MARS EXPLORATION PROGRAM

Mars Exploration Program and Mars Technology Program

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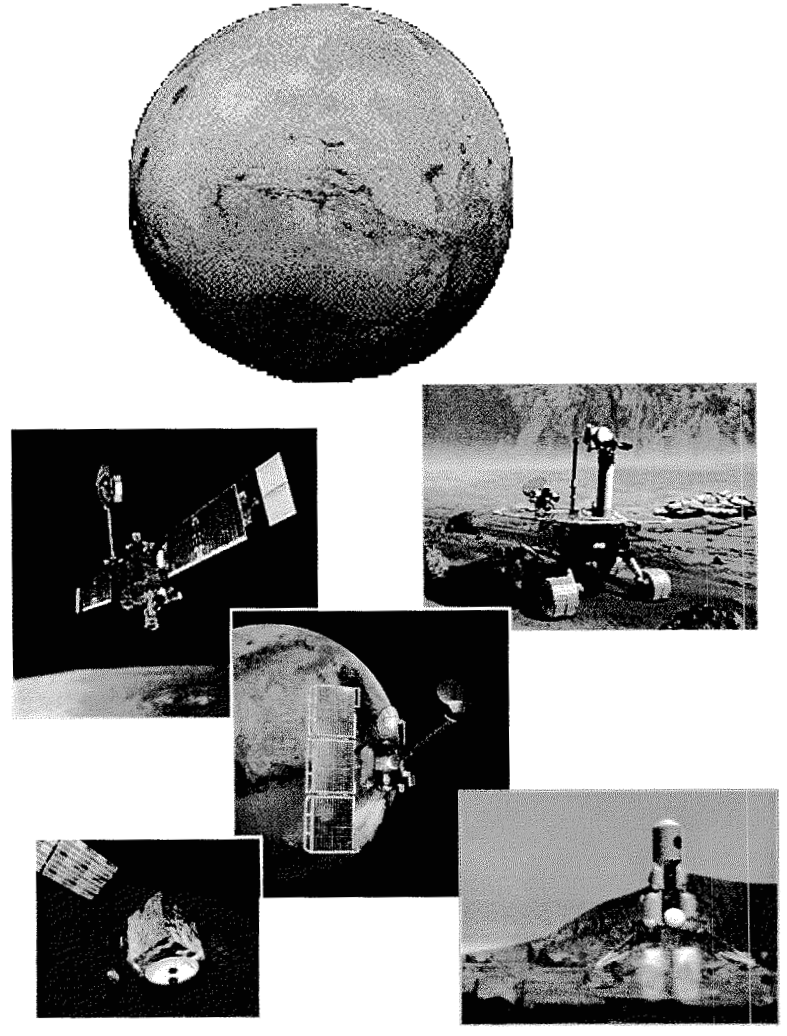
MARS EXPLORATION PROGRAM

Presentation Overview

- **Program Overview**
  - Recent Missions
  - Missions In Implementation
  - Future Missions
- **Technology Topics**
  - Navigation Technologies
  - Entry, Descent, and Landing Technologies
  - Science Instrument Technologies
  - Sample Return Technologies
- **Summary**

Mars Exploration Program



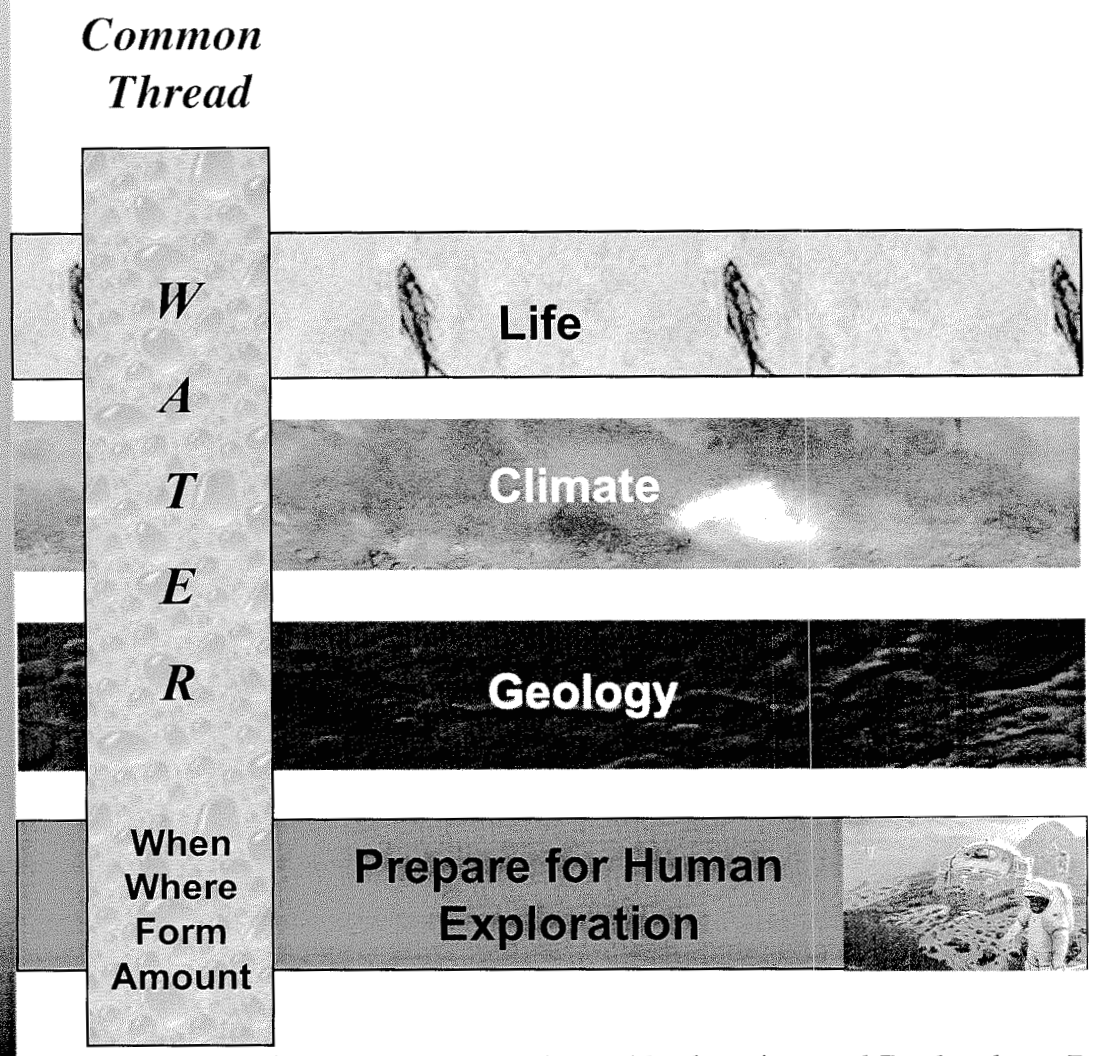
A science-driven, technology enabled effort to characterize and understand Mars, including its current environment, climate, and geological history and biological potential

Central among the questions to be asked is…
"Did life ever arise on Mars?"

The exploration strategy is known as "Follow the Water"

The Mars Science Strategy: "Follow the Water"

MARS EXPLORATION PROGRAM



Understand the Potential for Life Elsewhere in the Universe

Understand the Relationship to Earth's Climate Change Processes

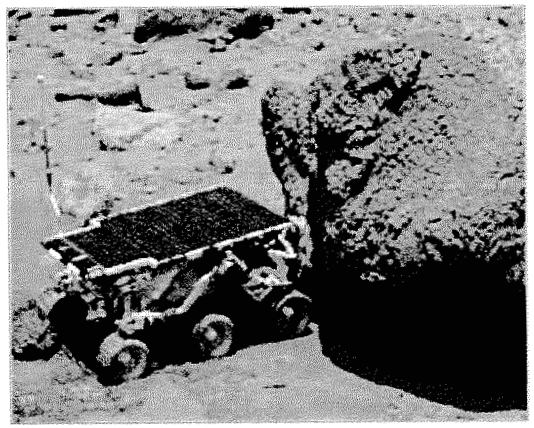
Understand the Solid Planet: How It Evolved

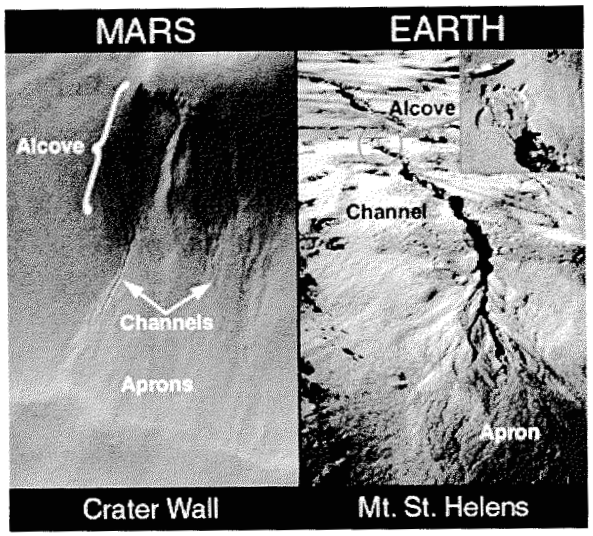
Develop the Technology & Engineering Necessary for Eventual Human Exploration

Recent Missions

Mars Pathfinder - 1996

- Successfully demonstrated surface mobility and robust entry & landing system
- Stereoscopic imager and chemical analyses of rocks enhanced surface geology
- Suggested rocks formed in running water, during a warmer past

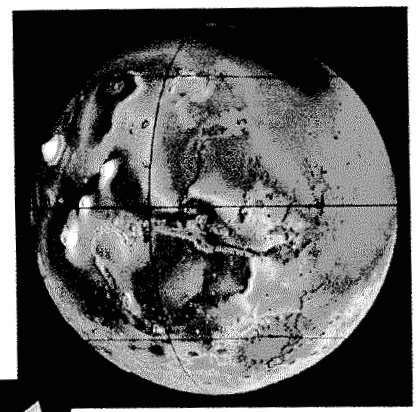


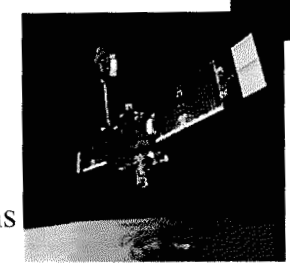


Mars Global Surveyor - 1996

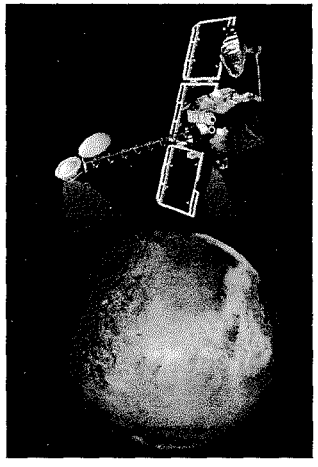
- Images suggest ample water and thermal activity in Mars' history
- Gullies and other features suggest recent sources of liquid near the surface, possibly at 100 to 400 meters
- Global topography indicates flat northern hemisphere may represent the location of a large ancient ocean.
- Successfully demonstrated Aerobraking into circular orbit

New Global Mars Topography from MOLA





Missions In Implementation

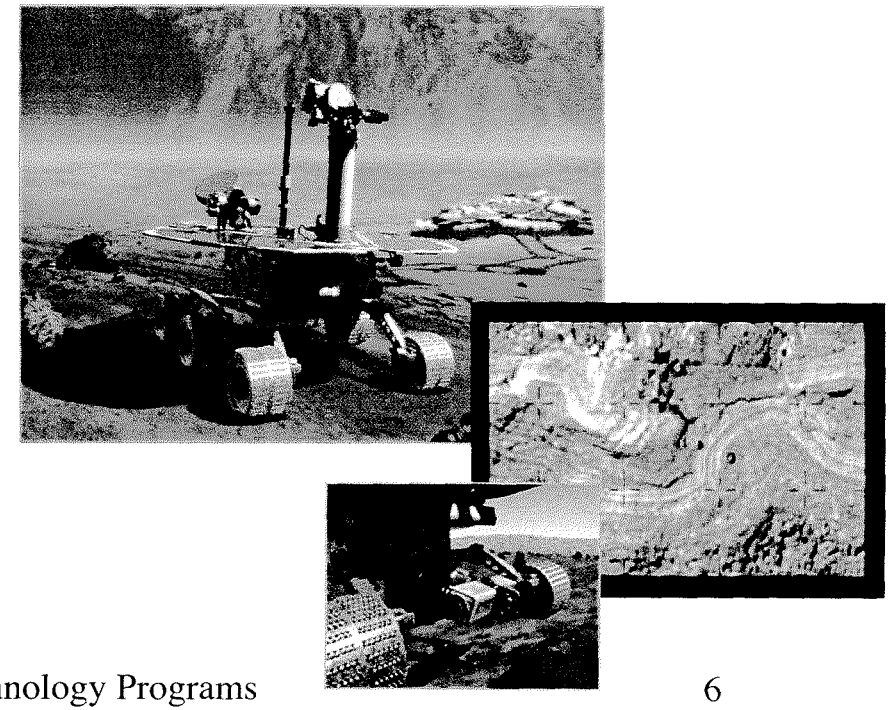


Mars 2001 Odyssey

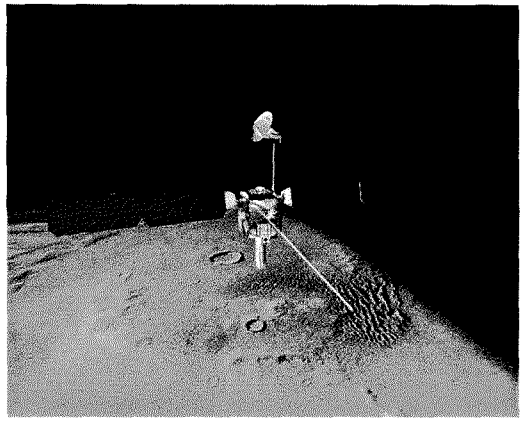
- Map the mineralogy and morphology of the surface
- Map the elemental composition of the surface and determine abundance of hydrogen in the shallow subsurface
- Measure the near-space radiation environment
- Also using Aerobraking to circularize orbit

2003 Twin Mars Exploration Rovers

- Will learn about the climate on Mars and scout for regions where mineralogical evidence of water has been found.
- The Rover twins will determine the geologic record of the landing site, what the planet's conditions were like when the Martian rocks and soils were formed, and help us learn about ancient water reservoirs.
- Will provide first microscopic view of Mars



Future Missions (1 of 2)

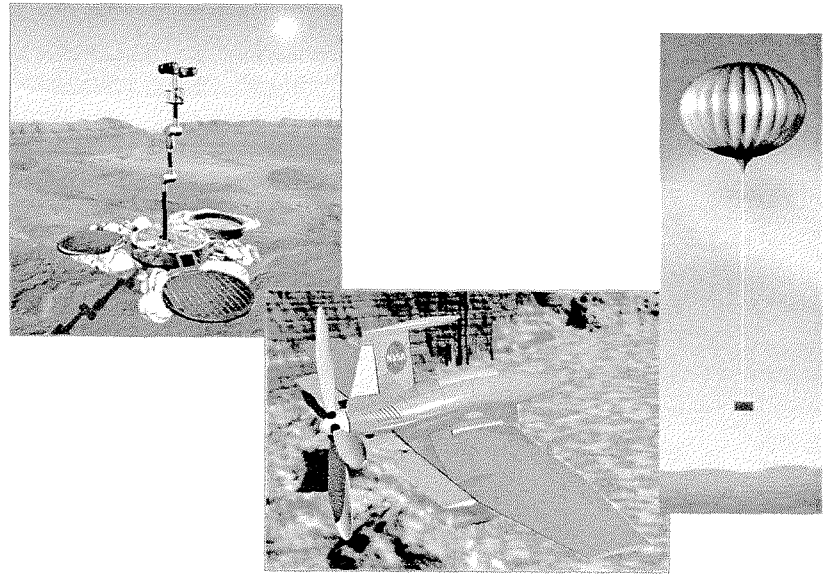


Mars Reconnaissance Orbiter

- Observe at much higher spatial resolution at hundreds of targeted sites
- Characterize Mars' seasonal cycles and atmospheric structure
- Characterize sites for future landed missions.
- Detect on Mars the presence of liquid water and ground ice in the upper surface.
- Enhance data return from future landers by providing relay to Earth.

Mars Scouts

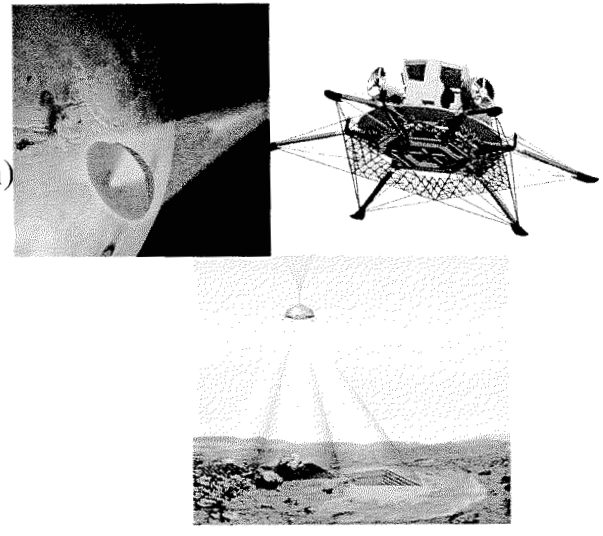
- Competed Proposals for Missions of Opportunity
- Orbital, Landed, and Aerial Concepts Proposed
- Complements the "Roadmap" Missions, soliciting best ideas from community

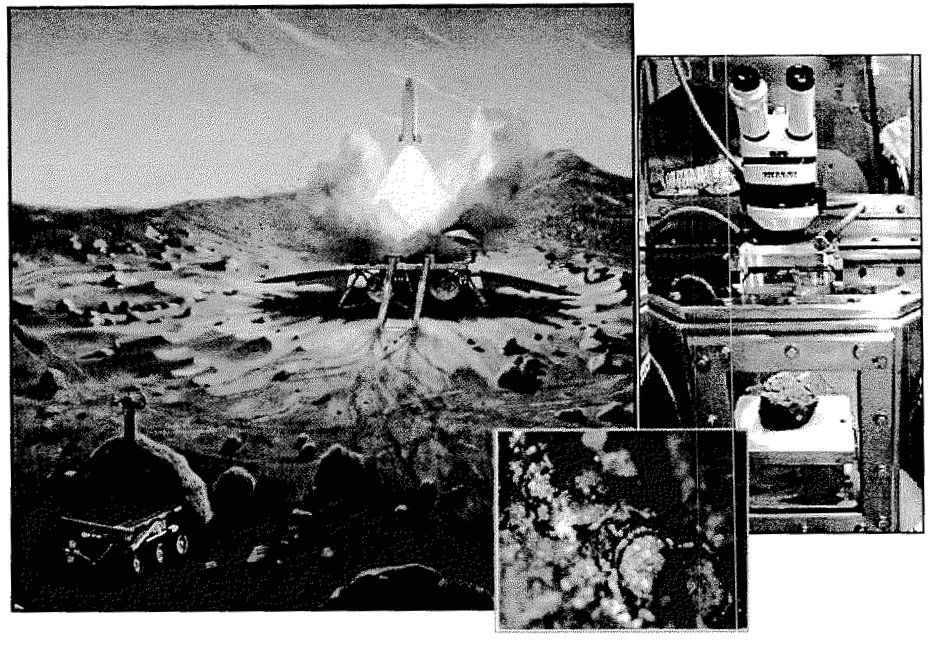


Future Missions (2 of 2)

Mars "Smart" Lander/Mobile Science Laboratory

- *Conduct Significant Science and Demonstrate Advanced Capabilities*
  - –Precision Entry/Descent/Landing
  - –Safe landing (hazard detection/avoidance, robust touchdown system)
  - –In-situ sample acquisition and analysis
  - –Surface Exploration/Long-range mobility: Visit multiple, diverse sites
  - –Feed-Forward Technology to Future Mars Missions





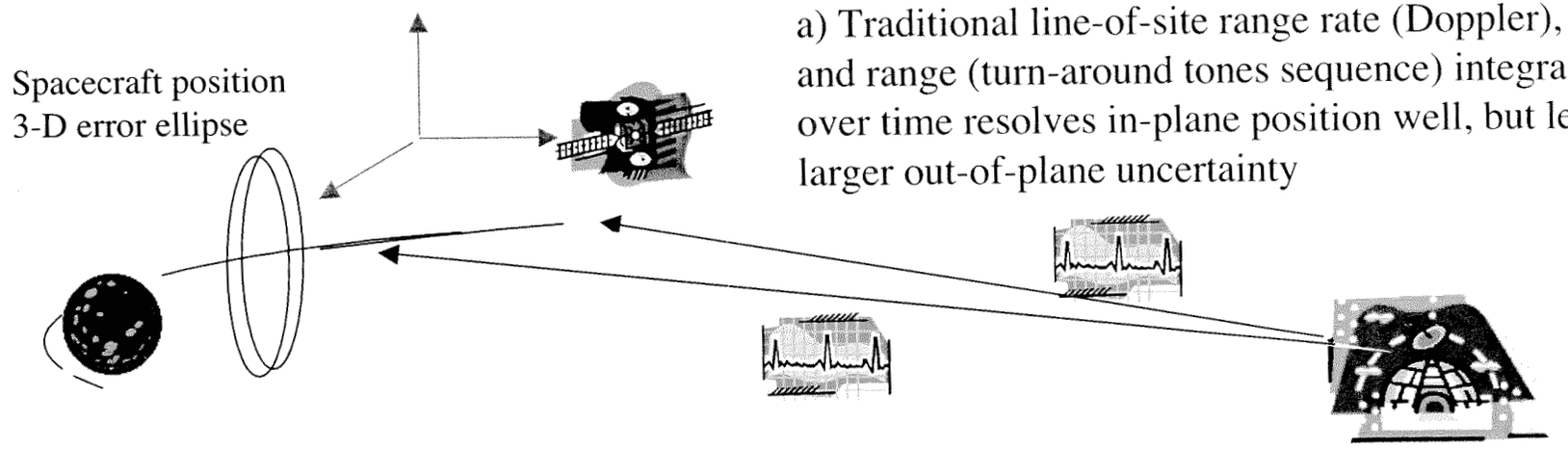
Mars Sample Return

- Mars samples analyzed in the world's finest laboratories by the best scientists will provide:
  - –Chronology of the planet's evolution
  - –Record of climate change and the history of water
  - –Presence (or absence) of organic and pre-biotic chemistry
  - –Evidence of past and present life

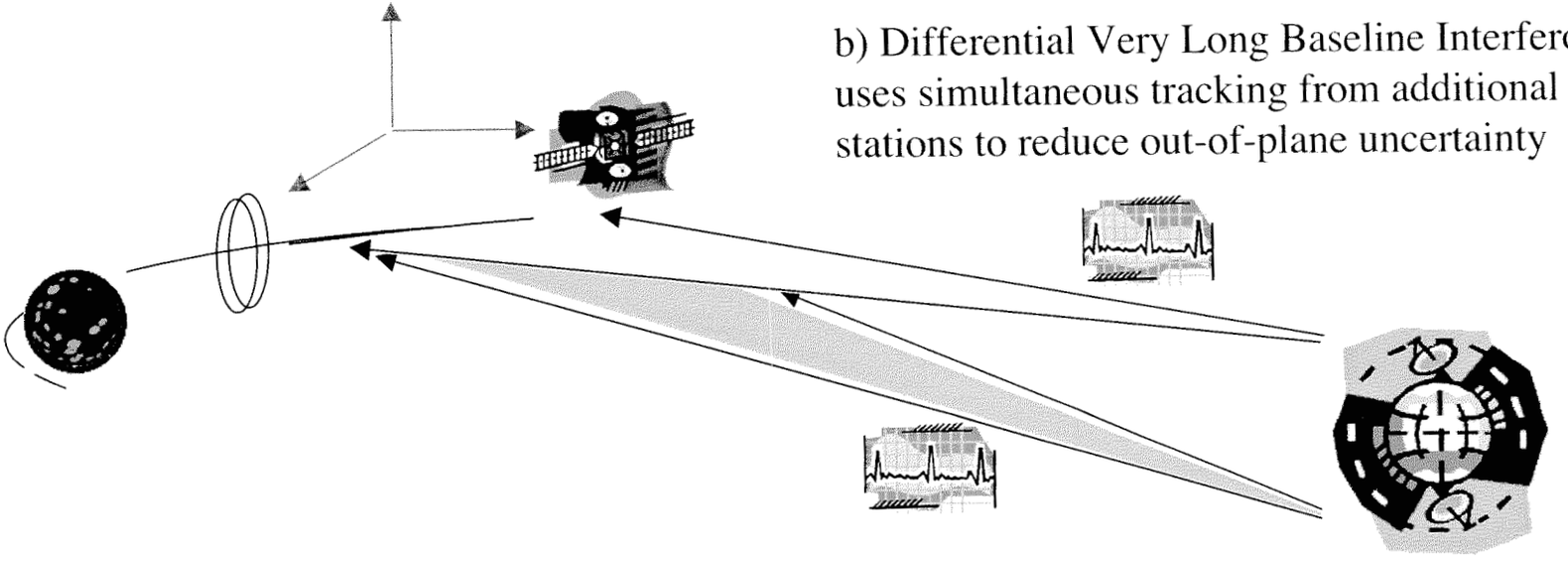
Technology Program Themes

- **Multi-mission Technologies**
  - Core technologies, benefiting multiple Mars missions
  - Ongoing investment in exploration capabilities
  - Advancing both engineering and science payload technologies
  - Benefits to both NASA-led missions and missions undertaken by international partners
- **Mission-Focused Technologies**
  - Designed to support specific missions
  - Capabilities advanced by that mission become available for future missions
  - Missions also "assigned" specific technology demonstration requirements to benefit applications of key technologies by future missions

Ground-based Approach Navigation



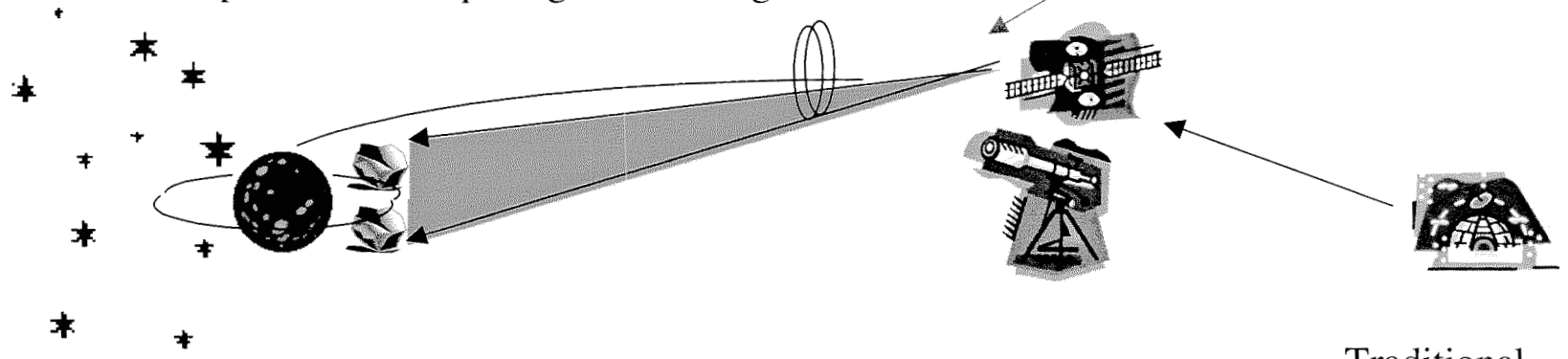
a) Traditional line-of-site range rate (Doppler), and range (turn-around tones sequence) integrated over time resolves in-plane position well, but leaves larger out-of-plane uncertainty



b) Differential Very Long Baseline Interferometry uses simultaneous tracking from additional ground stations to reduce out-of-plane uncertainty

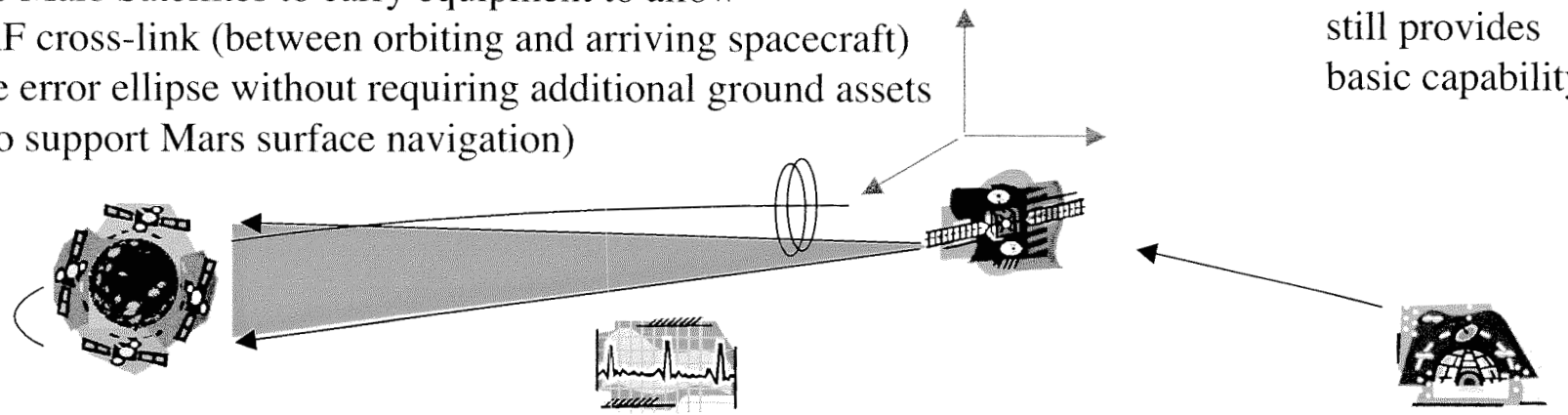
Target-Relative Approach Navigation

c) Future Mars Satellites to carry equipment to allow onboard optical navigation by imaging motion of Mars' moons across starfield to reduce error ellipse without requiring additional ground assets

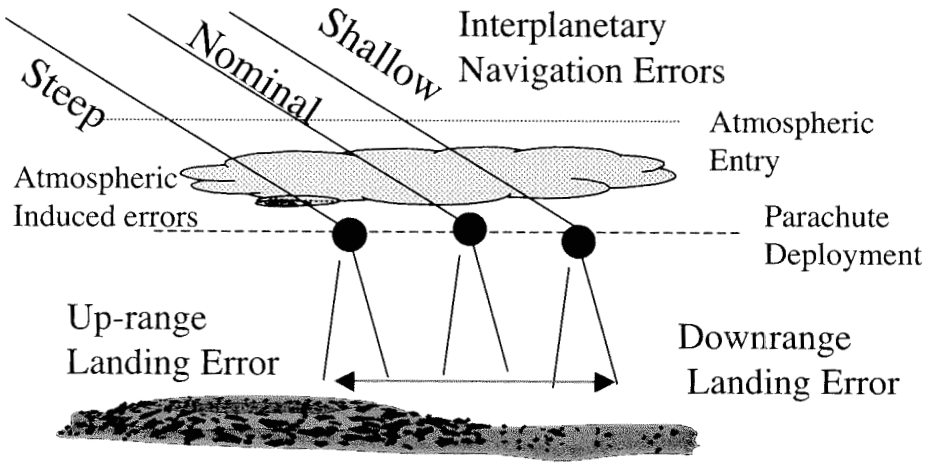


Traditional line-of-site still provides basic capability

d) Future Mars Satellites to carry equipment to allow In-situ RF cross-link (between orbiting and arriving spacecraft) to reduce error ellipse without requiring additional ground assets (Can also support Mars surface navigation)



Guided Entry Technology

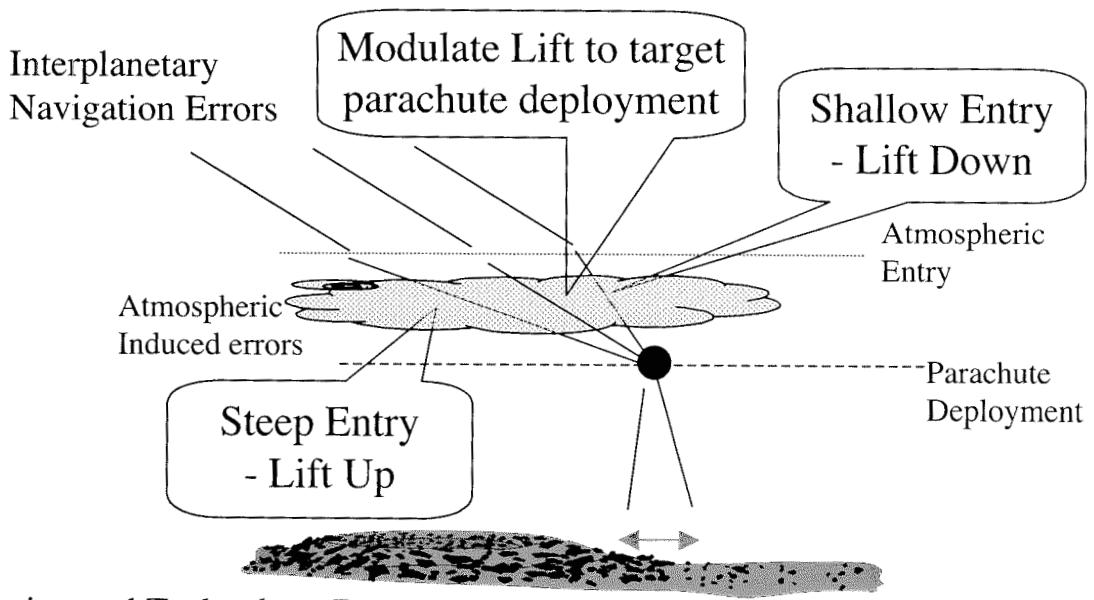


Ballistic or Unguided Lifting Entry

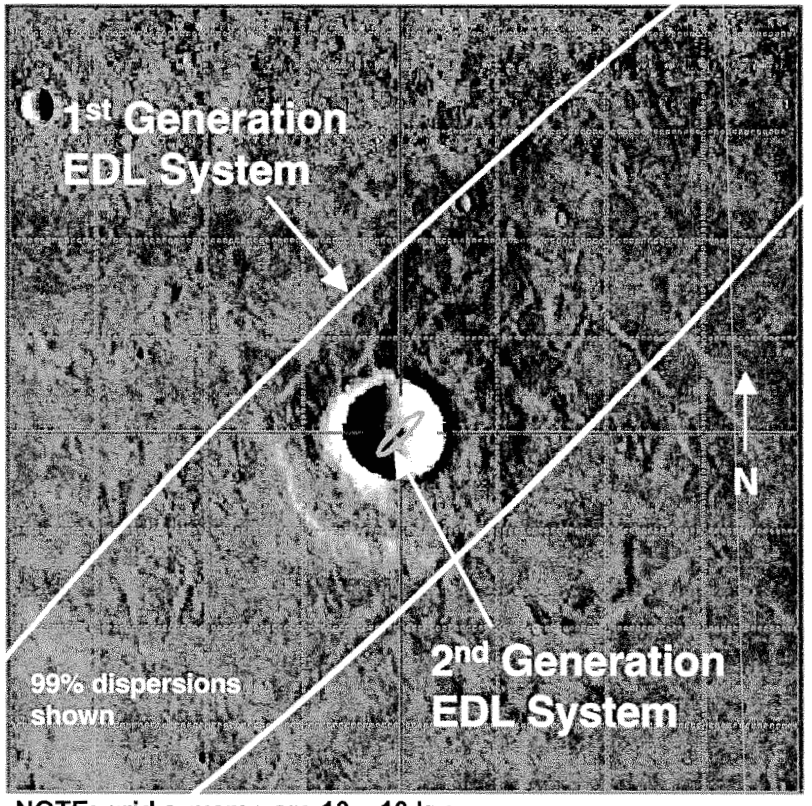
- Arrival/Entry Navigation errors uncorrected

Guided Lifting Entry

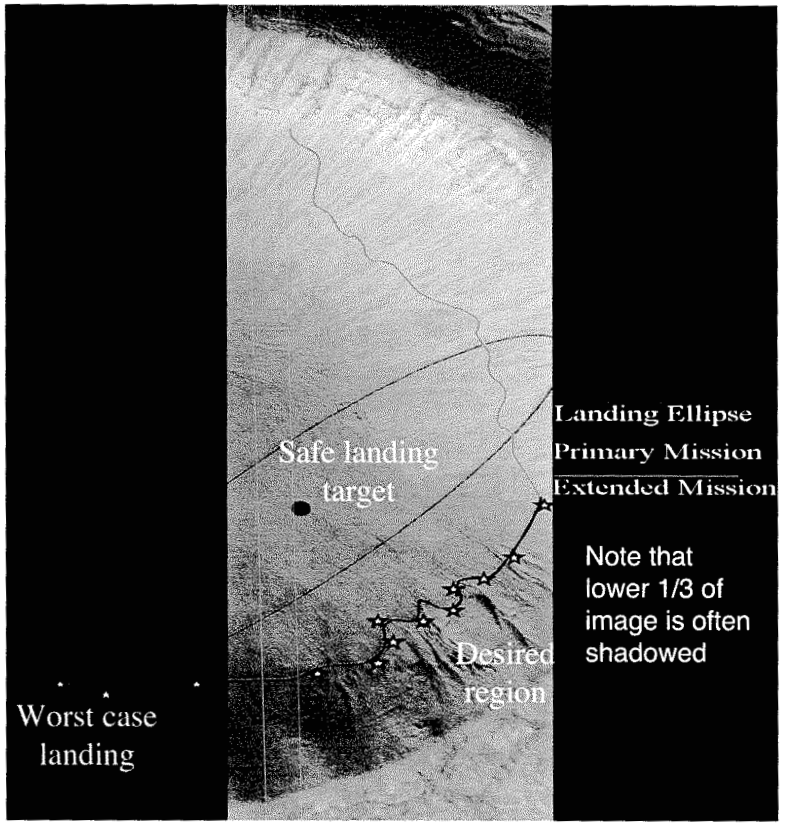
- Arrival/Entry Navigation "flown-out" with modulated lift guidance strategy



Precision Landing Application

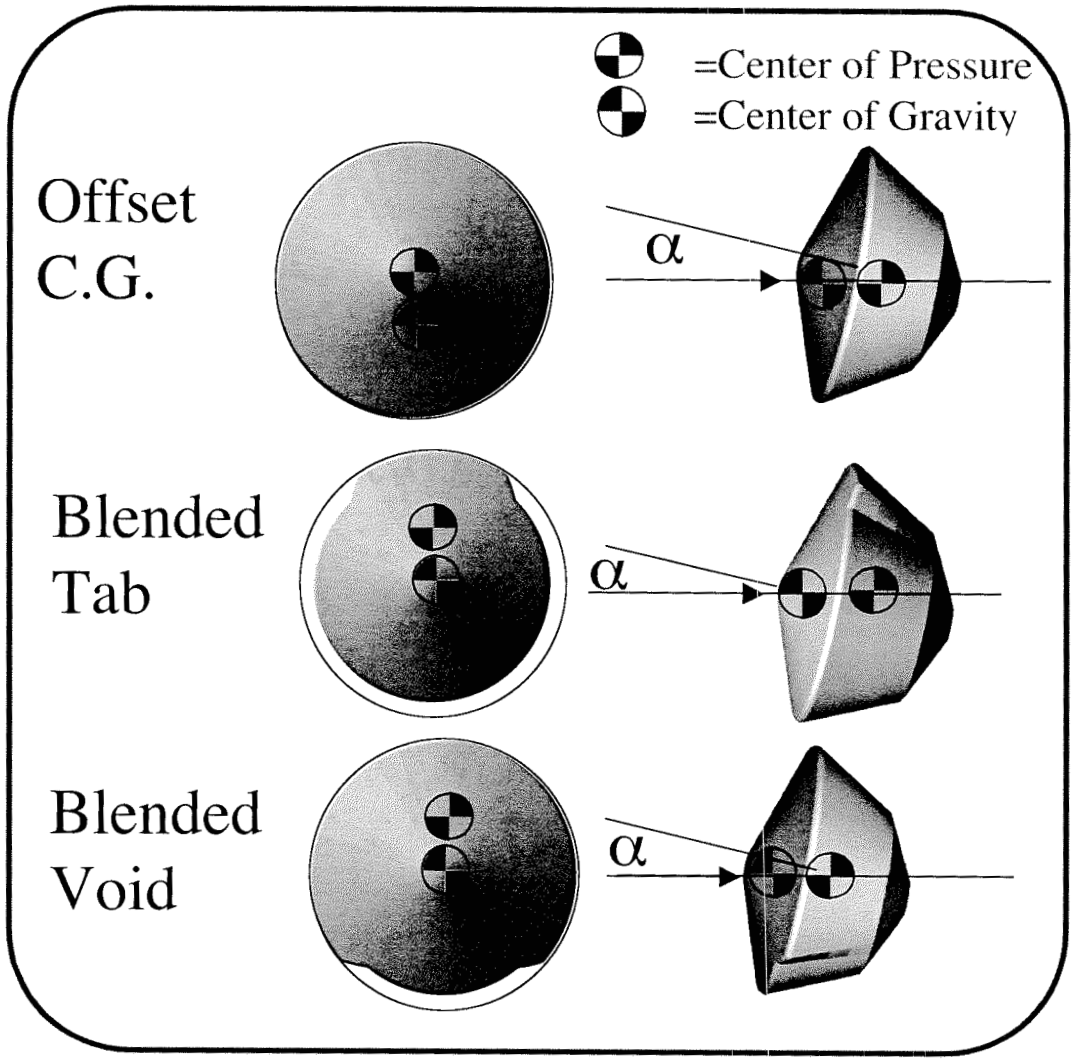


NOTE: grid squares are 10 × 10 km

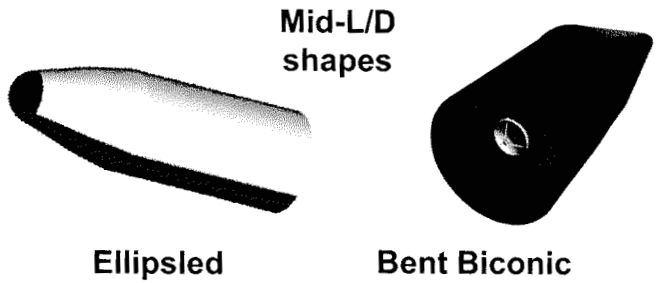


- **Target: Crater in Elysium Planitia**
  - **36.7° N Lat., 252.3° W Lon.**
  - **10 km diameter**
  - **Contains "gully" features**
- **"Go-to" Rover Traverse Capability**
  - **Target site chosen for safety**
  - **Rover capability employed to reach surface features of interest**

Entry Body Aerodynamics

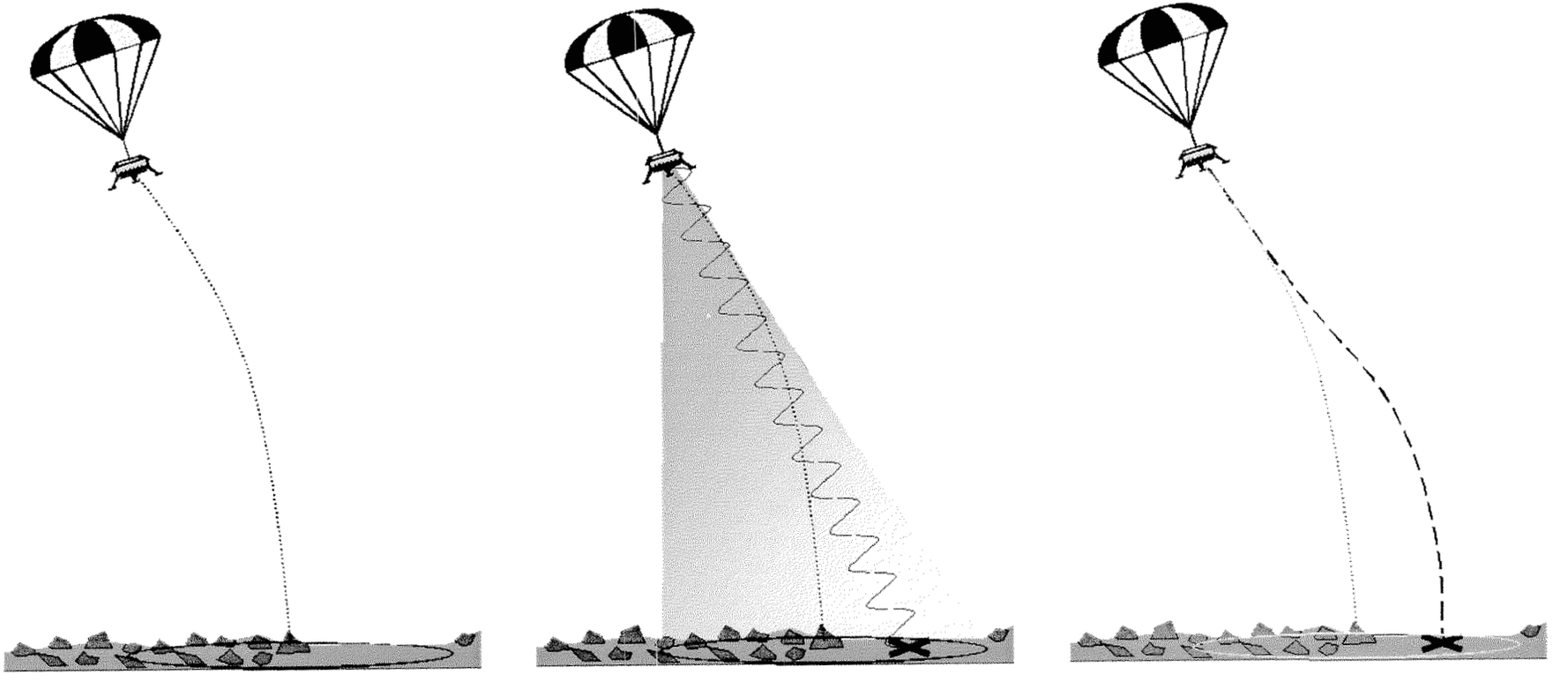


- Different options available to induce angle of attack/lift within family of Viking heritage for low L/D
- Other shapes require future flight qualification for higher L/D



Active Hazard Avoidance Landing

Key Areas For this Technology:
Sensor Technology, Feature Recognition, and Maneuverability

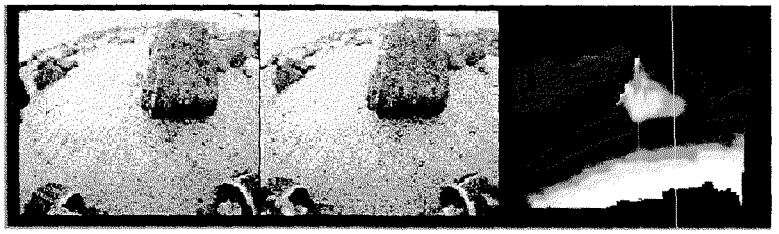


Maneuver Envelope Prediction **Hazard Detection/Site Designation** **Descent Trajectory Computation**

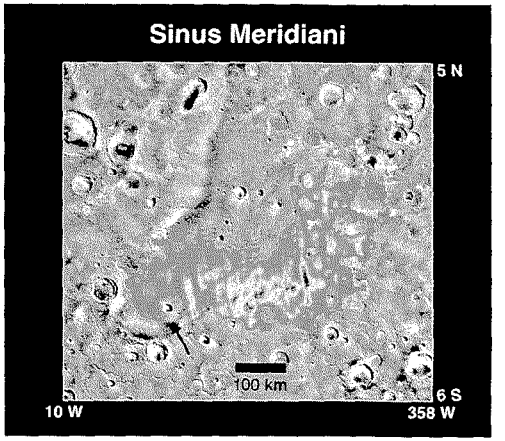
Science Instrument Technologies

Hyperspectral Imaging

- Identify mineral composition from spectral response
- Applications from orbit and from surface
- Image compression technology becoming important



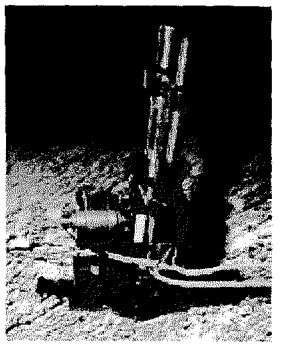
Use of stereo and hyperspectral imaging on surface of Mars to characterize geology



Identification of Hematite by MGS Thermal Spectrometer

Subsurface probes

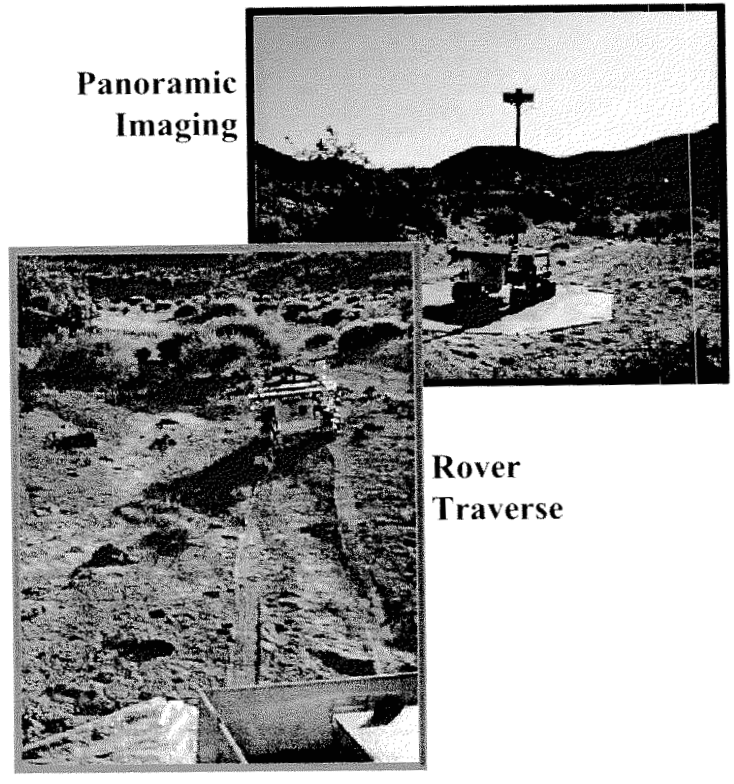
- Passive (Gamma Ray, High Energy Neutron) or Active (Ground penetrating radar)
- Also applicable from orbit or (potentially) from surface
- Use to determine best places to pursue in-situ exploration (surface drilling)



Potential prototype Mars drill

Surface Operations Autonomy

Key Areas For this Technology:
Autonomous Traverse and Autonomous Science Operations



Spring 2001 Field Experiments:

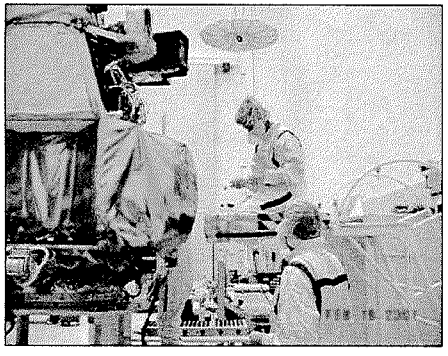
- Mars Technology Program's FIDO (Field Integration, Dynamics and Operations) rover and team was utilized by Mars Exploration Rover (MER) Project to conduct realistic field experiments
- Simulated 20 sols of MER'03 mission
- Performed
  - *in-situ* measurements at 2 locations
  - *in-situ* measurements on 3 rock/soil targets
  - 200 meters total integrated traverse distance

Sample Return Technologies

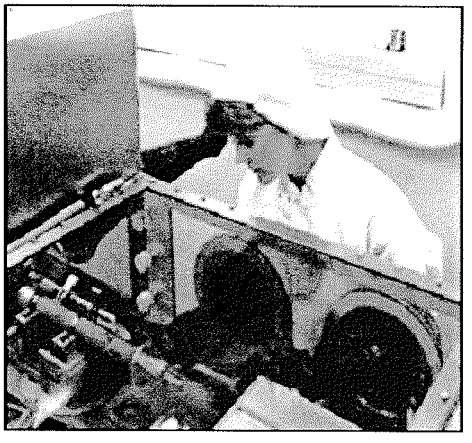
Objectives:

Develop and validate enabling technologies for

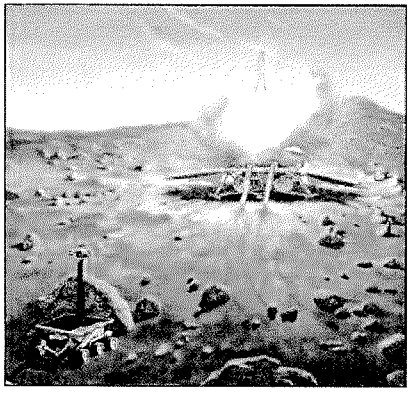
- returning a sample from surface of Mars
- protecting Earth from Martian organisms
- safe handling and analysis of returned samples



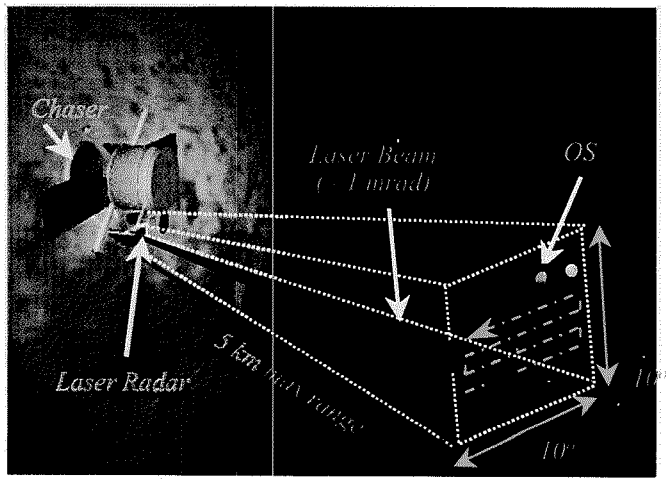
Forward Planetary Protection



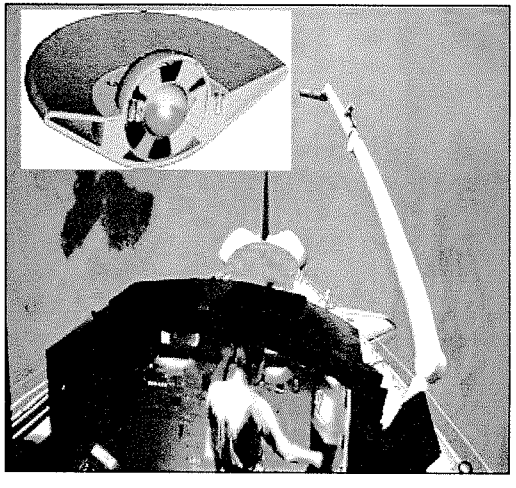
Returned Sample Handling



Mars Ascent Vehicle



Rendezvous and Sample Capture



Sample Containment and Earth Return

Summary

- Mars Exploration Program comprises a series of missions integrated into a coherent ongoing program
- Technology development and infusion allows both the incorporation of new capabilities as well as the continuous improvement of existing capabilities