Expanding Our Reach Into The Solar System

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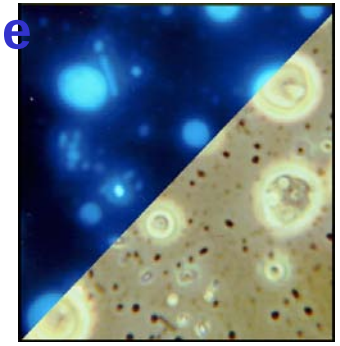
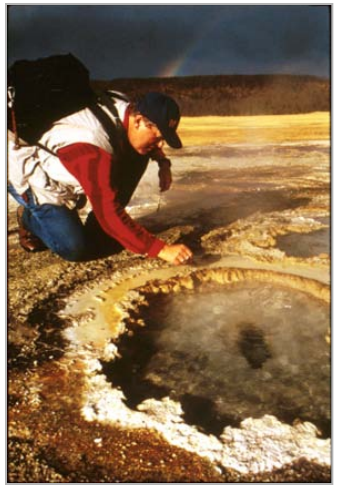
Space Exploration: Humans or Robots?

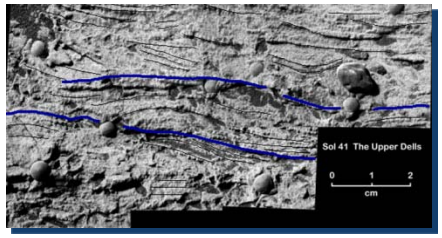
- **We explore and utilize space for a variety of reasons**
  - –Science, National Interest, Return on Investment and others
- **All space exploration is human exploration**
  - –Sometimes humans are physically present, many times we send our robotic emissaries
  - –Robots are excellent at 3-D's: Dull, Dirty, Dangerous work and they do what you tell them to do
  - –Humans excel at adaptation in an unstructured environment
  - –Of all science goals humans would be particularly valuable for exploring the surfaces of other worlds and collecting samples
- **NASA's FY 2011 Budget Advances both Human and Robotic Exploration**

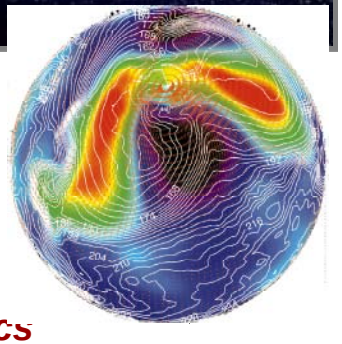
Astrobiology - the Scientific Heart of Space Exploration

- Interdisciplinary study of life in the universe created in 1996
- Three fundamental questions
  - How does life begin and evolve?
  - Does life exist elsewhere in the universe?
  - What is life's future on Earth and beyond?
- Astrobiology seeks to define habitable environments and biosignatures







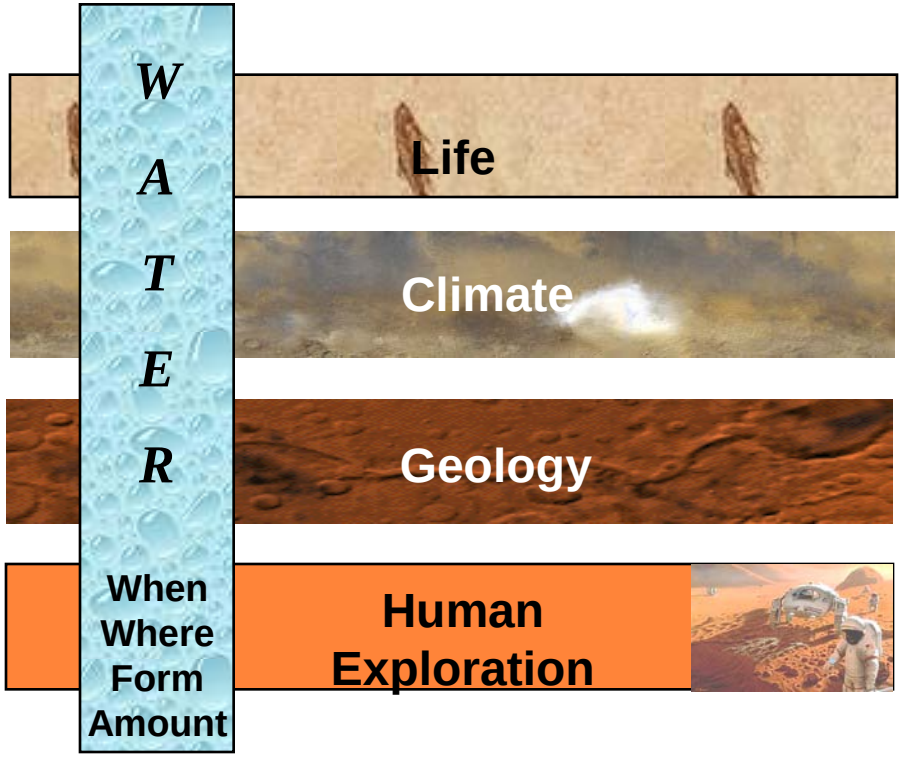


Exploring Mars: Following the Water

Why Mars?
It is the most Earth-like of the planets
The most likely to have past or present life
Reachable every 26 months

Why Water?
Liquid water is required for life as we know it.

Common Thread



Today's Robotic Mars Exploration Program

Mars Global Surveyor

Mars Odyssey

Mars Reconnaissance Orbiter

Mars Exploration Rovers

Phoenix Scout

Mars Science Laboratory

Redefined in October 2000 after twin failures in 1999

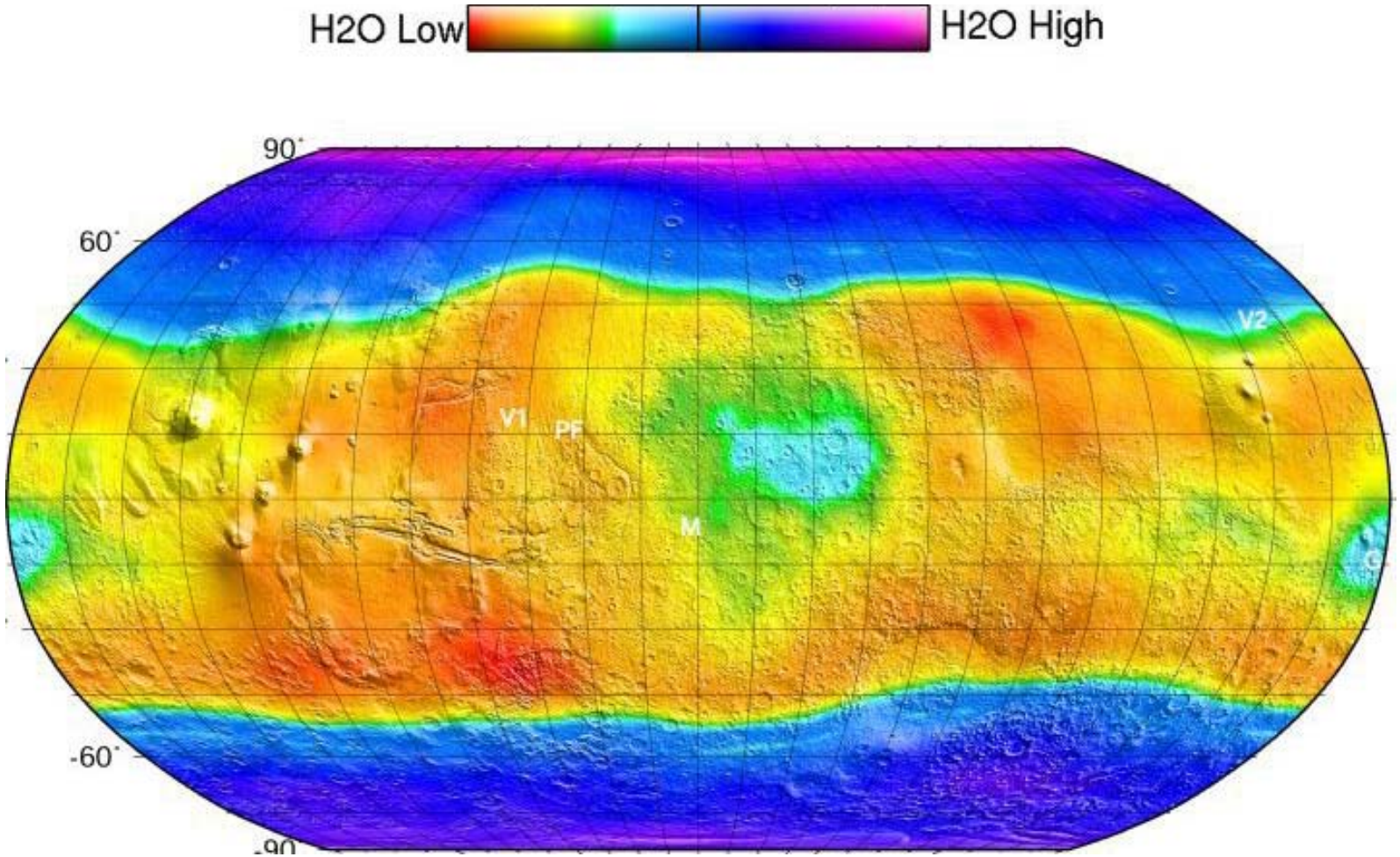
A science-driven effort to characterize and understand Mars as a dynamic system, including its present and past environment, climate cycles, geology, and biological potential.

Central among the questions to be asked is…

"Did life ever arise on Mars?"

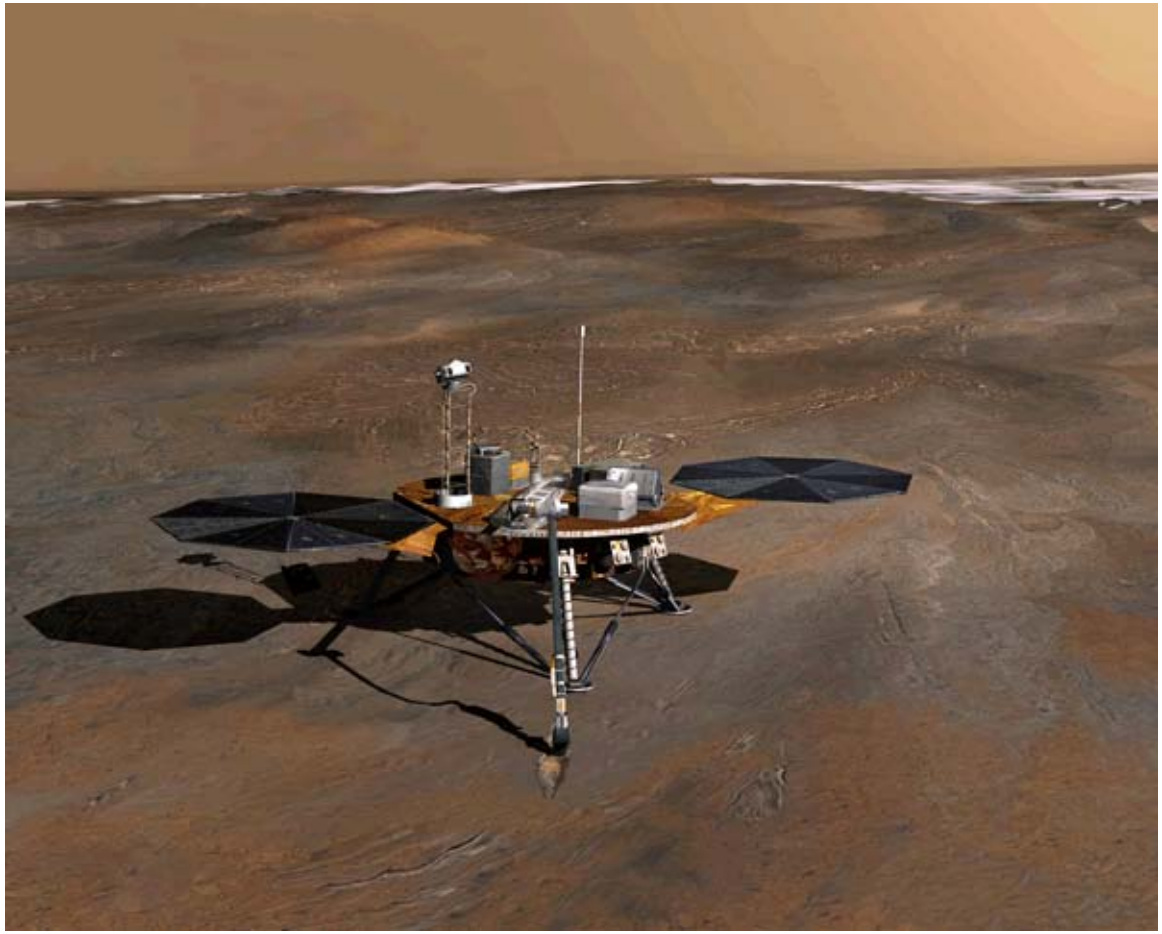
The science strategy is known as "Follow the Water."

Mars Odyssey Finds Water Ice From Orbit



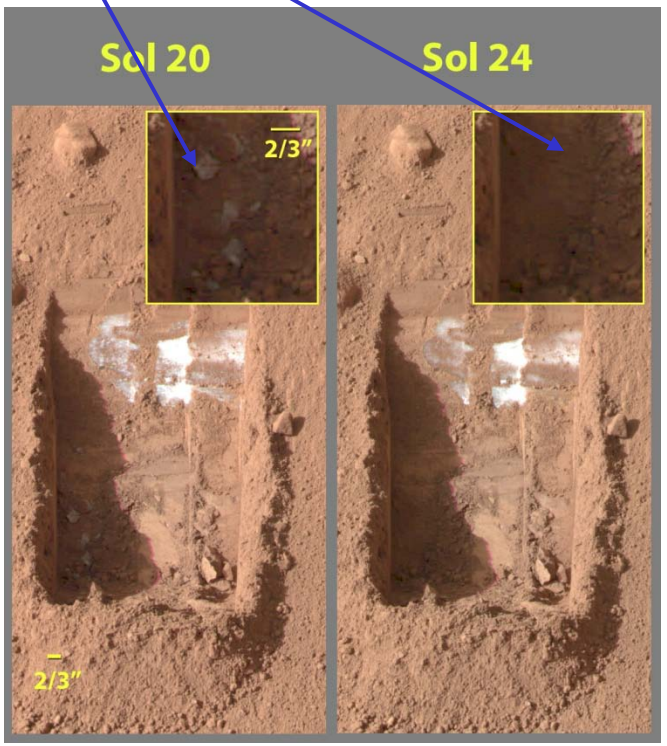
Measurements show strong evidence of underground water ice

Mars Phoenix Confirms Polar Ice!



Landed at Mars Northern Plains (69 deg) May 25th, 2008

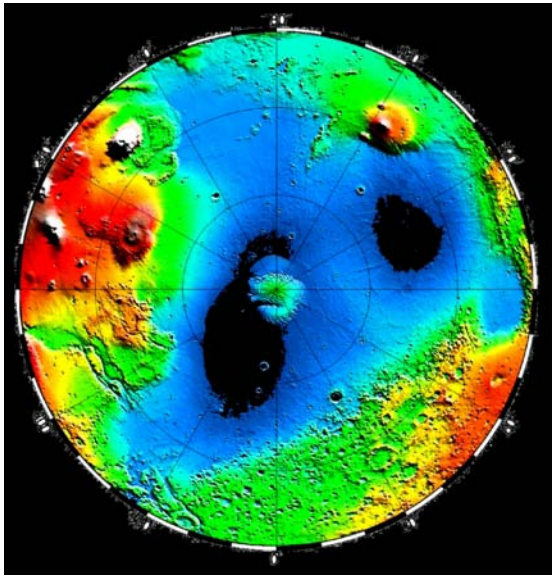
Ice found, then evaporates



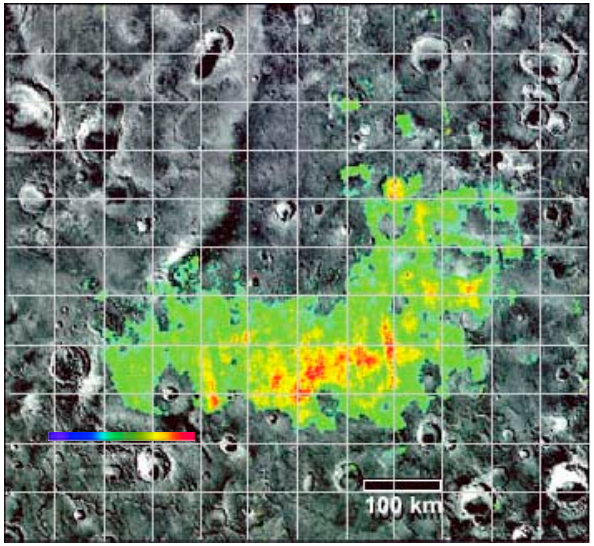
•Confirmed by on-board chemical measurements

The Water Picture from Mars Global Surveyor

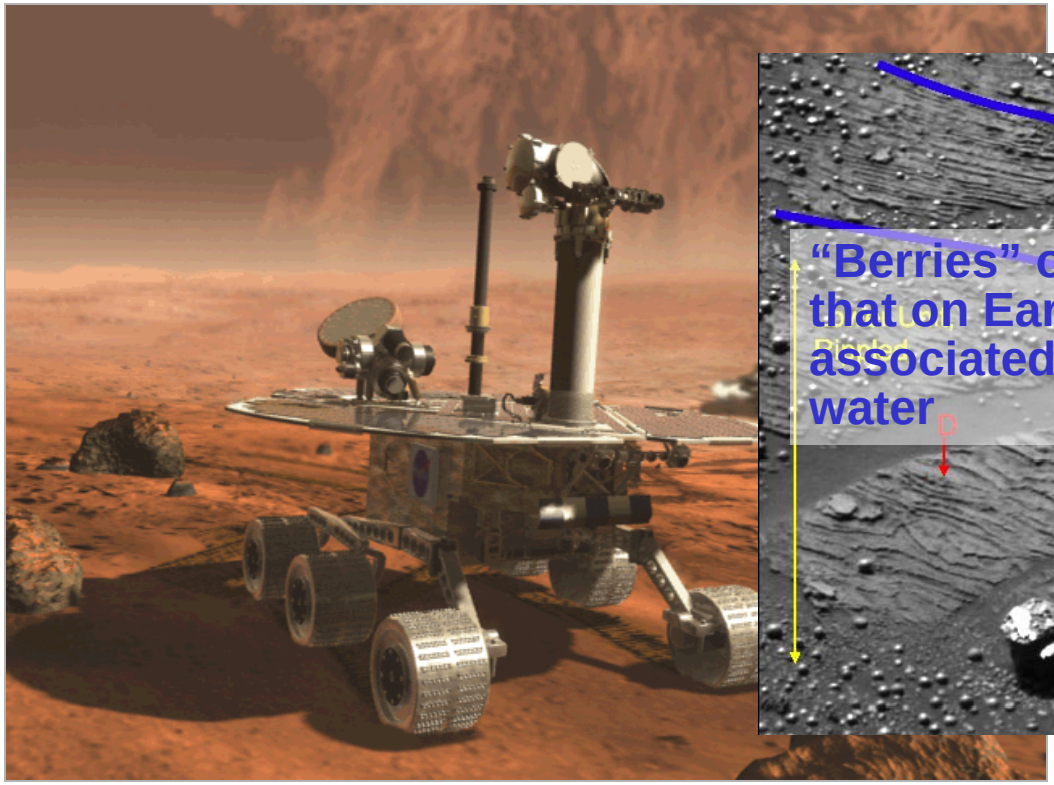
Flat northern hemisphere may represent the location of a large ancient ocean.

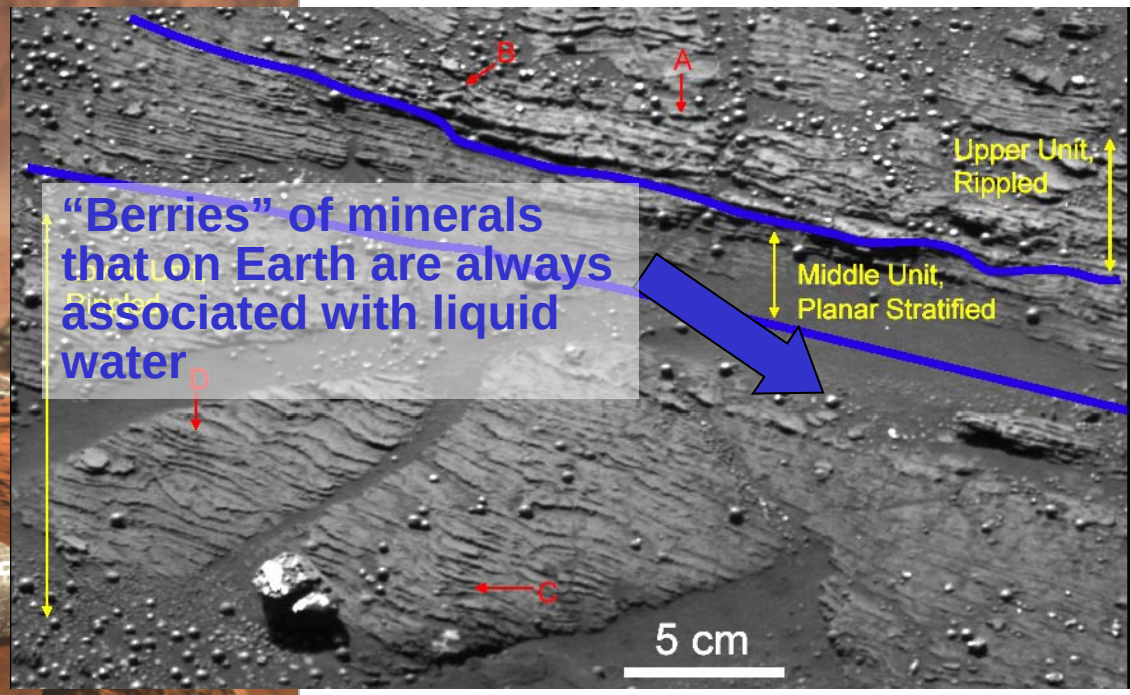


Minerals consistent with long exposure to water



Mars Rovers Find the Water Minerals!





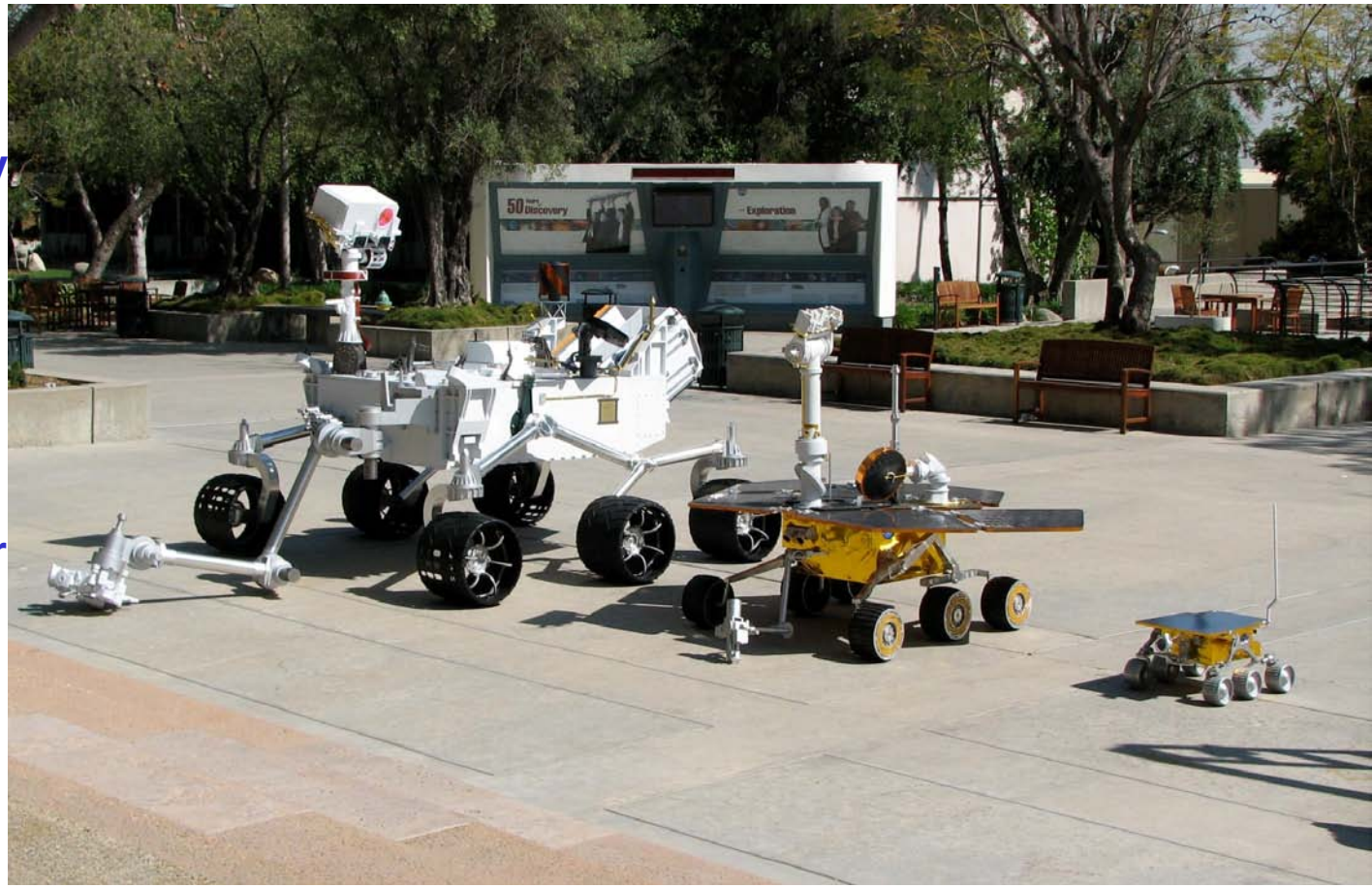
"Berries" of minerals that on Earth are always associated with liquid water

5th year of operations!!

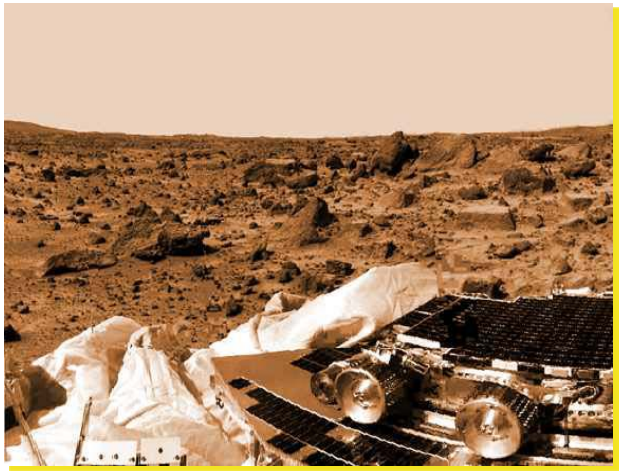
Next: 2011 Mars Science Laboratory

- In-situ science with the first astrobiology instrument (X-ray diffraction)
- Next generation roving capability (10's of kilometers)
- Radioisotope power for long duration
- Precision entry decent & landing

Rover Family Tree



Human/Robot Comparison



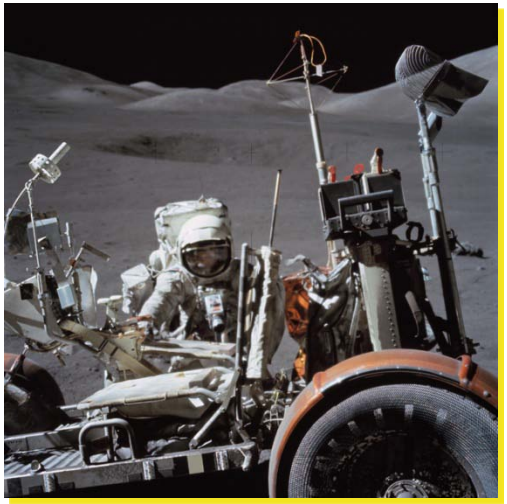
It takes the MER rover a day to do what a field geologist can do in about 45 seconds. -- **Steve Squyres MER PI**

The Spirit rover drove 3.6 km in 8 months and examined roughly 25 rocks. It cannot collect rocks.

Apollo 17 comparison

Drove 36 km in 20 hours of EVA (less time driving)

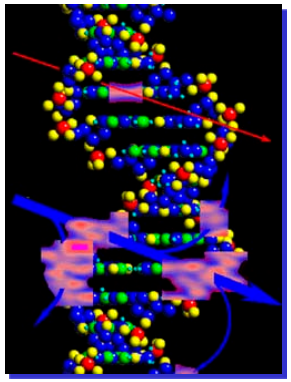
Collected 110 kgs of rocks from 30 sites; analysis still ongoing



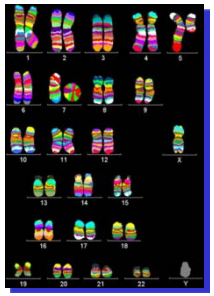
Challenges of Human Exploration of Mars

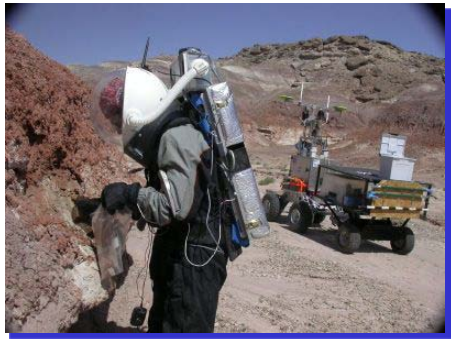
Must be affordable in budgetary and human terms

$$$ +



The biomedical problem must be solved

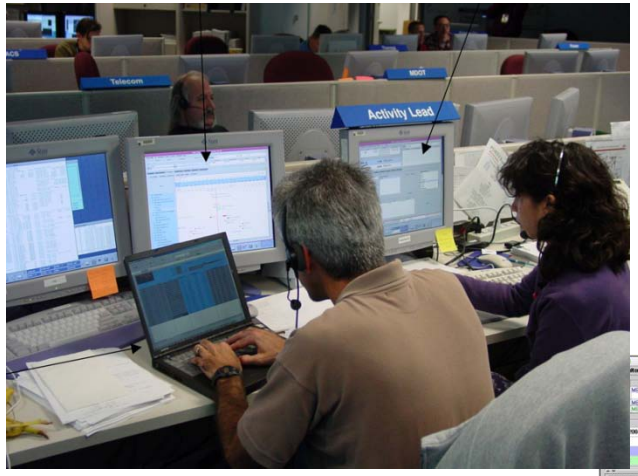


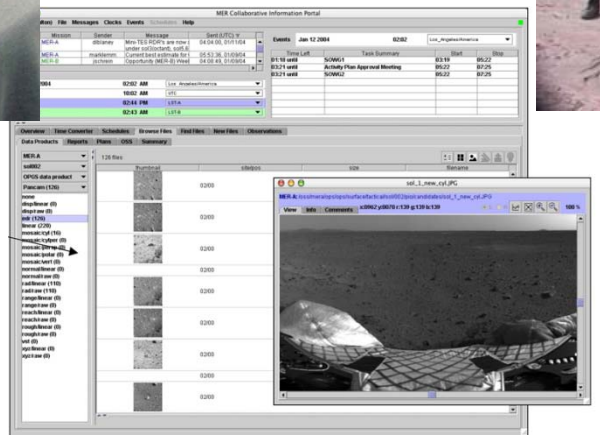


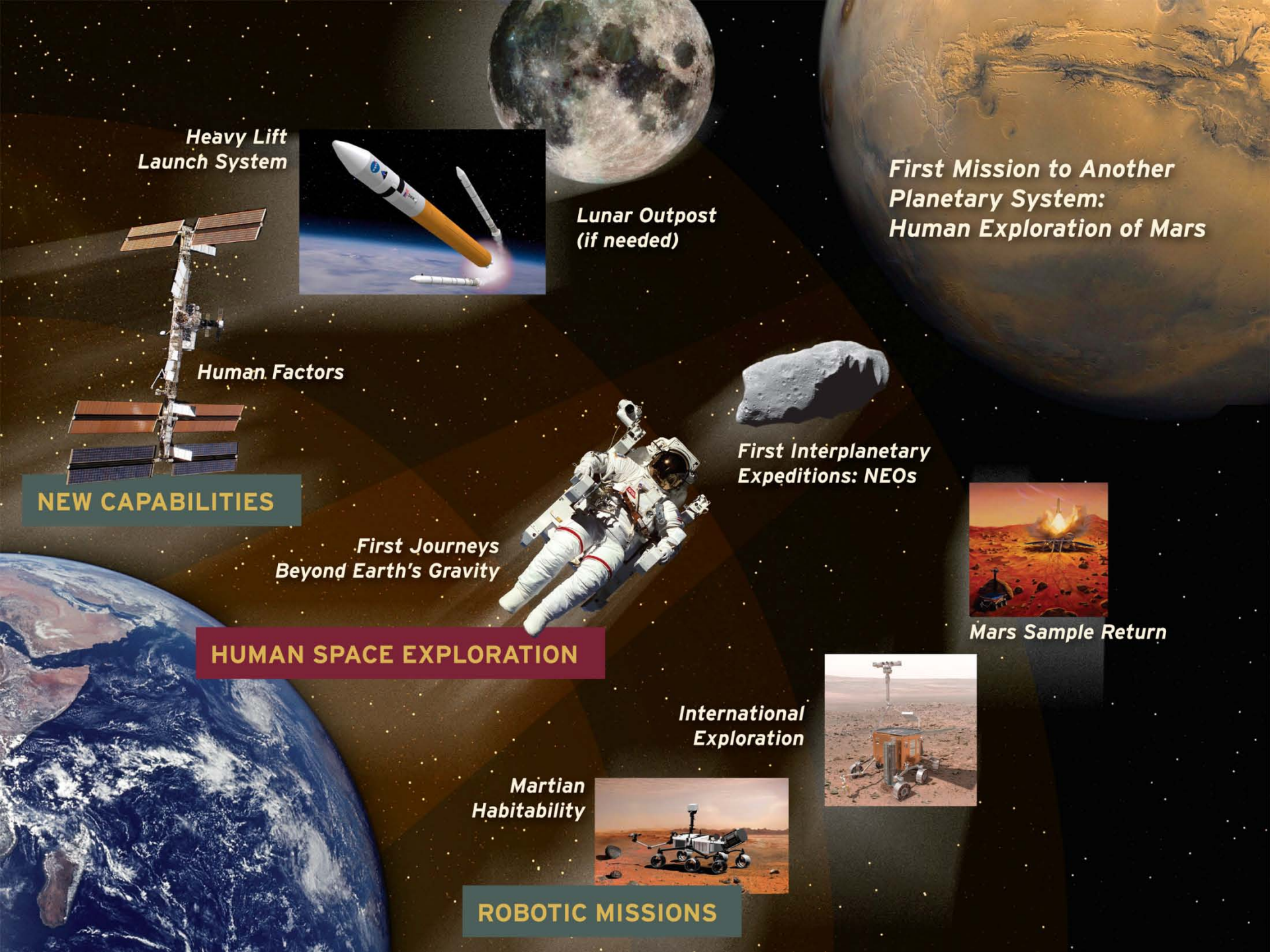
Technology must be available

IT Challenges for Space Exploration Beyond LEO

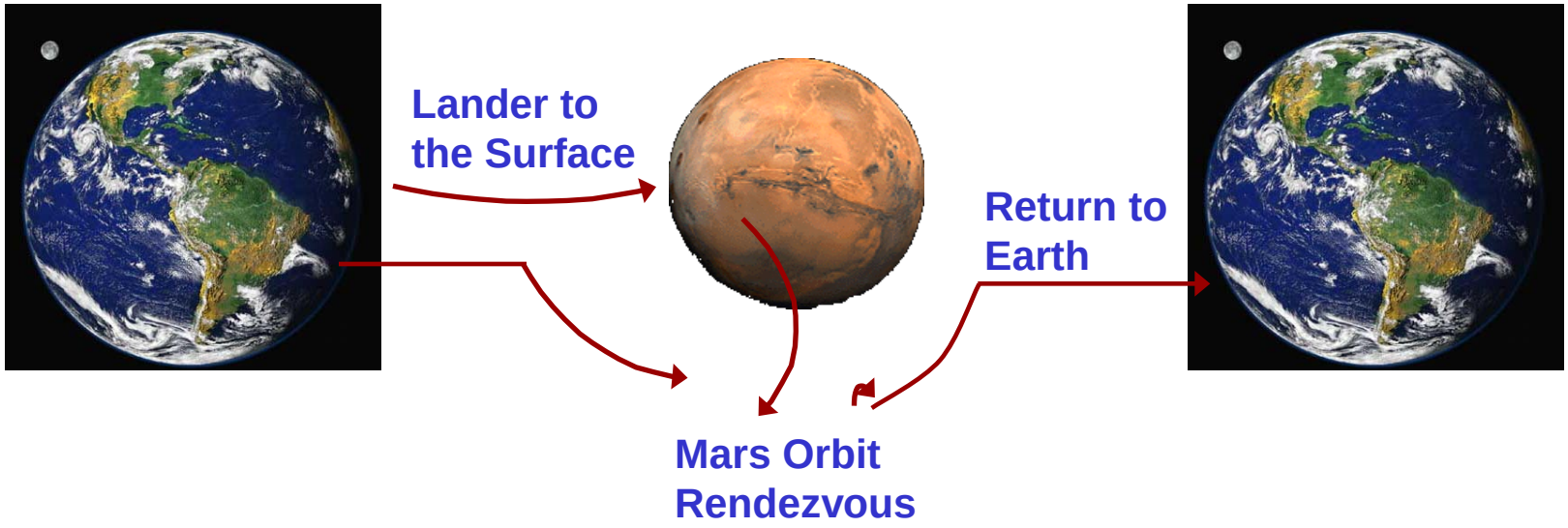
- Management of large data sets
- Autonomy and mobility on other worlds
- Human/machine interaction and telepresence interface






Heavy Lift
Launch System
Lunar Outpost
(if needed)
First Mission to Another
Planetary System:
Human Exploration of Mars
Human Factors
NEW CAPABILITIES
First Interplanetary
Expeditions: NEOs
First Journeys
Beyond Earth's Gravity
Mars Sample Return
HUMAN SPACE EXPLORATION
International
Exploration
Martian
Habitability
ROBOTIC MISSIONS

Mars Sample Return Campaign



International collaboration probable
Key Astrobiology Science Goal
Precursor to Humans at Mars:
- Examination of soil toxicity
- End-to-End Travel Demonstration

The Future of Space Exploration:
Searching for Life with Humans and Robots Together