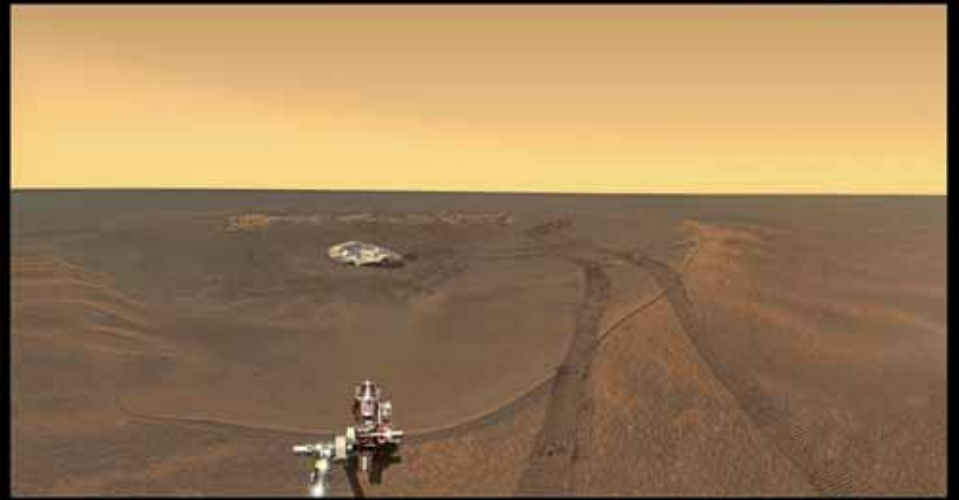


# Science and Exploration: *Moon to Mars*



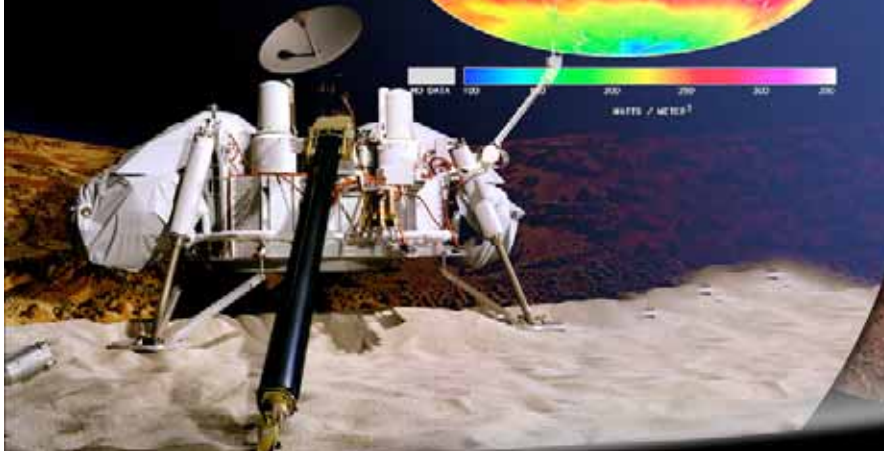
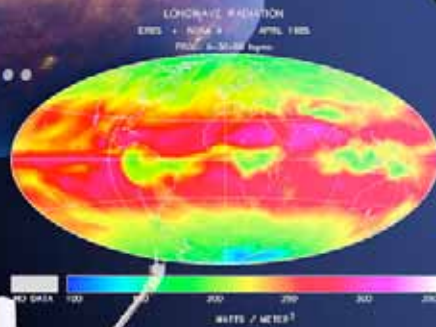
**Dr. Jim Garvin**  
NASA Chief Scientist  
*Exploration Conference*  
*Orlando, Florida*  
*Feb. 1, 2005*

# The Advance of Science at NASA *Enabling Exploration !*

WE WILL BE...

WE ARE...

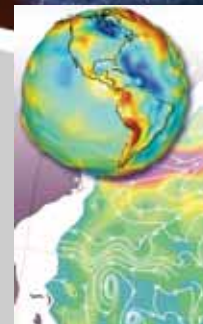
WE WERE...



# Science supports Exploration



LRO



**Space Science**  
*"Discovery-oriented"*

**Earth Science**  
*"Prediction-oriented"*

Basic inventorying  
0<sup>th</sup>-order questions

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”



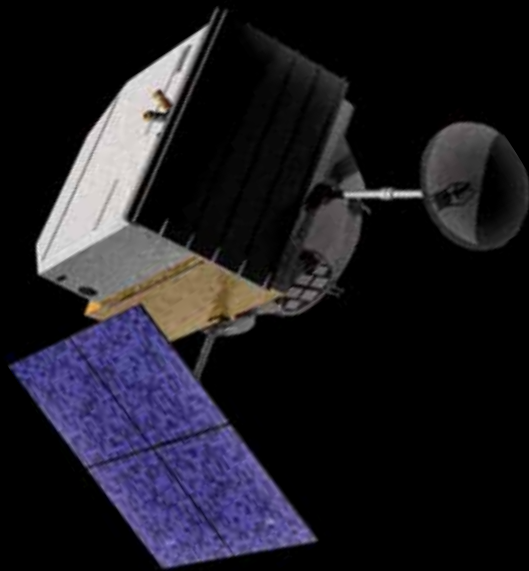
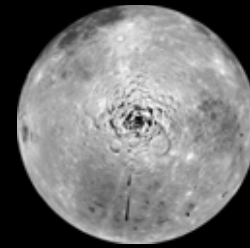
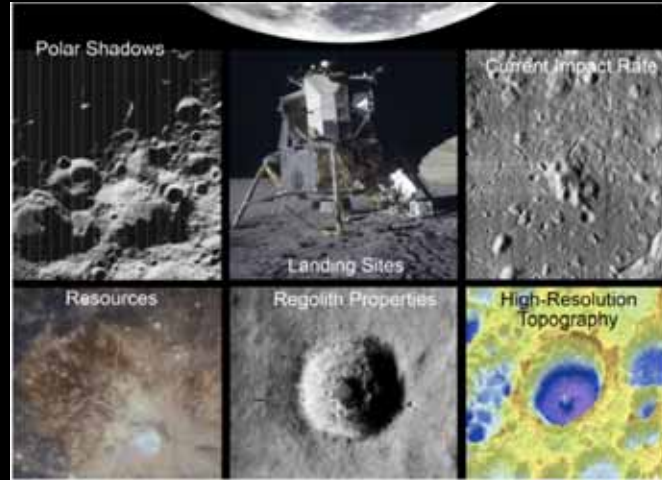
Apollo



MER Oppty

**SCIENCE will inform and guide Exploration...**

# *A First Step in Exploration: 2008 Lunar Reconnaissance Orbiter*



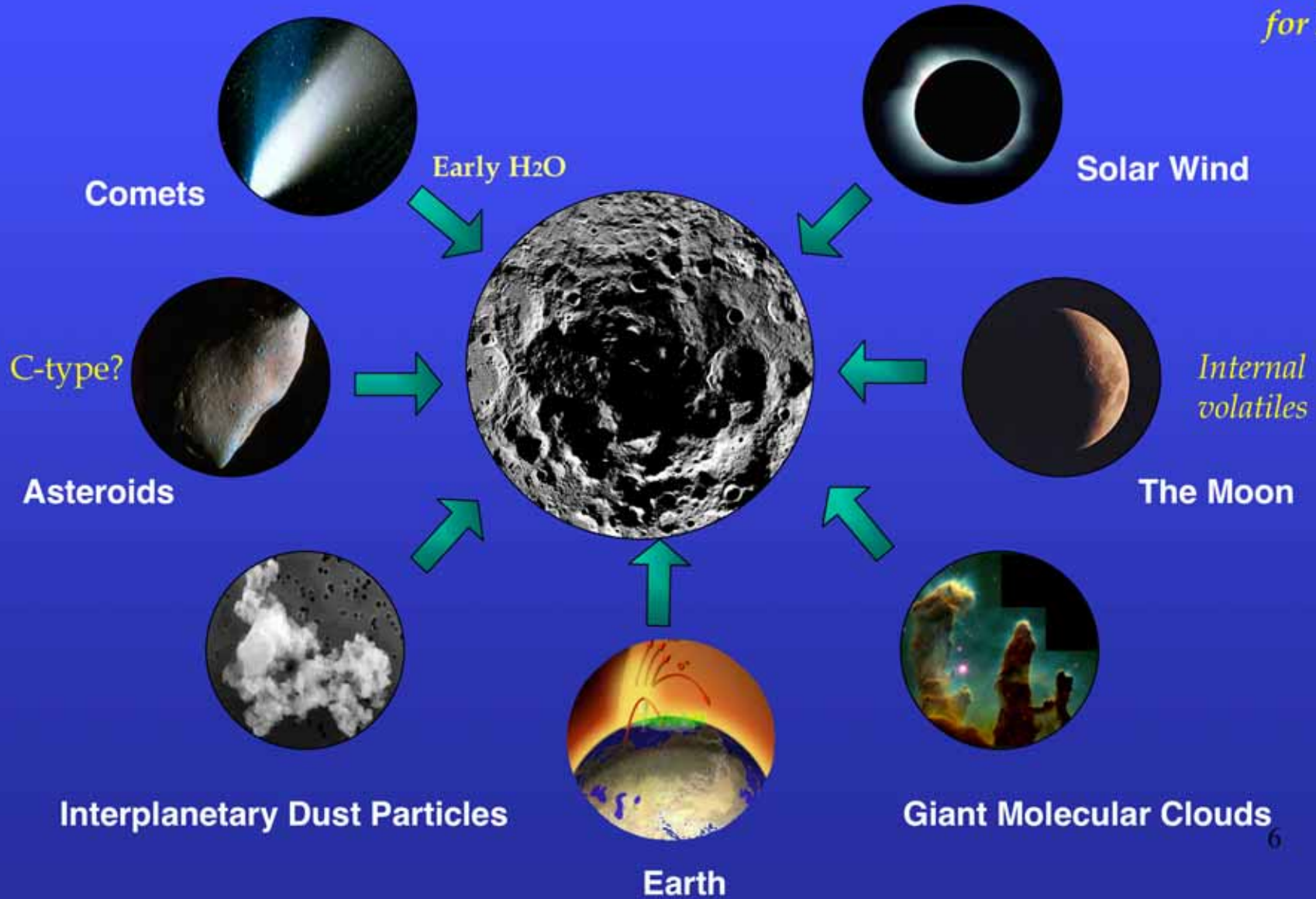
LRO

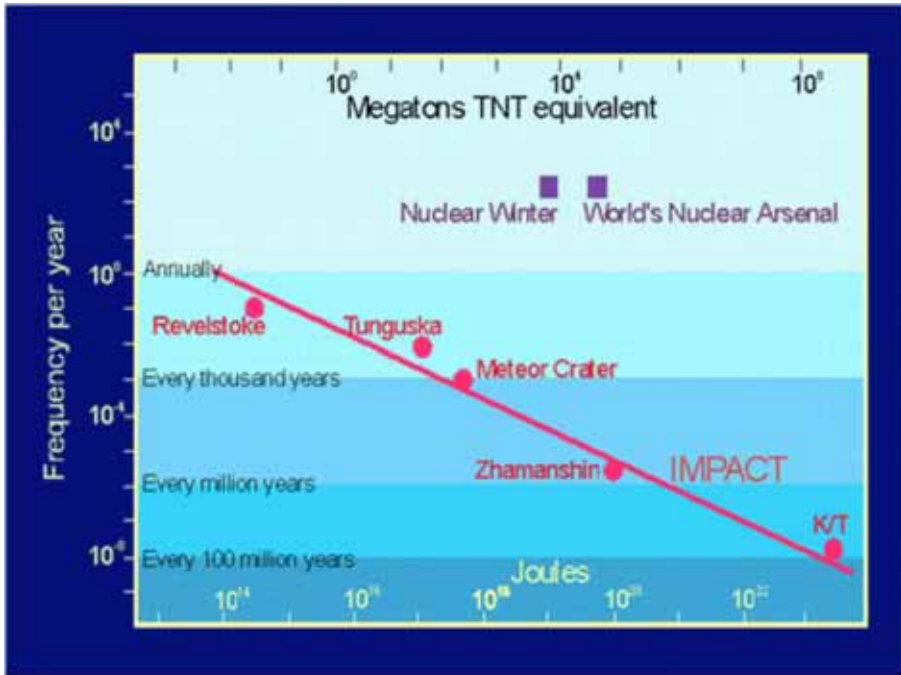


# Scientific Linkages: *Moon Volatiles*



*In Prep  
for Mars*





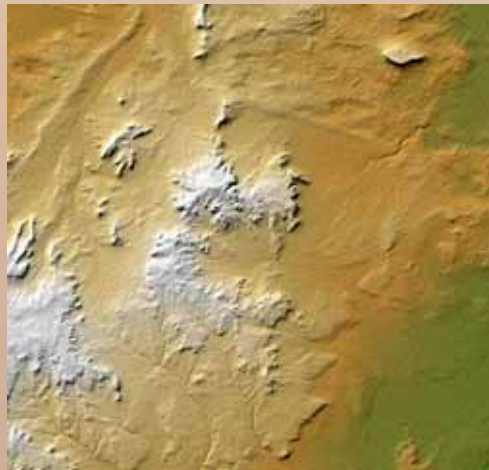
Cosmic Collisions... The risks of planetary impacts



Tycho



Meteor



Zhamanshin



Popigai

**Exploration of the MOON and Mars will catalyze new understanding of IMPACTS on Earth**

# Mars : a “Final Frontier”

Using Science to get us there...



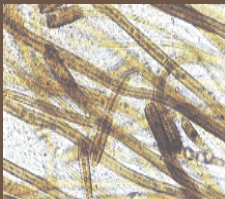


*NASA's Mars  
Exploration  
Program  
Objectives*

Was the environment on Mars ever right for emergence of life?

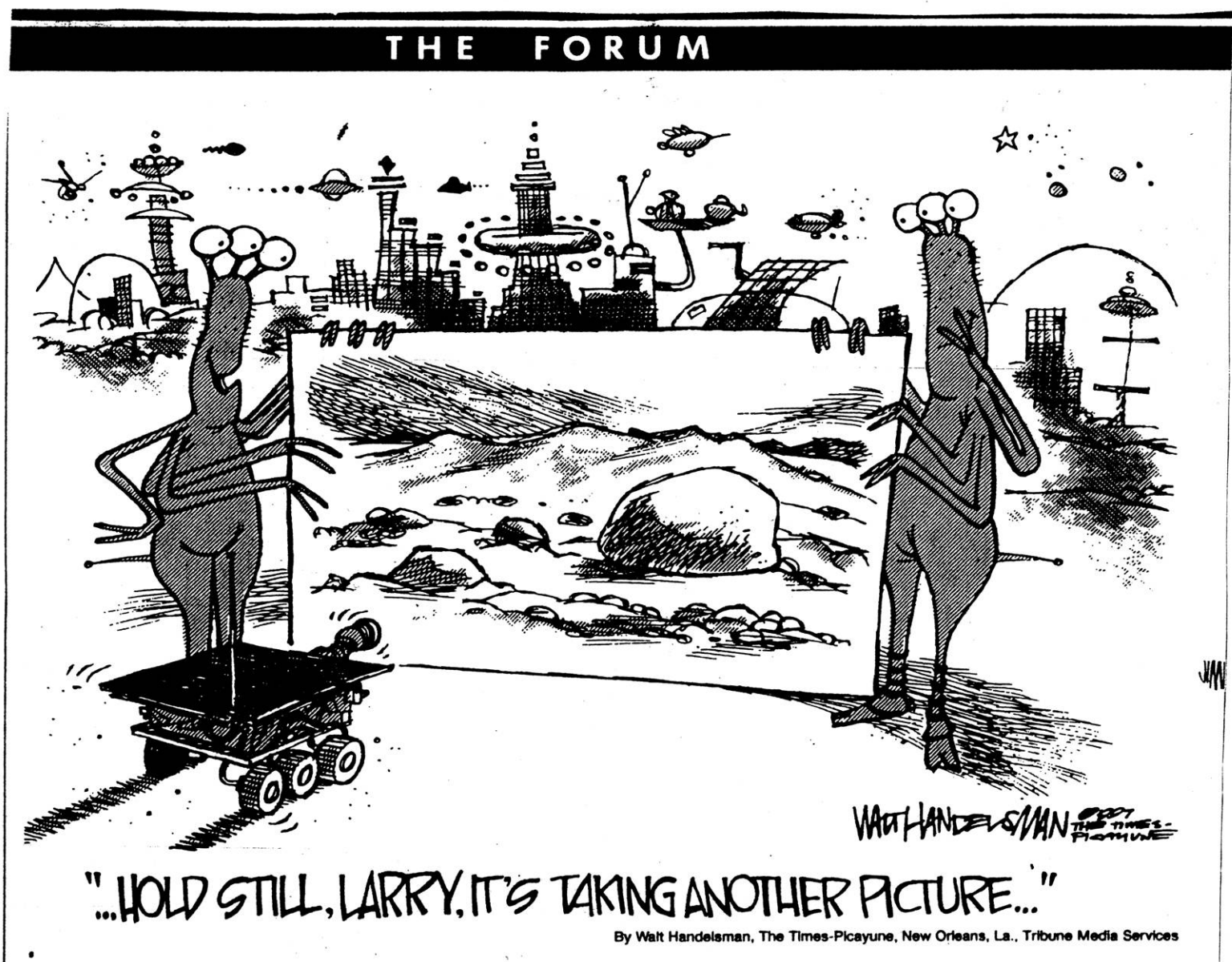
If so, did life emerge on Mars?

If it did, is there life on Mars now?



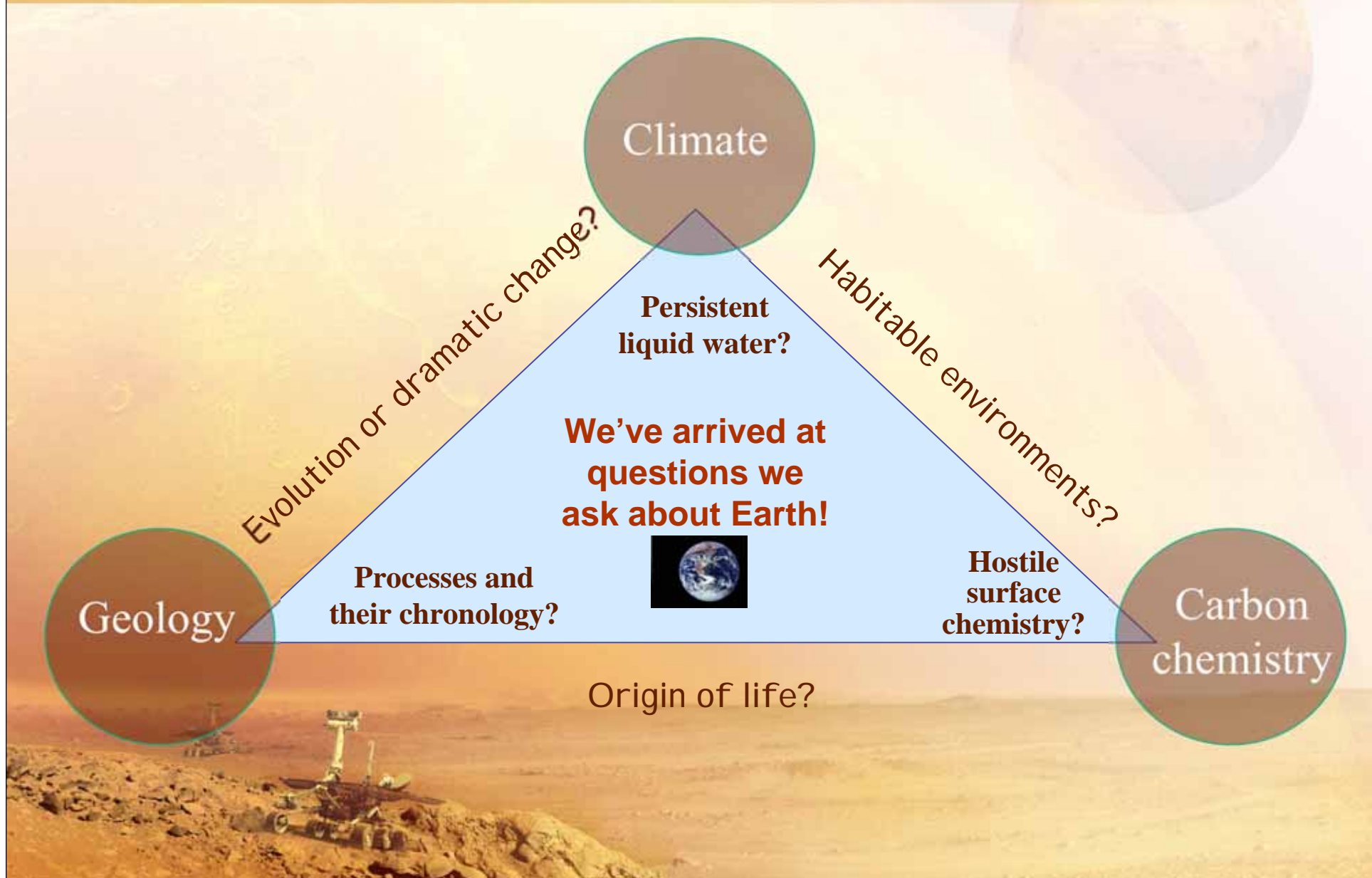


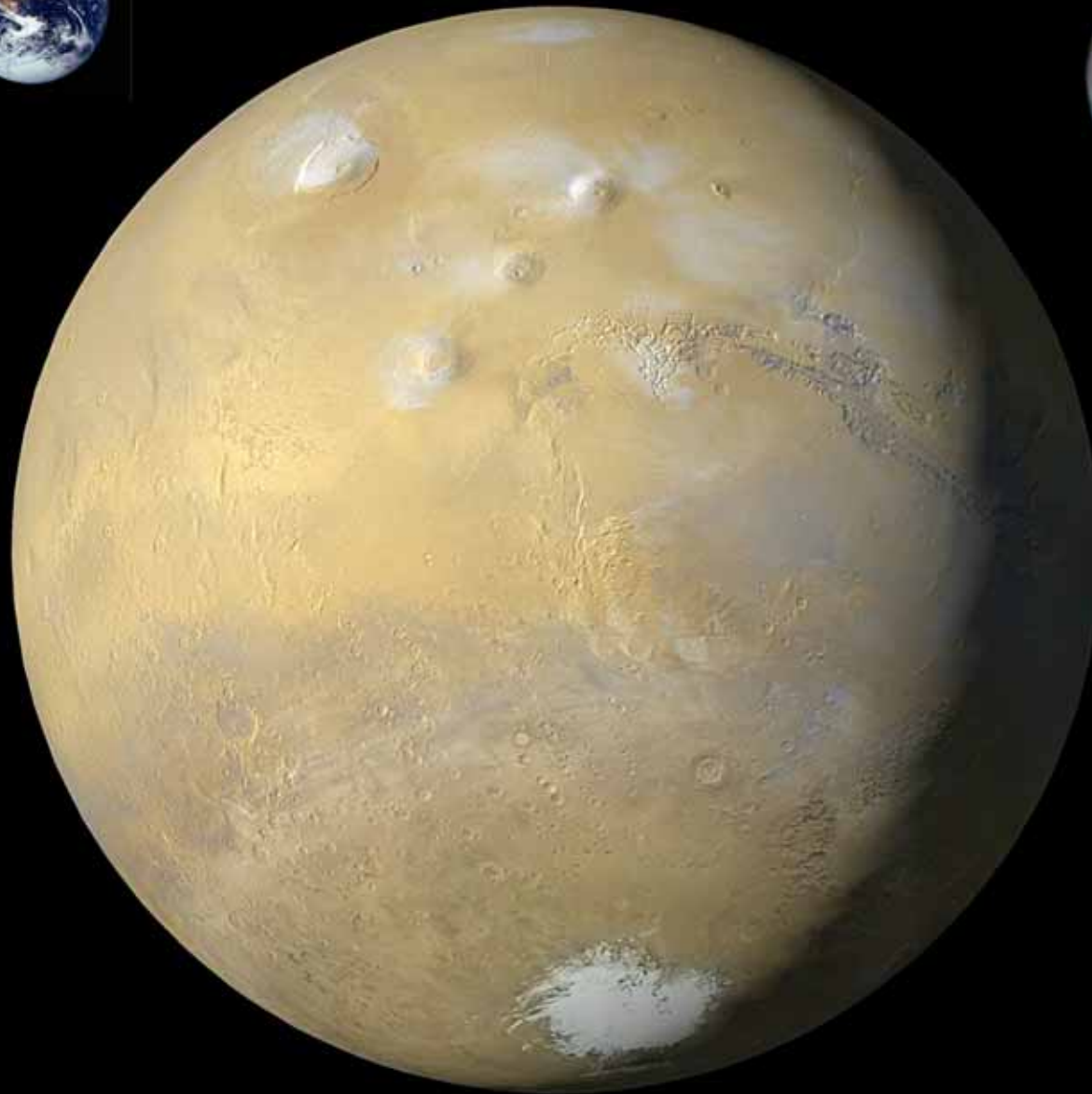
# Searching for Life on Mars: *Are we ready?*





# Exploration asks the Question...



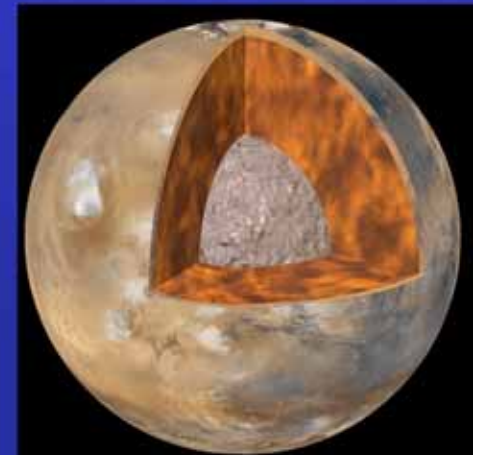


June 26, 2001

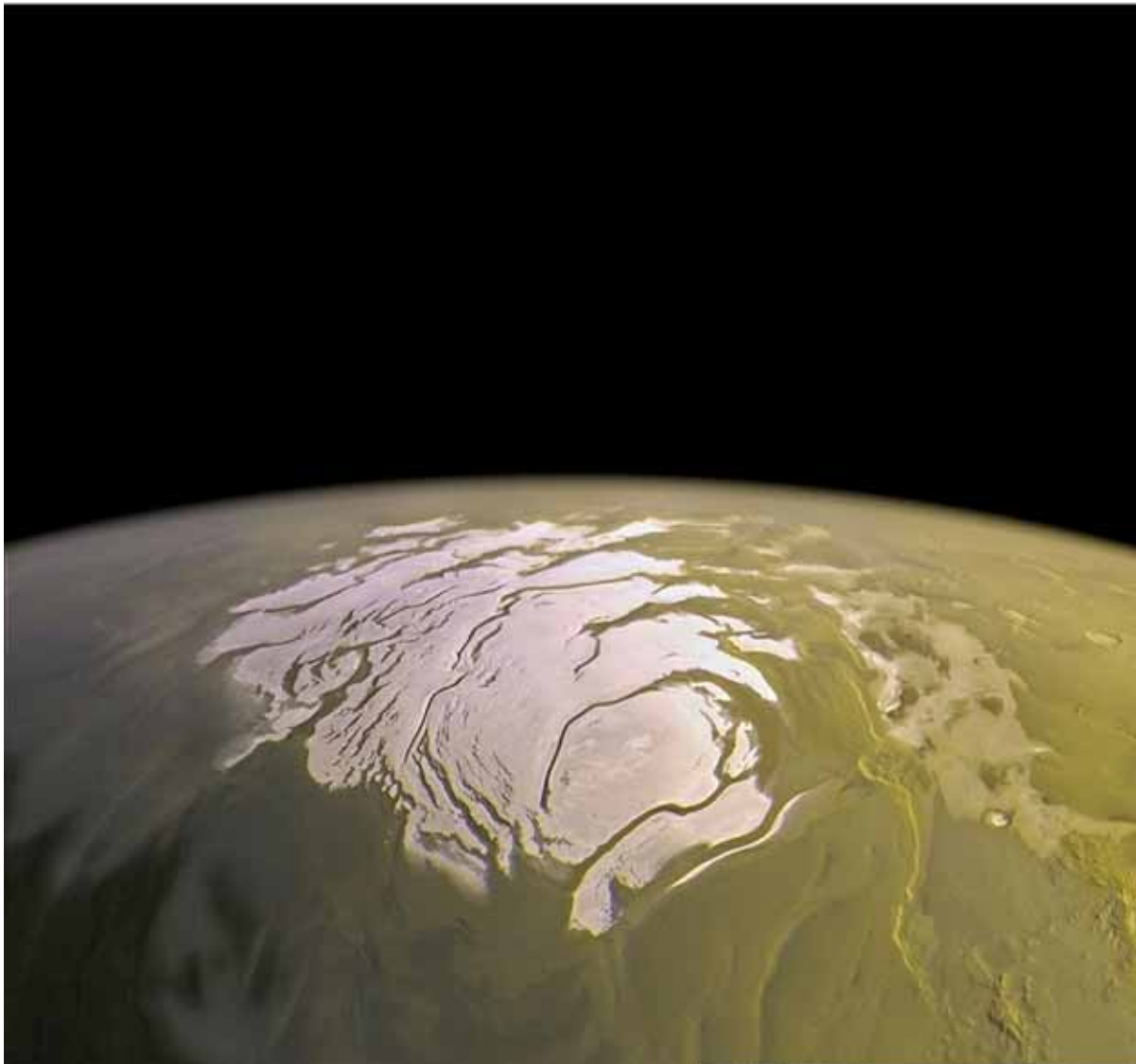


September 4, 2001

**Mars:**  
interacting  
systems from  
outside in...



*MARS: Polar Science:  
Where Water and Climate  
interact...*



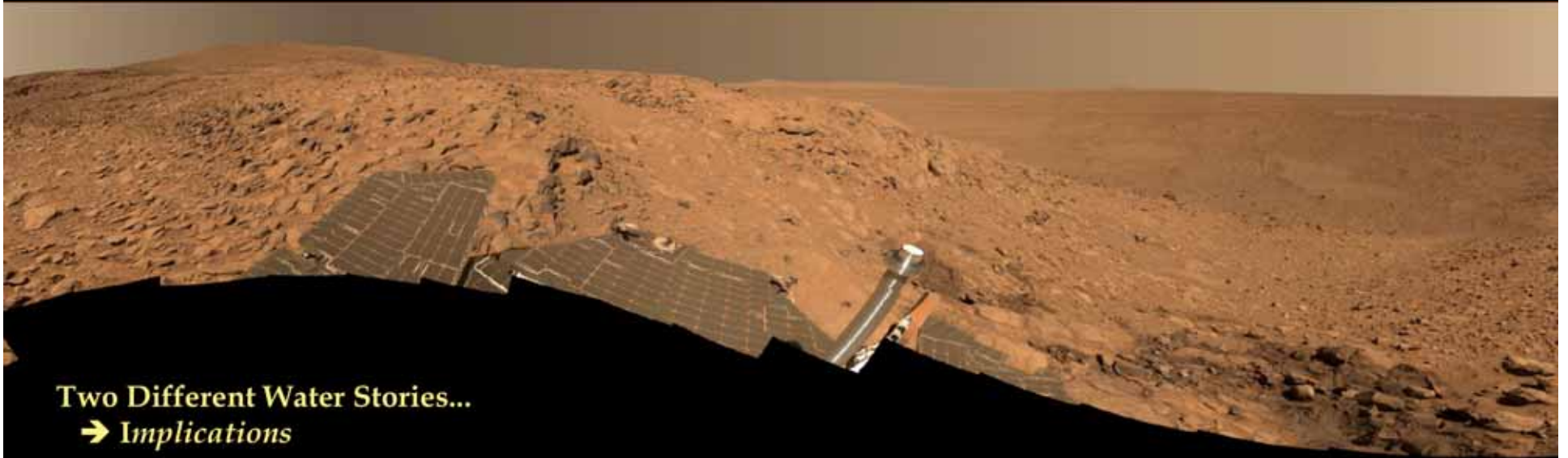
**N. Polar systems**



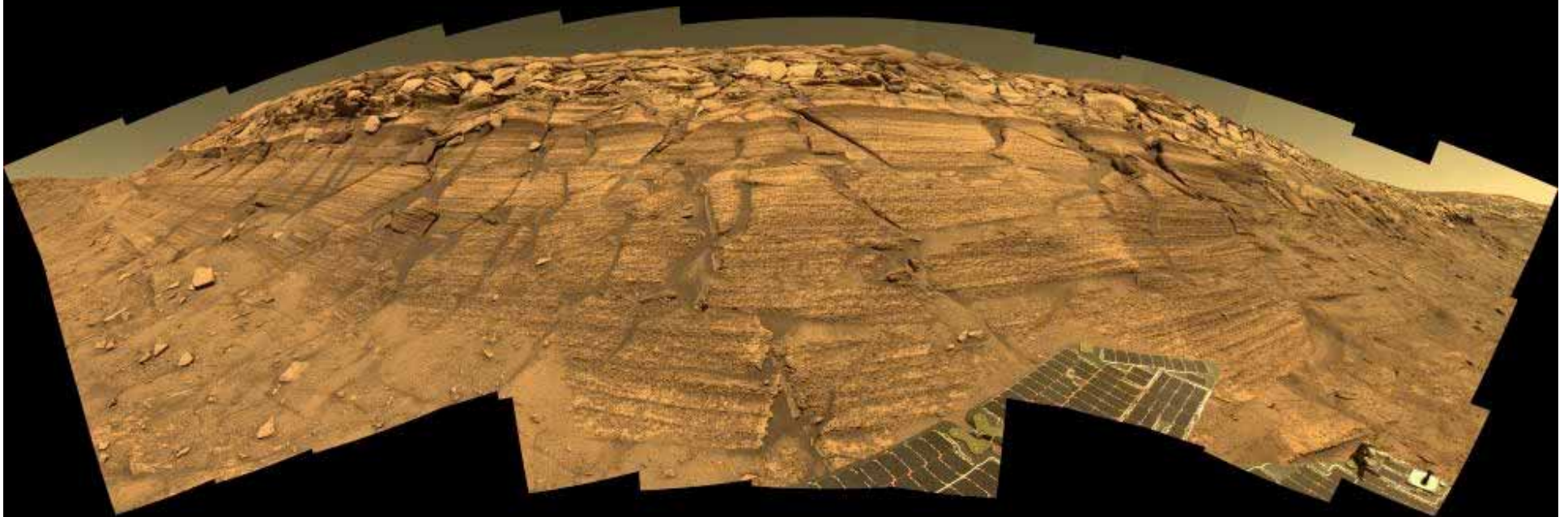
**S. Polar dynamics**



## *Spirit at the Columbia Hills*



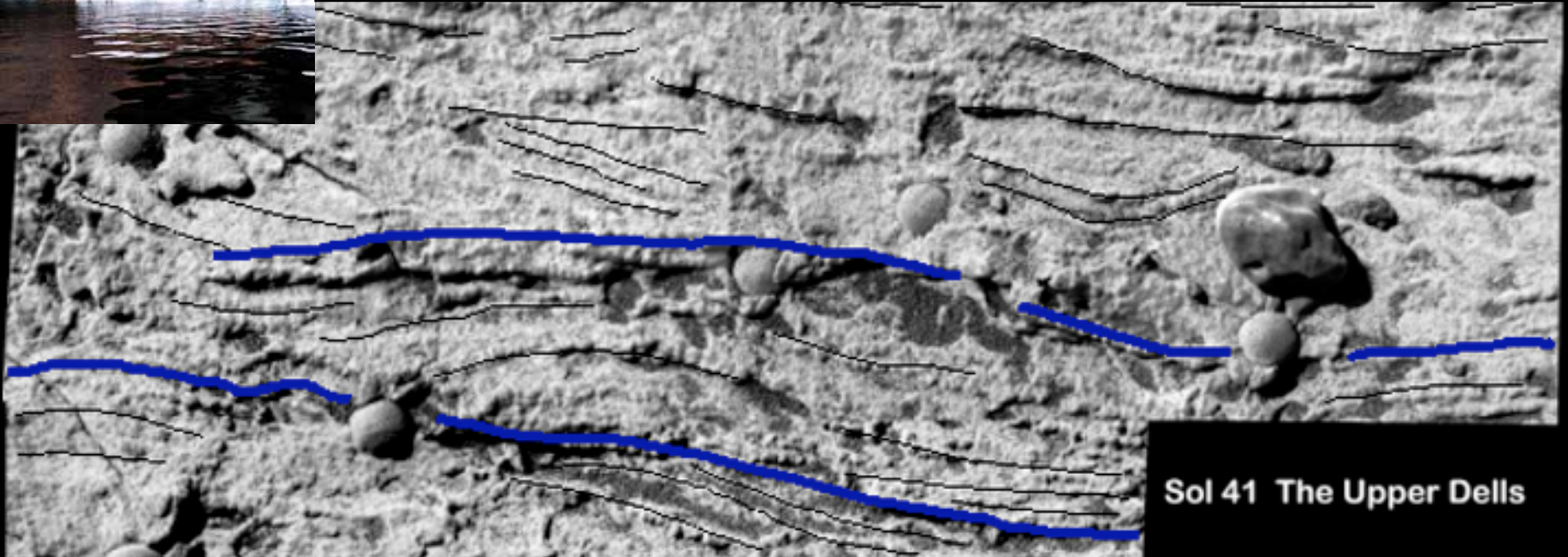
Two Different Water Stories...  
→ *Implications*



*Opportunity at Burns Cliff in Endurance Crater*

# Mars Science Highlights

*Opportunity Discovers Evidence of Rocks Deposited and Soaked in a Body of Water!*



Sol 41 The Upper Dells



Earth Analogue

# Earth as a Testbed : *Evaporites* as potential habitats...Sulfate salts



*Antarctic Dry Valley (Don Juan Pond): IKONOS*

**COLD-BASED EVAPORITES**



*Great Salt Desert, Iran: IKONOS*

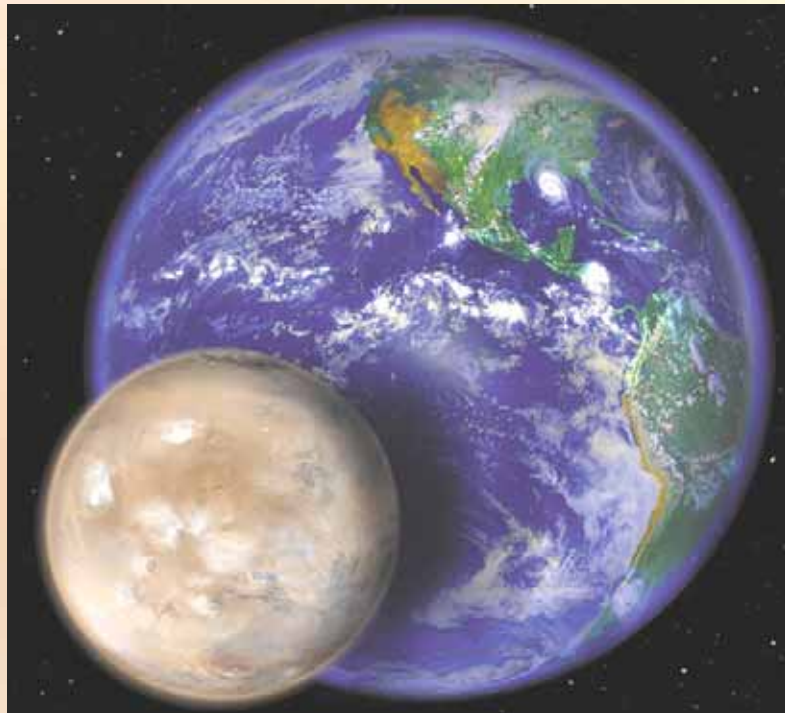
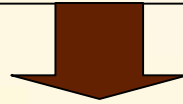
**DESERT EVAPORITES**





# Where to Look?

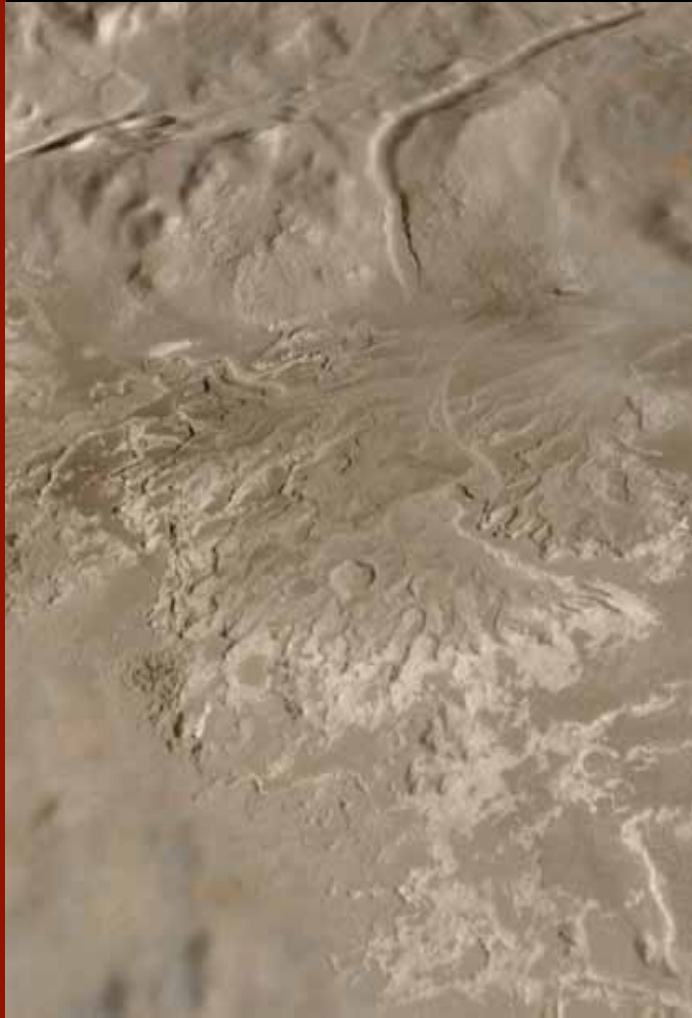
- *Mars has a surface area equivalent to the land area of Earth. Where on Mars should we look for an answer?*



- **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*



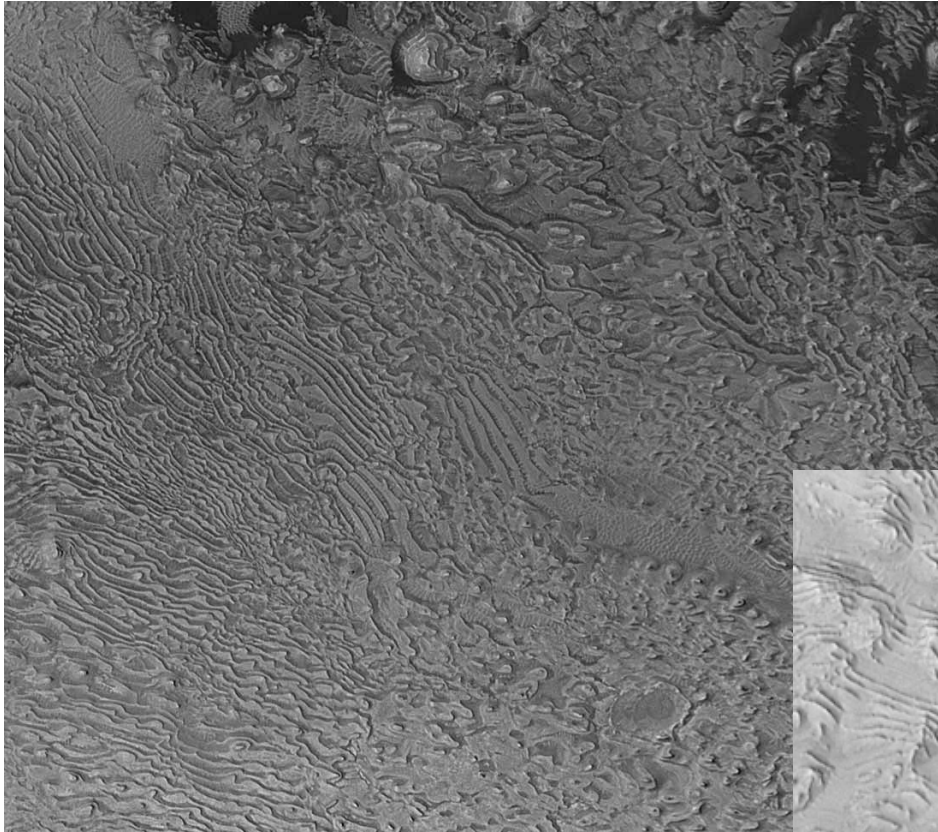
**DELTA: *Long-standing bodies of water required, whether Earth or Mars!***



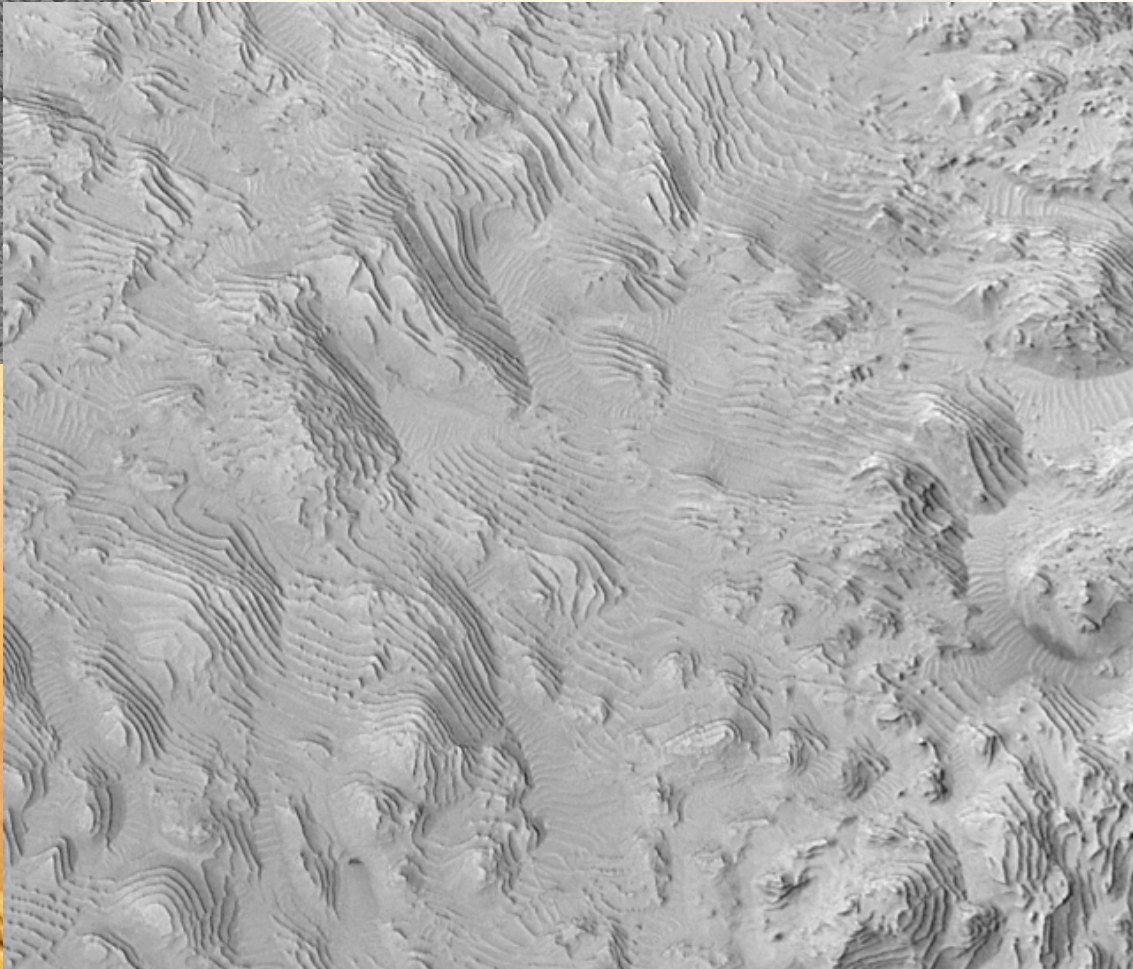
Holden Crater "delta" (MGS/MOC)



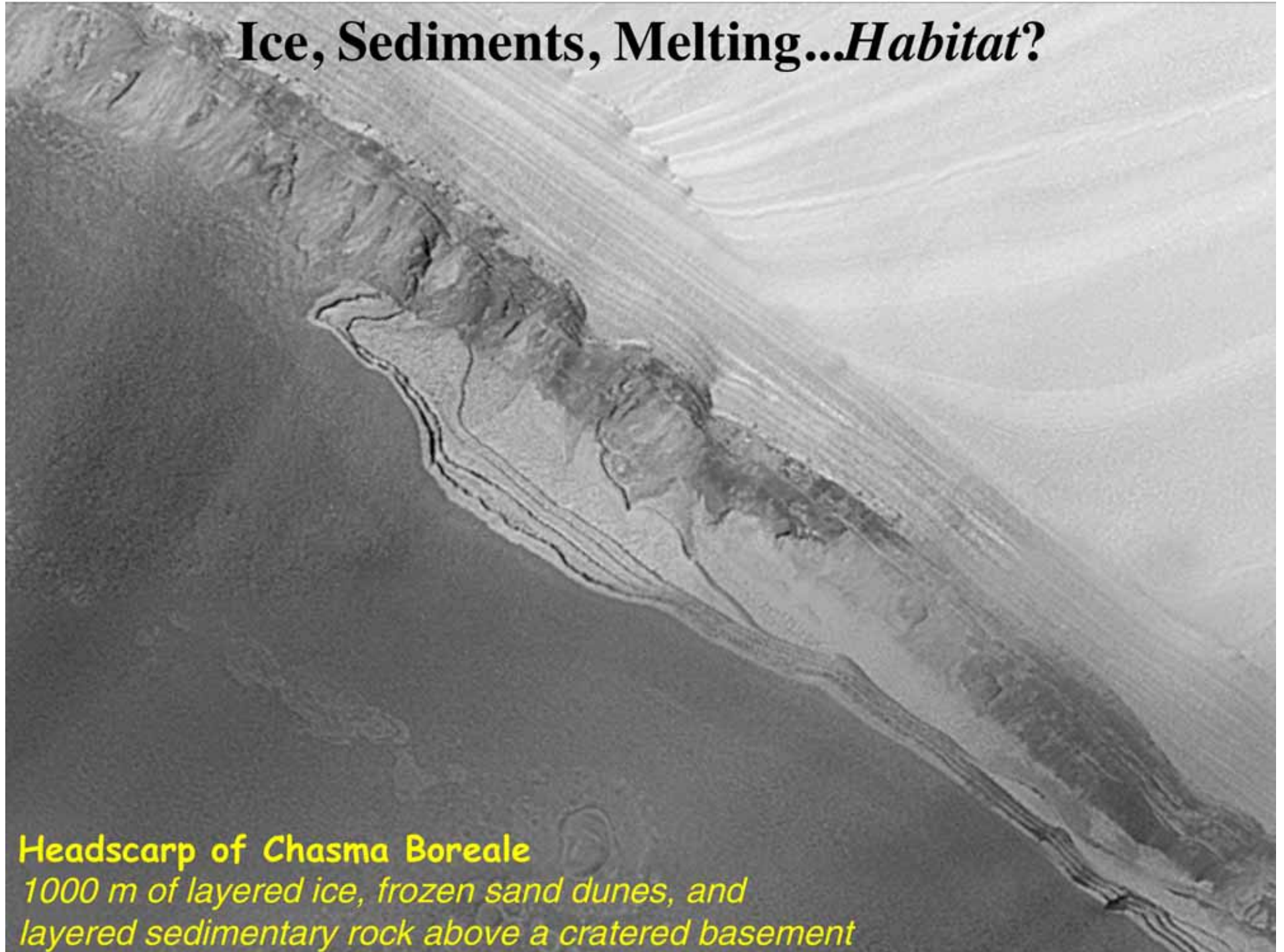
Volga River Delta (Landsat 7)



**Exploring Preservation Potential:**  
*Ongoing robotic exploration identifies  
the possibilities...now to get there*



# Ice, Sediments, Melting...*Habitat?*



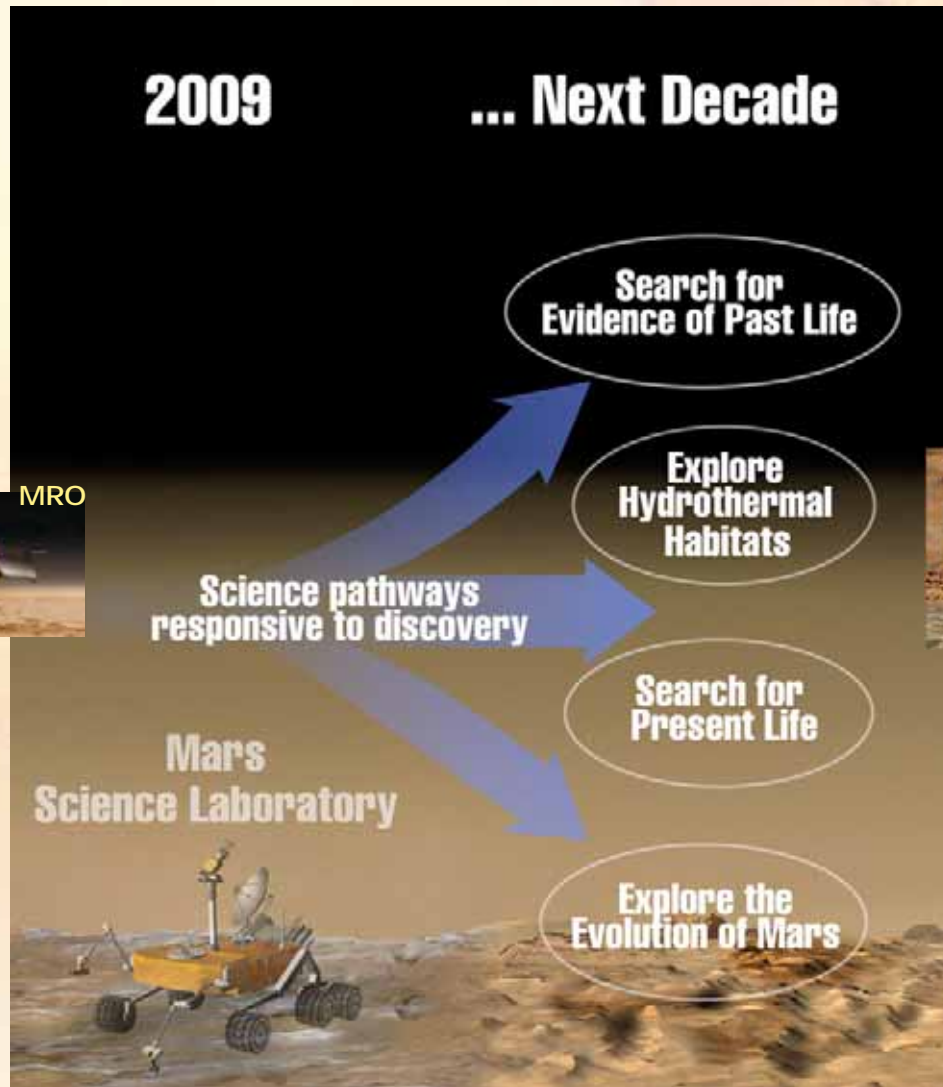
## **Headscarp of Chasma Boreale**

*1000 m of layered ice, frozen sand dunes, and layered sedimentary rock above a cratered basement*



# 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

## Case: Search for Life on Mars

### NASA is uncertain:

- Whether evidence of life can be found
- If it's there, what form it might take
- How evidence of life is distributed
- What instruments can best detect it

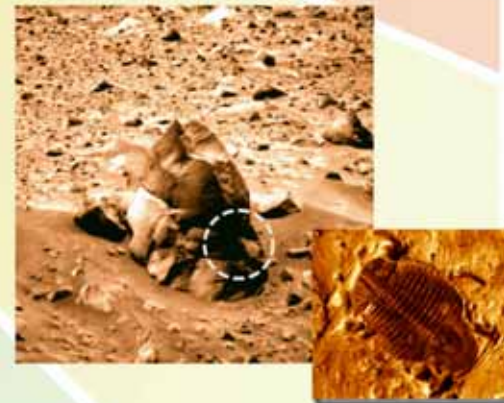
*Impossible to Quantify Value*

*Unfathomable*



*Humans  
on Site...  
Impact  
on  
outcomes?*

*Extraordinary*



*Exciting*



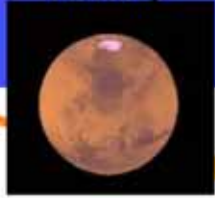
*Null*



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

DISCOVERY

Climate History



Sample Selection



Ancient Water



Validate Paleo-Life



Resources



Extant Life?



EXPLORATION

ROBOTICS ROBOTICS ROBOTICS HUMANS ROBOTICS & HUMANS



Site Selection



Sample Selection



Return Sample



Field Studies



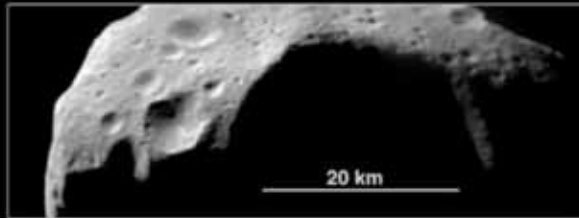
Deep Drilling



Reconnaissance

Exploring Mars

*Mathilde, a dark C-type asteroid*



The material of the surface has a similar color to a dark comet nucleus.

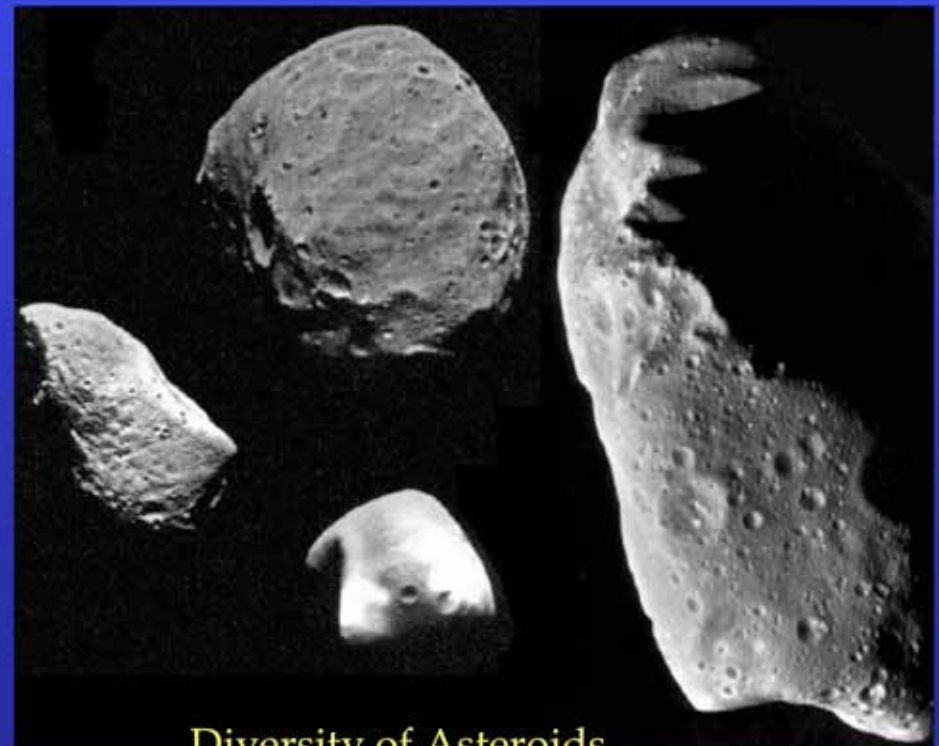
C-type offer unique science possibilities



Ida and moon

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

*Targets for human exploration??*

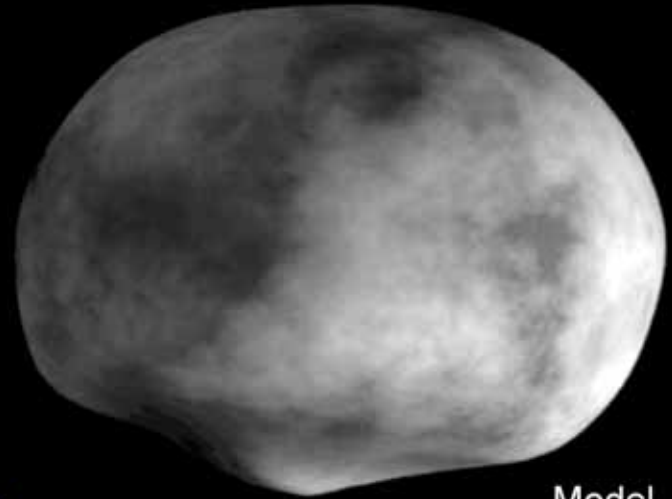


Diversity of Asteroids

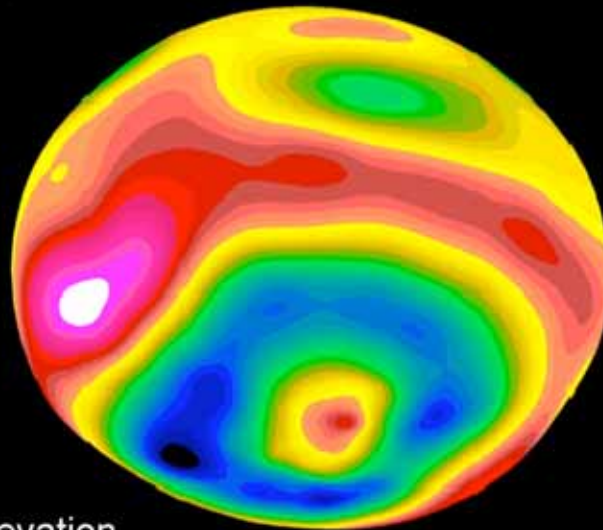




HST



Model



Elevation



-12km

+12km

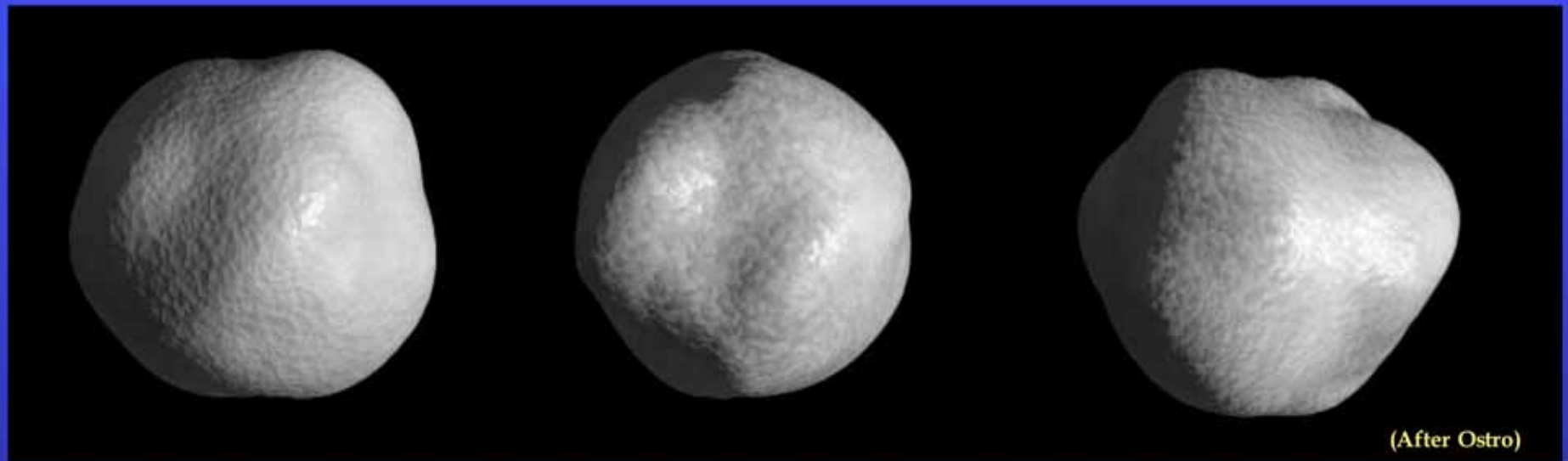
Meteorite from Vesta



**Asteroid Vesta** (~ 550 km across [AZ size])

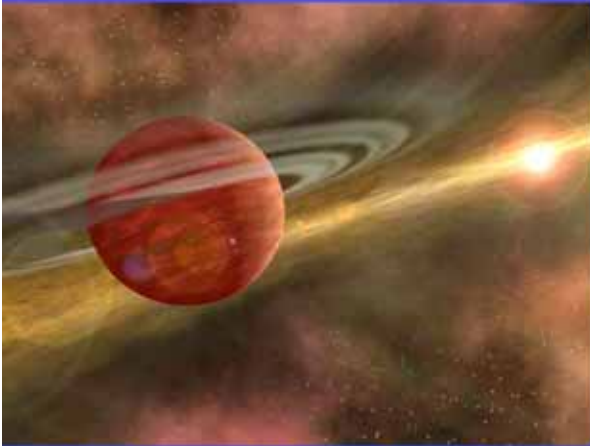
Hubble Space Telescope • Wide Field Planetary Camera 2

# TARGET for HUMAN EXPLORATION near Earth?



**1998 KY26: ~ 30m diameter C-type NEA**

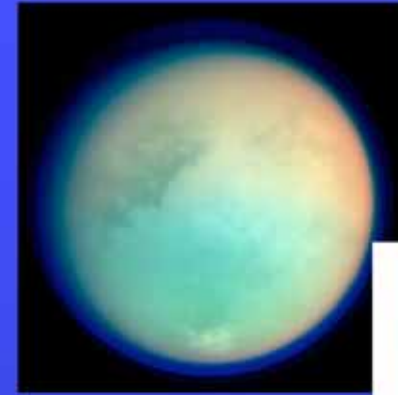
# EXPLORATION is HAPPENING at NASA !



Spitzer: Astrophysics



Moon from Earth (SAR)!



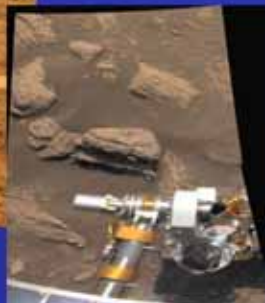
TITAN:  
Possibilities!



Europa: a Next Step?



MER on Mars



Samples: keep on giving!

A composite image showing the Earth's horizon, the Moon, and Mars in space. The Earth's horizon is a curved line separating a blue and white sky from a black space. The Moon is a large, grey, cratered sphere in the upper right. Mars is a smaller, reddish-orange sphere in the center. The text "From the Moon to Mars and Beyond, Scientifically" is overlaid in yellow on the black background.

**From the Moon to Mars and Beyond,  
*Scientifically***