The Advance of Science at NASA

Enabling Exploration!
Science supports Exploration

**Space Science**
“Discovery-oriented”

- Basic inventorying
- 0th-order questions

**Earth Science**
“Prediction-oriented”

- Boundary conditions
- Higher-order questions

**Comprehensive scientific investigations into the Origin, Evolution, and Destiny of the Earth, Moon, Mars, and Beyond**

→ **Exploration**
Exploration as a new “context”

Apollo

MER Oppty

SCIENCE will inform and guide Exploration...
A First Step in Exploration: 2008 Lunar Reconnaissance Orbiter
Scientific Linkages: *Moon Volatiles*

- Comets
- Solar Wind
- Early H₂O
- Internal volatiles
- The Moon
- Giant Molecular Clouds
- Interplanetary Dust Particles
- C-type?
- Asteroids

LRO Addresses...
Exploration of the MOON and Mars will catalyze new understanding of IMPACTS on Earth
Mars: a “Final Frontier”

Using Science to get us there...
Was the environment on Mars ever right for emergence of life?

If so, did life emerge on Mars?

If it did, is there life on Mars now?
Searching for Life on Mars: Are we ready?

"Hold still, Larry, it's taking another picture..."

By Walt Handelsman, The Times-Picayune, New Orleans, La., Tribune Media Services
Exploration asks the Question...

We’ve arrived at questions we ask about Earth!

- Climate
- Geology
- Carbon chemistry
- Evolution or dramatic change?
- Habitable environments?
- Persistent liquid water?
- Processes and their chronology?
- Hostile surface chemistry?
- Origin of life?
Mars: interacting systems from outside in...
MARS: Polar Science: Where Water and Climate interact...

S. Polar dynamics

N. Polar systems
Opportunity at Burns Cliff in Endurance Crater

Sprint at the Columbia Hills

Two Different Water Stories...

Implications
Mars Science Highlights

*Opportunity Discovers Evidence of Rocks Deposited and Soaked in a Body of Water!*
Earth as a Testbed: *Evaporites* as potential habitats... *Sulfate* salts

- Antarctic Dry Valley (Don Juan Pond): IKONOS
- Great Salt Desert, Iran: IKONOS

**Cold-Based Evaporites**

**Desert Evaporites**
Where to Look?

- Mars has a surface area equivalent to the land area of Earth. Where on Mars should we look for an answer?

- Look in areas with **High Habitability Potential**
  - Areas that have several elements considered necessary for life
  - Key
    - Water — where it might have been and, where it might be now
    - Complex carbon chemistry
    - Sources of disequilibrium trace gases
    - Hydrothermal areas
DELTAS: Long-standing bodies of water required, whether Earth or Mars!
Exploring Preservation Potential:
Ongoing robotic exploration identifies the possibilities...now to get there
Headscarp of Chasma Boreale
1000 m of layered ice, frozen sand dunes, and layered sedimentary rock above a cratered basement

Ice, Sediments, Melting... *Habitat?*
Mars Exploration: Investigation Pathways

- **Guiding Principles:**
  - *Scientific discoveries yet to be made will alter current plans*
  - Technology development will affect the pace of the program
  - Budget will always constrain the plan
  - *To remain resilient, all futures are defined in terms of a series of potential pathways — not a deterministic queue of missions*
Scientific Outcomes can be largely Unknown

While all knowledge is valuable, NASA anticipates extraordinary scientific results from the Vision for Space Exploration...
Climate History

Sample Selection

Ancient Water

Validate Paleo-Life

Resources

Extant Life?

Reconnaissance

Site Selection

Sample Selection

Return Sample

Field Studies

Deep Drilling

Exploring Mars
Mathilde, a dark C-type asteroid

C-type offer unique science possibilities

Certain Asteroids offer high scientific discovery potential relevant to the search for life’s origins... C-types etc.

Targets for human exploration??

Ida and moon

Diversity of Asteroids
Asteroid Vesta (~ 550 km across [AZ size])
Hubble Space Telescope • Wide Field Planetary Camera 2
TARGET for HUMAN EXPLORATION near Earth?

1998 KY26: ~ 30m diameter C-type NEA

(After Ostro)
EXPLORATION is HAPPENING at NASA!

Spitzer: Astrophysics

Moon from Earth (SAR)!

Europa: a Next Step?

TITAN: Possibilities!

MER on Mars

Samples: keep on giving!
From the Moon to Mars and Beyond, Scientifically