *Exploration improves our ability to solve problems*
  - increased imagination and knowledge base permits recognition of innovative approaches and solutions
  - helps focus energies on posing the right questions, or, questions that can be addressed and answered
- *Exploration excites and inspires the creative, productive segment of society*
  - Facilitates intellectual connections and relations that might not otherwise occur (the 'ah-ha!' syndrome)
  - Frontiers are unknown, mysterious places that stimulate imagination

Exploration ≠ Science

- Exploration is going into the unknown, probing the frontier, looking over the next hill.
  - It has structure, but is not directed
  - Discoveries sometimes build on each other, sometimes are isolated
- Science is the process by which we explain nature
  - It has a well-defined, directed structure (observation, hypothesis, experiment, verification)
  - Scientific knowledge is cumulative and self-correcting
- Both are dynamic, not static. Science always follows exploration
- *Exploration is more important than science!*

Why Human Spaceflight?

Scientific reasons

- People bring unique capabilities to space exploration
  - Conduct field science, requiring intense interaction of human with environment
  - Repair and maintain complex equipment and installations
- Machines do not and will not possess intelligence of necessary magnitude to explore the solar system adequately
  - Robots are good in remote, hostile environments to provide first-order, reconnaissance information
  - Robots can be designed to answer focused questions (hypothesis testing) or make precision measurements
    - *But:* Don't always know ahead of time what measurements are significant and which are irrelevant

Why Human Spaceflight?

Intangibles

- The Inspirational Motivation
  - People in space are our surrogates; vicarious exploration
  - Cathedral-building; scale is too big for one generation
  - A human window onto the universe
- The Drama
  - Marked upsurge of public interest during crises (e.g., Apollo 13)
  - Humans solving life-and-death problems under the the pressure of time is one of the oldest dramas
- The Spectacle
  - A reincarnation of our pioneer/frontier origins
  - Encourages a communal perspective
  - Belief in something bigger than ourselves

Science in the Vision for Space Exploration

- Science ***enables*** the Vision
  - Provides strategic knowledge base for operations and activities
  - Provides guidance on destinations and objectives
- Science is ***enabled by*** the Vision
  - New exploration provides opportunities for scientific discovery
  - Infrastructure needed for the Vision permits science that would not be otherwise possible

A Science Research Agenda for the Vision

- **Origins**
  - The beginnings of our universe, solar system, planets, and life
- **Evolution**
  - The physical, chemical, and biological processes that have affected the universe and the sequence of major events in our history
- **Fate**
  - What the lessons of galactic, stellar, and planetary history tell us about the future and our place in the universe

The Value of the Moon

- Science
  - A natural laboratory for planetary science
  - A platform to observe the universe
- Inspiration
  - A new directed goal for an agency previously without one
  - A nearby world to explore and use
- Resources
  - Materials and energy for cislunar space

A Natural Laboratory for Planetary and Space Science

Origin of Earth-Moon system

Crustal formation and evolution

Impact bombardment of Earth-Moon system

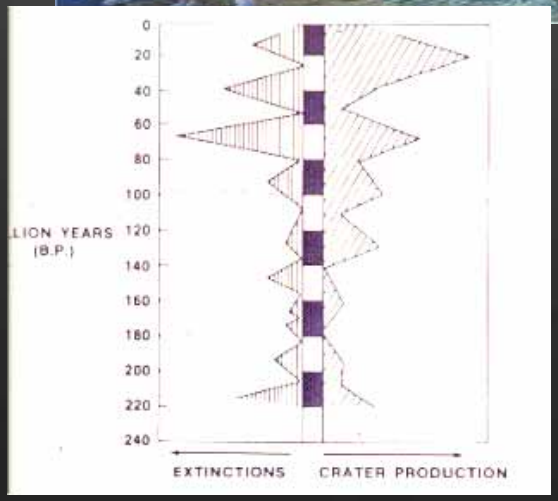
Volcanic processes and history

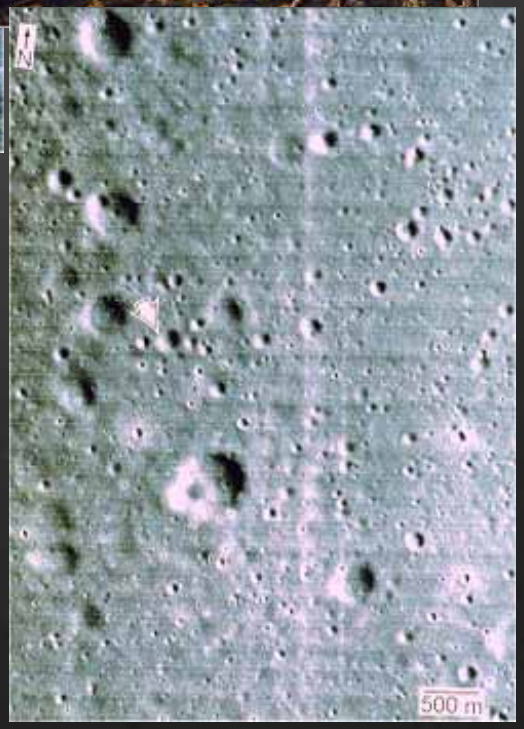
Structural deformation: styles and history

Moon as a probe of solar and galactic history

Reconstructing the Impact Record

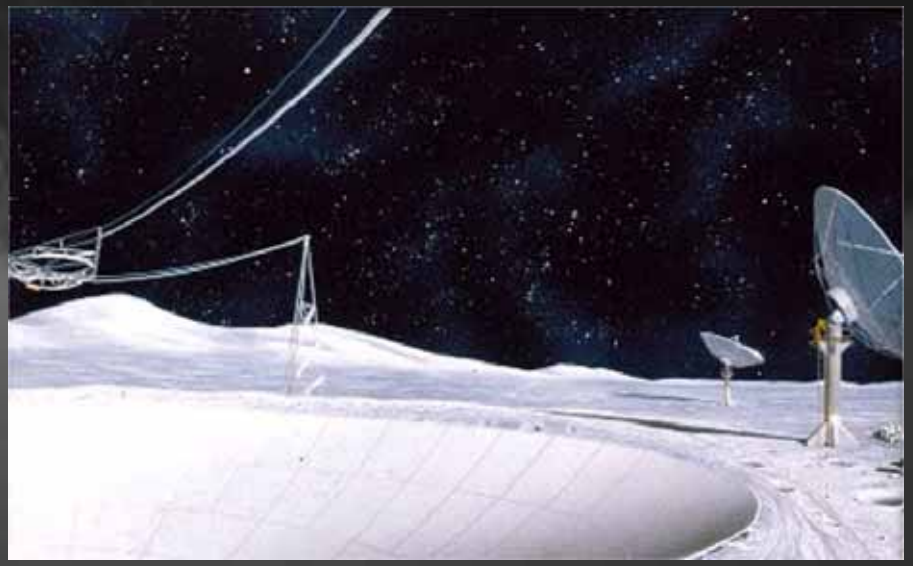
- KT impact 65 my ago wiped out 90% of fossil families
- Incomplete statistics suggest such impacts may occur periodically
- Earth geologic record too incomplete to assess the effect
- Moon retains impact record of Earth-Moon system





A Platform to Observe the Universe

- No atmosphere; full spectrum from DC to gamma-rays visible from lunar surface
- Far side of Moon only known place in universe permanently shielded from Earth's radio noise
- Stable platform permits extremely sensitive instruments to be built and operated



- Dark areas near poles a natural resource for cooled IR detectors
- Natural topography can be used to construct large dish antennas
- Cold, dark sky; two weeks of night time

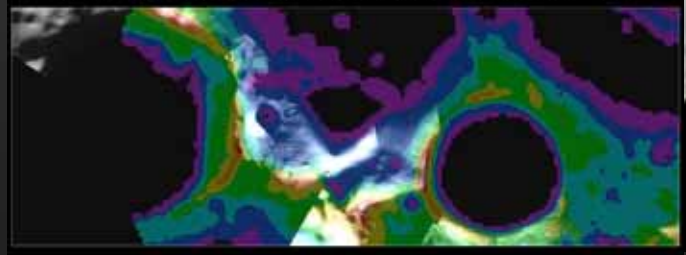
Inspiration: A Place to Live and Work in Space

- A natural Space Station, already in Earth orbit, ready to inhabit
- Learn the skills we need to live off-planet
- Learn how to explore planetary surfaces (the roles of humans and machines)
- Societal and psychological impacts of human space communities
- Opportunities for exploration and discovery

Resources: Materials and Energy for Space and Earth

- Water ice in shadowed regions of both poles
- Extract oxygen, metals from lunar materials for construction, propellant
- Retrieve solar-wind gases (e.g., hydrogen and other volatiles) implanted on lunar dust grains
- Collect solar energy with photoelectric arrays built from lunar materials and beam energy to Earth or cislunar space

Goldstone bistatic "same sense polarization" image



Clementine lighting map

Science and the Vision

- Vision for Space Exploration offers opportunities for new and unique scientific observations and discoveries
- Exploration traditionally has opened new scientific frontiers and disciplines and sometimes changes paradigms (e.g., Darwin on the *Beagle*)
- Scientific community should help NASA define a research agenda to maximize the productivity of the Vision
- We should broaden our understanding of the meaning of “science” to include applied sciences (e.g., prospecting)