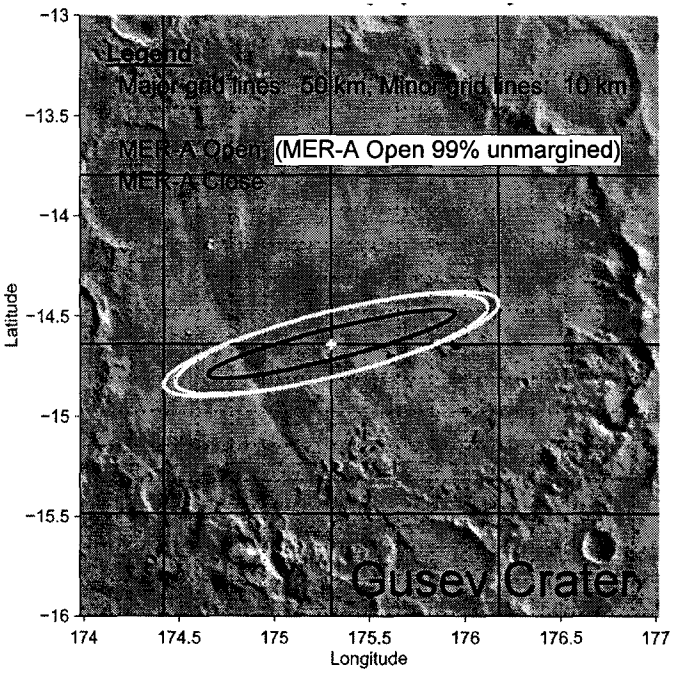
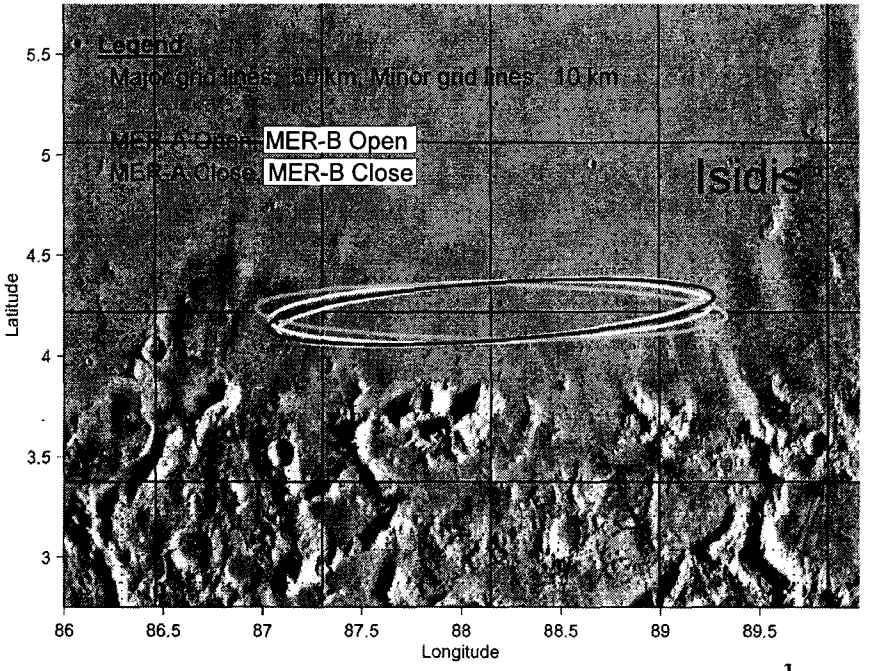
Landing Ellipse Geometry

- Landing ellipse size and orientation affected by:
  - Navigation delivery errors (and the latitude of the landing site).
  - Atmospheric and aerodynamic uncertainties.
  - Other unmodelled effects.
    - "EDL margins" added to cover the effects of sustained winds, atmosphere modeling errors, distance traveled from impact to roll stop, cross-track control uncertainty, etc..
  - Launch date.

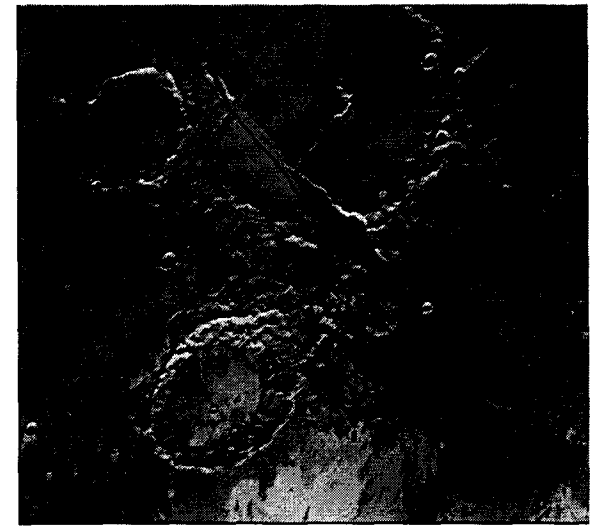
Mission	Landing Site Region	99% Landing Ellipse (including EDL margins)		Major Axis Azimuth with respect to true North (deg)
		Major Axis (km)	Minor Axis (km)	
		Open/Close	Open/Close	Open/Close
MER-A	Gusev	96 / 103	19 / 19	76 / 74
	Isidis	132 / 127	16 / 17	88 / 85
MER-B	Hematite	117 / 112	18 / 19	86 / 82
	Elysium 2 *	165	15	95

* Landing ellipse data for the Elysium site are only approximate.





MRO Project Summary



Salient Features

- ***4 Earth years in Mars orbit***
  - *2 years science observations plus relay support*
  - *2 years relay mode with capability to extend science operations*
- ***International science payload with meter scale imaging, 20 m resolution mineralogical mapping, and 6 m ground sampling context imaging from 300 km altitude***
- ***Navigational Experiment / Relay Telecom Payload/ Ka band operational demonstration***
- ***Launch: August 2005; Arrive: March 2006; Primary science phase: Dec. '06 - Dec. '08***

Science

- ***Characterize Mars' seasonal cycles and daily variations of water, dust, and carbon dioxide.***
- ***Characterize Mars' global atmospheric structure, transport and surface changes.***
- ***Search sites for evidence of aqueous and/or hydrothermal activity.***
- ***Map and characterize in detail the stratigraphy, geologic structure and composition of Mars surface features.***
- ***Characterize the Martian ice caps and profile the upper crust while searching for subsurface water and ground ice.***
- ***Characterize the Martian gravity field and upper atmosphere in greater detail.***
- ***Identify and characterize many sites for future landed missions.***

MARS EXPLORATION PROGRAM

Science/Engineering Payload Description

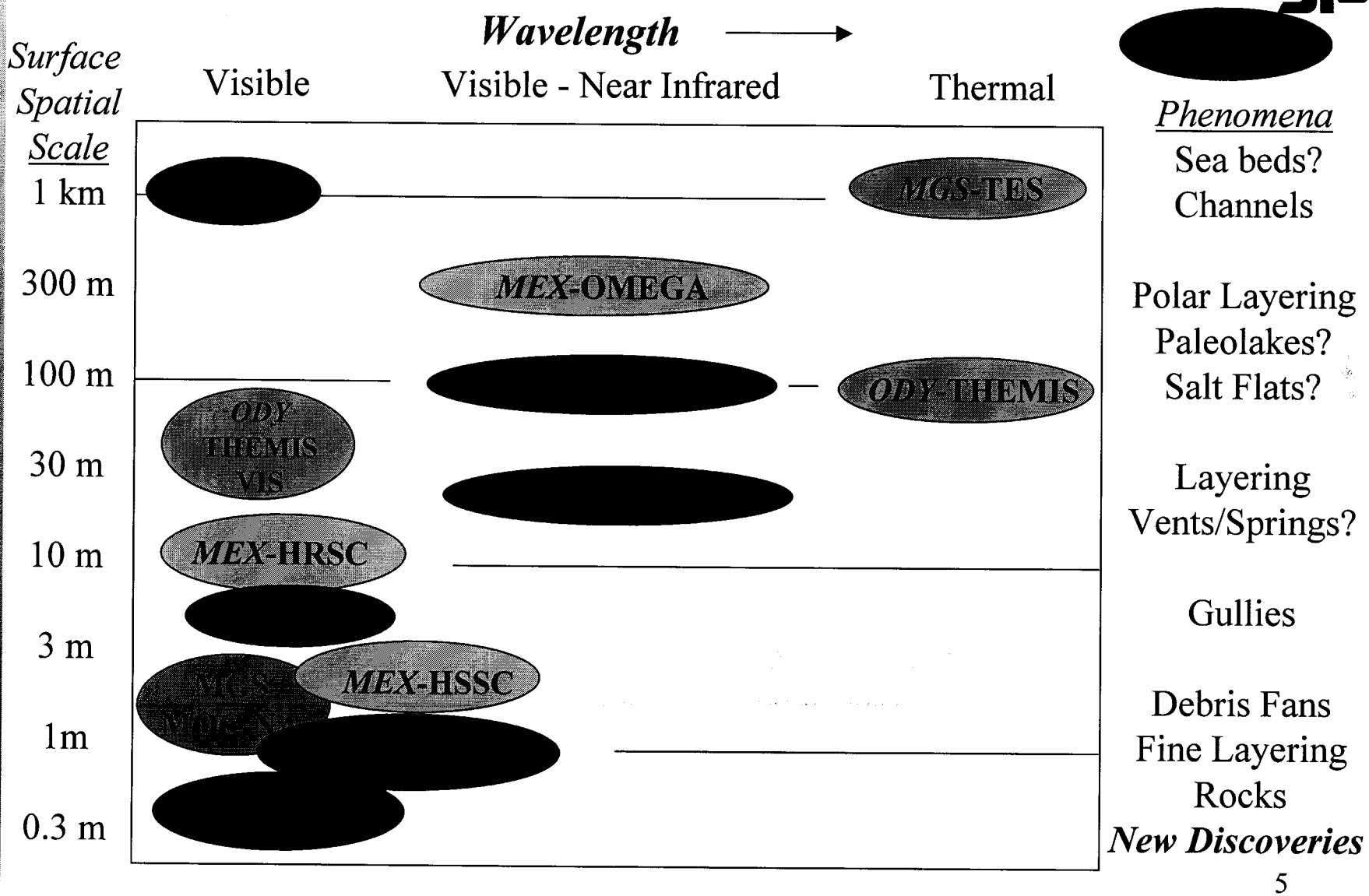
Name	Type	Provider	Ground Sampling Distance @ 300 km	Swath @ 300 km	Other	Mass (kg) CBE	Orbital Average Power (W) CBE
HiRISE	Optical Targeted	UA/BA	30 cm/pixel	6 km	3 colors	45	47
CRISM	Optical Targeted	APL	20 m/pixel	11 km	0.4 - 4.0 µm	27	40
Context Imager	Optical Regional	Facility MSSS	6 m/pixel	30 km	Panchromatic Minus Blue	3	9
Sounding Radar (SHARAD)	Radar Regional	Facility ASI	< 1x6 km (w) < 7 m (v)	6 km (w) 1 km (v)	20 MHz Center 10 MHz Bandwidth	12	31
MARCI	Optical Global	MSSS	1 to10 km/pixel	limb-to-limb	0.25 - 0.75 µm, 180° optics	2	6
MCS	Atmo-spheric Global	JPL	~ 5 km vertical	0-80 km (v) @limb	12 - 50 µm 0.3 - 3.0 µm	8	8
OpNav	Optical Nav	JPL MT	24 µrad/pixel Phobos/Deimos	--	0.45 - 0.6 µm	3	0
Electra	Radio	JPL MT/MRO	--	--	UHF	15	80 (p)
Ka Band Demo	Radio	JPL TMOD/MRO			Ka Hardware	9	79 (p)
Total Science Payload Engineering Payload						124	141

peak power = (p)

MRO Following the Water: Major Questions Remain

- *Were there ancient seas, lakes, or springs?*
  - => Survey planet for sites showing mineralized sediments (e.g., hydrates & carbonates), which may also preserve biosignatures <= ***CRISM***
  - => Observe surface layering & geologic structure <= ***HiRISE, CTX, SHARAD***
- *What is the nature of layered terrain?*
  - **=> Characterize deposits at poles & elsewhere** <= *HiRISE, CRISM, CTX, SHARAD*
- *Are there subsurface water/ice reservoirs?*
  - => Search for signs of near-surface water release or active hydrological systems ("springs", gullies, mineral l deposits) <= ***CRISM, HiRISE***
  - => Probe shallow subsurface for layering and water/water ice <= ***SHARAD***
  - ⇒ Detect release of water vapor from ground sources <= ***MCS***
- *Are hydrothermal systems active today?* <= *HiRISE, CRISM, CTX*
- *Where are ice and dust accumulating today?*
  - **=> Characterize water & dust transports & surface changes** <= *MCS, MARCI,CRISM*
  - **=> Monitor polar processes** <=*MCS, MARCI, CTX*

Relation to Other Mars Missions for Imaging



Science Instruments

- **High-Resolution Imaging Science Experiment (HiRISE)**
  - HiRISE, a very-high-spatial-resolution camera, designed to acquire targeted, monochromatic images describing local to regional surface processes, stratigraphy, and geology. The HiRISE instrument will have the following attributes:
    - Ability to resolve 1-meter-scale objects and differences in surface morphology
    - Swath width greater than 3.5 km
    - Signal to noise ratio of order 50 to 1 or more

Science Instruments (cont.)

- **Compact Reconnaissance Imaging Spectrometer (CRISM)**
  - CRISM, a hyper-spectral imaging spectrometer, designed to detect aqueous minerals and hydrothermal deposits, if present, describing surface composition and structure through a combination of high-spatial-resolution, hyper-spectral targeted observations and of regional survey at reduced spatial and spectral resolutions. The CRISM instrument will have the following attributes:
    - Ground sampling scale $\leq$ 40 m/pixel
    - Swath width $\geq$ 7 km
    - Spectral range of 0.4 to 3.6 microns
    - Spectral resolution of 10 nanometers or better
- **Context Imager (CTX)**
  - CTX, a monochromatic camera, to provide moderate-spatial-resolution context information for the high-spatial-resolution imager (HiRISE) and the moderate-spatial-resolution imaging spectrometer (CRISM) and to provide independent information on climate and regional surface processes.
    - Ground sampling scale $\leq$ 7.5 m/pixel
    - Swath width $\geq$ 20 km
    - Signal to noise ratio of order 20 to 1 or more

Science Instruments (cont.)

- **Mars Color Imager (MARCI)**
  - MARCI, a multi-color camera based on the Mars Climate Orbiter MARCI Wide-Angle Camera, designed to provide daily global atmospheric and surface monitoring. The MARCI instrument will have the following attributes:
    - Limb-to-limb field of view (instrument field of view from 140° –180°)
    - Two UV and up to five visible color bands in the wavelength range 0.25 - 0.8 microns
- **Mars Climate Sounder (MCS)**
  - MCS, a profiling radiometer, designed to characterize daily the structure of the global atmosphere and monitor periodically the radiation balance of the polar regions. MCS shall address the objectives of the Mars Climate Orbiter PMIRR investigation by having the following attributes:
    - Atmospheric limb profiling and on-planet observations in thermal infrared channels and in a broadband solar channel;
    - Measurements over the vertical range of 0-80 km with vertical sampling $\leq$ 6 km.

Science Instruments (cont.)

- **Shallow Radar (SHARAD)**
  - SHARAD, a ground-penetrating radar, designed to provide information on the polar ice caps and on the uppermost layers of the Martian crust in selected regions distributed globally over the planet. SHARAD is planned to have the following attributes:
    - Operating frequency greater than 10 MHz to probe the subsurface to depths < 1 km;
    - Footprint ground sample resolution of approximately 1-km x 7-km (down-track x cross–track);
    - Ability to probe areas of the Martian regolith to depths of several hundred meters with a vertical resolution [free-space range resolution] comparable to 15 m.
    - Instrument to be provided by the Italian Space Agency, ASI

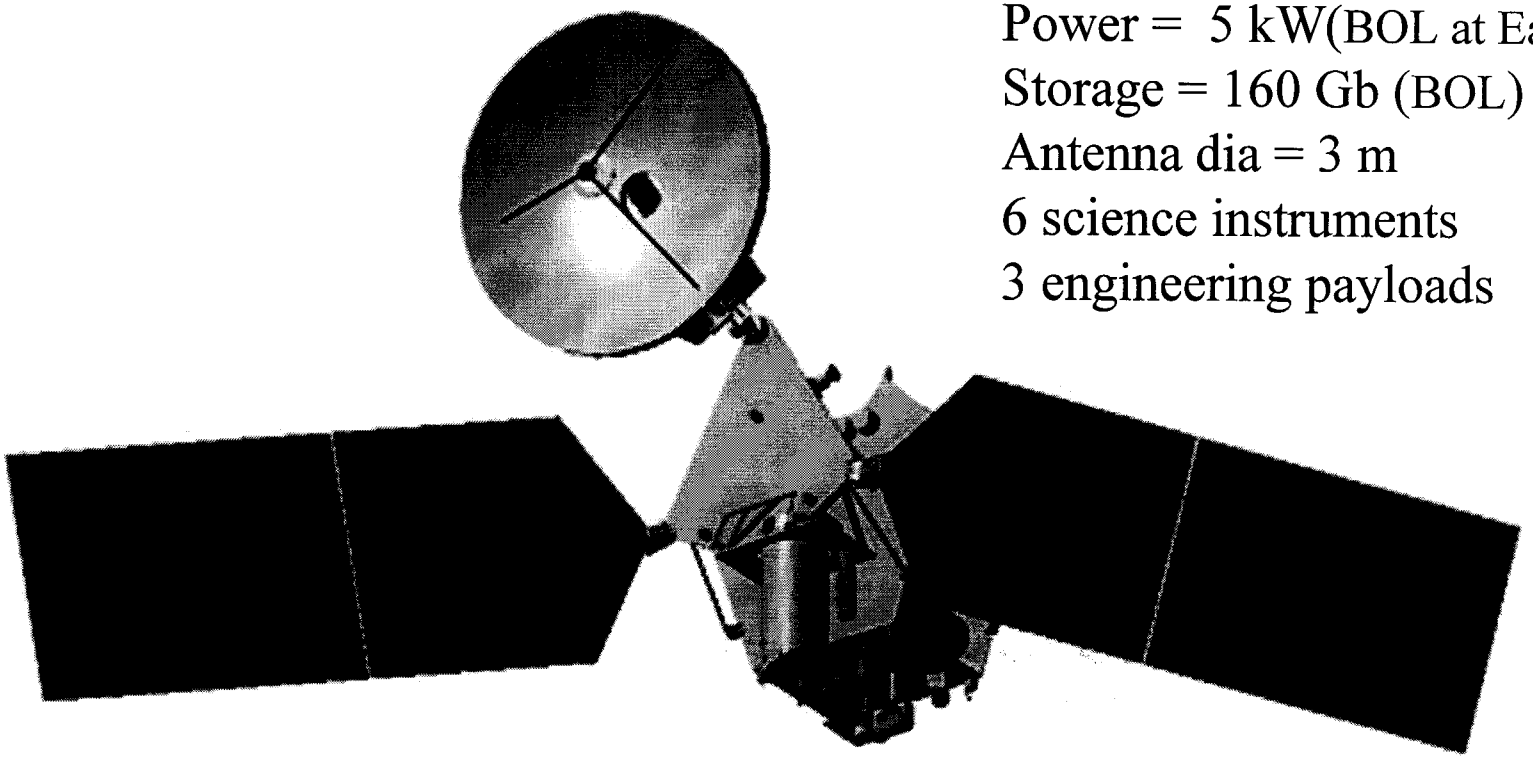
Science Instruments (cont.)

- **Gravity Science**
  - The Gravity Science Facility Investigation Team will analyze data acquired by tracking the MRO in orbit using the spacecraft telecommunications systems to characterize the Martian gravity field in greater detail than is possible with data from previous Mars missions.
- **Atmospheric Structure**
  - The Atmospheric Structure Facility Investigation Team will analyze data acquired by the spacecraft accelerometers during the aerobraking phase of the MRO mission to support mission operations and to improve knowledge of upper atmospheric structure and circulation.

MRO Technology Development

- **Optical Navigation Camera**
  - Potential low cost approach to precision navigation; hardware to be used on future missions; compared against Very Long Baseline Interferometry (VLBI) measurements; enable final maneuver to achieve 0.1° flight path angle accuracy or 1 km in position.
- **UHF Relay Payload (Electra)**
  - Standardized, CCSDS-compliant proximity link communications for contact with landers and orbiters; hardware to fly on all future NASA missions; designed to be software reconfigurable and frequency agile.
- **Ka-Band Operational Demonstration**
  - Ka-Band deep space telecommunications link demonstration enhances science data return by 10-20% by providing 2 additional 8 hour passes/week; allows for assessment of Ka-Band performance in deep space operations environment.

MRO General Description

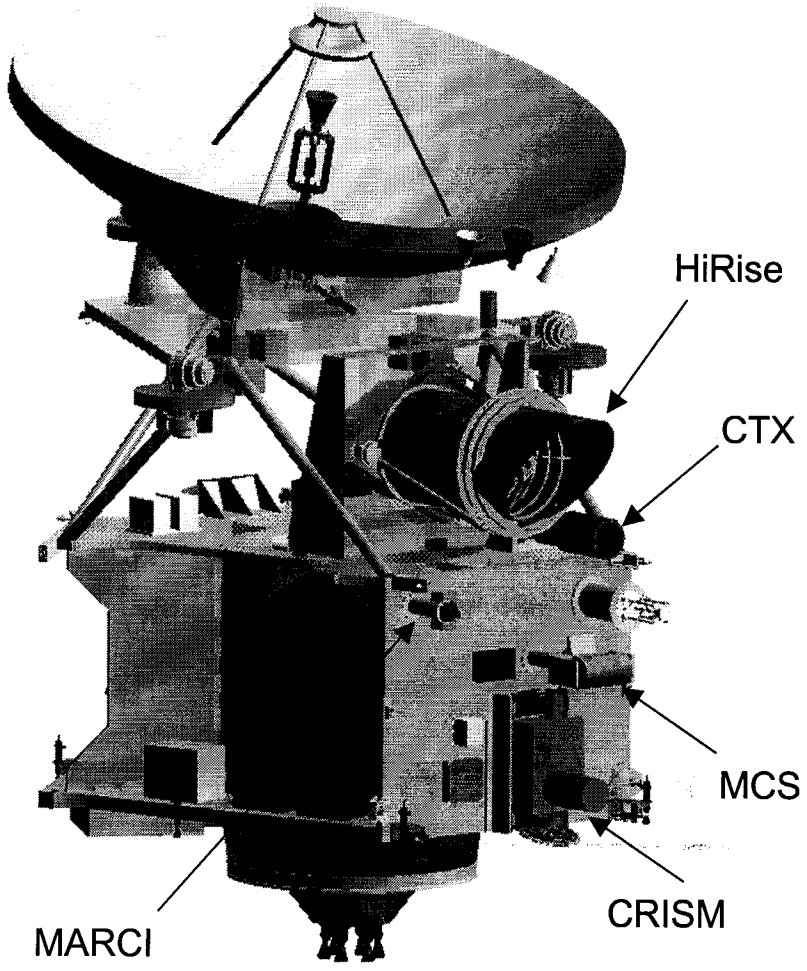


Orbiter Characteristics

Mass = 2000kg
Power = 5 kW(BOL at Earth)
Storage = 160 Gb (BOL)
Antenna dia = 3 m
6 science instruments
3 engineering payloads

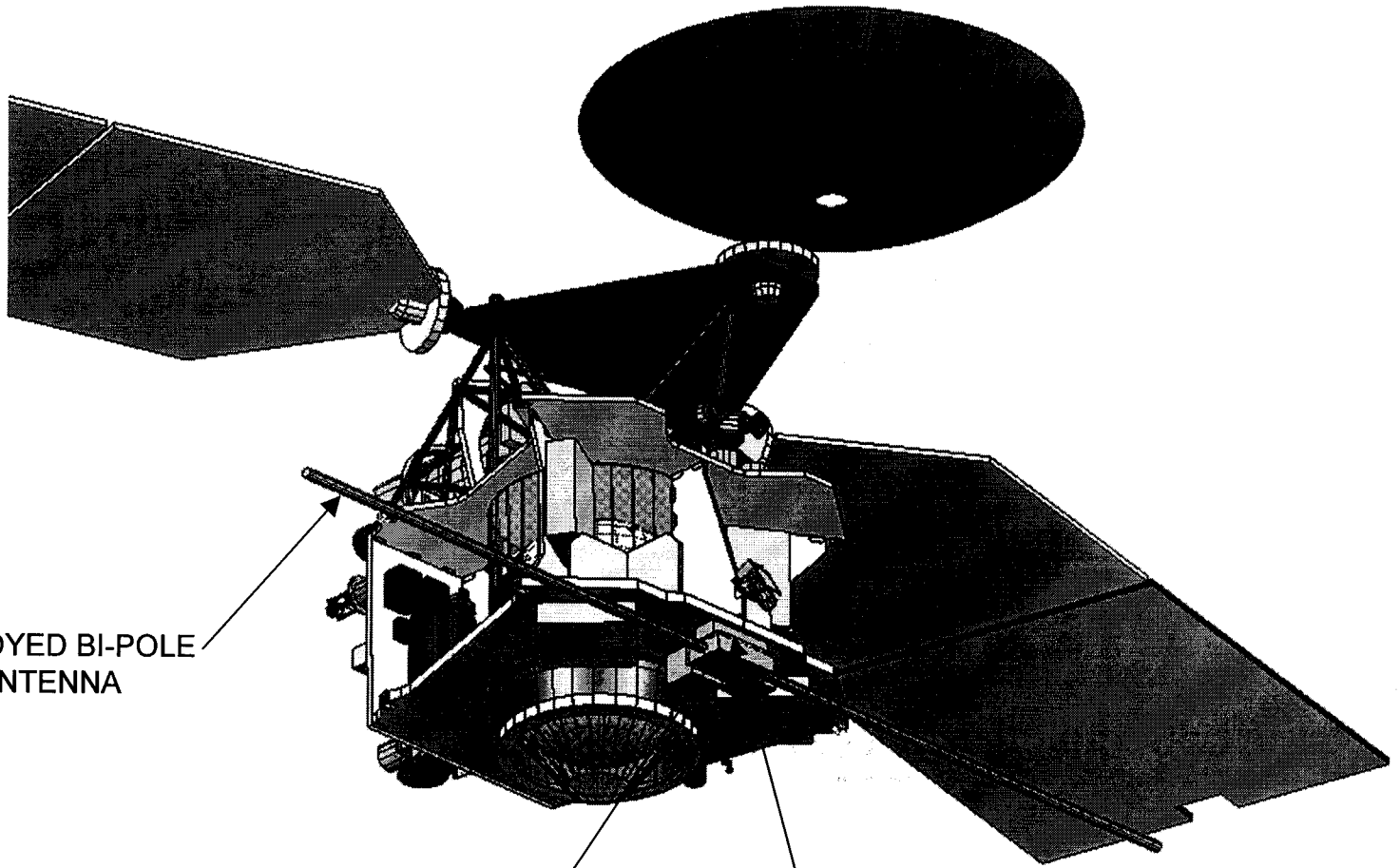
Primary Science Phase Configuration

MRO Science Payloads (NADIR Deck)



MARS EXPLORATION PROGRAM

MRO Science Payload (SHARAD)



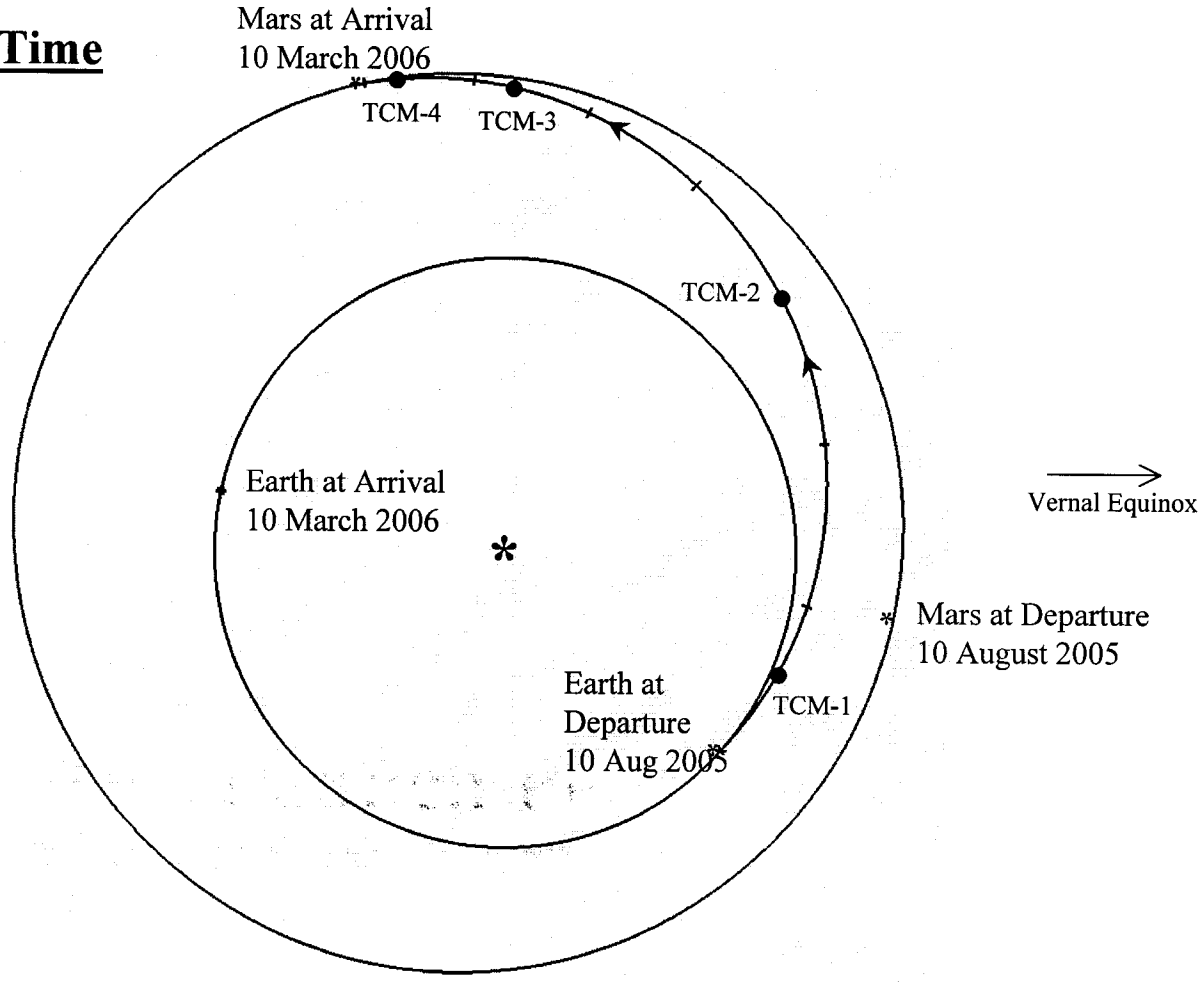
Cruise Trajectory - Launch Period Open

Earth-Mars Flight Time

~7 months (210 days)

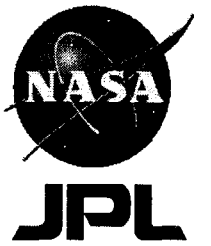
TCM Schedule

TCM-1: L+15 days
TCM-2: L+90 days
TCM-3: MOI-40 days
TCM-4: MOI-10 days
TCM-5A: MOI - 24 hrs
TCM-5B: MOI - 12 hrs



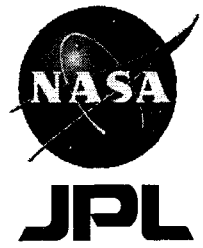
View from Trajectory North Pole
(30 day tick marks)

Orbiter Mission Description



- Primary science orbit (PSO) is 255 x 320 km, frozen, polar orbit.
- Periapsis frozen at the south pole and an ascending node at a local mean solar time of 3 p.m.
- Primary science phase lasting one Martian year (687 Earth days)
- Comparative Navigation Experiment and the Ka–Band Telecommunication Experiment to support of future Mars missions.
- Provide critical telecommunications relay capability for missions launched after MRO as part of the Mars Exploration Program.
- Nominal end of the MRO mission planned for December 31, 2010, approximately 5.4 years after launch.

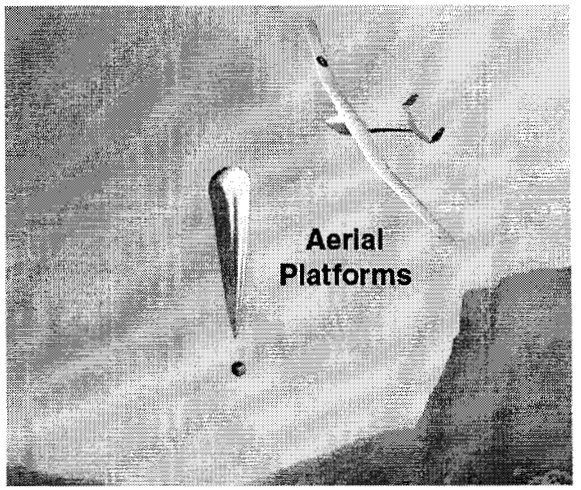
May '01 Scout Workshop



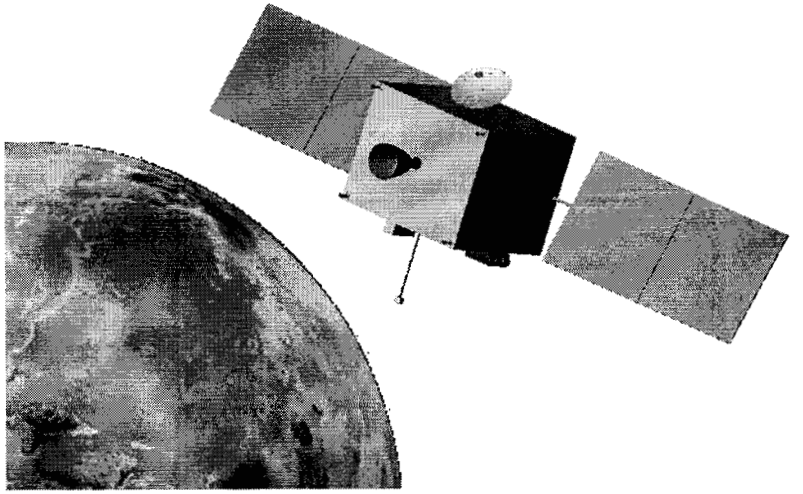
- **Pre-AO Workshop and NASA Funded Studies**
- **43 Concepts Submitted, 10 Selected for further study ($150K awarded to each)**
- **The Selected Concepts Helped to Prepare for the 2002 AO**
  - Possible Science
  - Needed Technology
  - Cost/Schedule/Risk
- **Selected Concepts for this pre-AO study DO NOT Prejudice the AO competition**

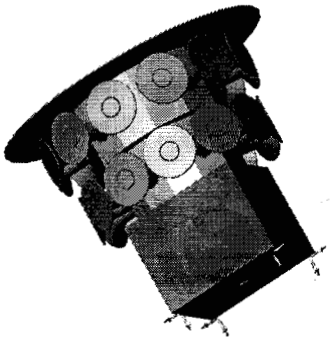
What are Mars Scouts?

- **PI-led missions:**



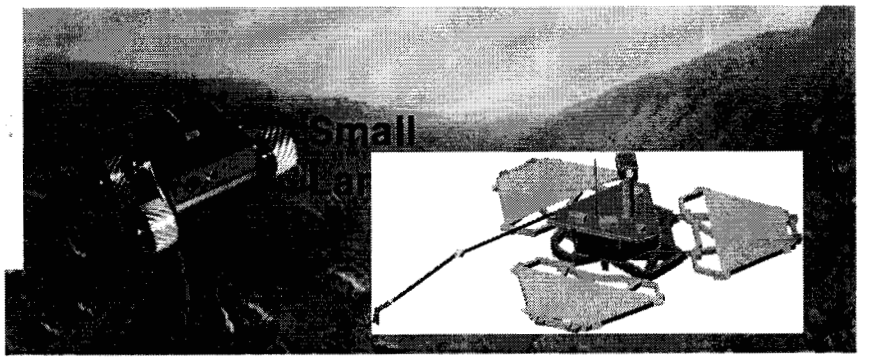
Orbital



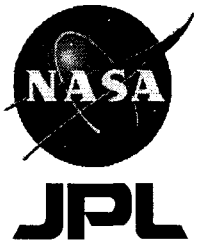


Network

Lander/Rover

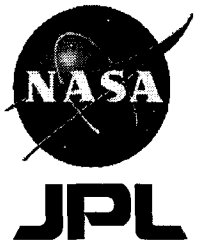


Ten Selected Scout Study Awards (June 2001)



Area	Study Title	PI (institution)	Short Description
Landers/Rovers	**The Urey Mission**	**Plescia (USGS)**	**Lander/Rover for age dating.**
↓	**The NAIADES**	**Grimm (Blackhawk Geoservices)**	**Low-frequency EM sounding for groundwater.**
↓	**Artemis**	**Paige (UCLA)**	**Multiple polar small landers to the north and south poles.**
↓	**Cryoscout**	**Carsey (JPL)**	**North Polar probe melts into ice.**
↓	**PASCAL**	**Haberle (ARC)**	**Global meteorology network.**
Orbiters	**Mars SAR**	**Campbell (Smithsonian)**	**Global imaging radar from orbit.**
↓	**Mars Atm Const Obs**	**Kursinski (UA)**	**Radio sounding of Mars atmosphere from multiple orbiters.**
↓	**Mars Env Obs**	**Janssen (JPL)**	**Orbital observation of Mars' atmosphere.**
Aerial	**KittyHawk**	**Calvin (UNR)**	**Multiple gliders observing Valles Marineris.**
Other	**Sample Collection for Investigation of Mars**	**Leshin (ASU)**	**High altitude Martian dust collection and return to Earth via Mars atmospheric flyby.**

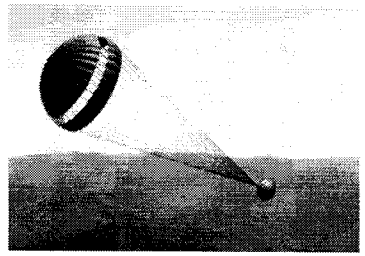
Scout Summary

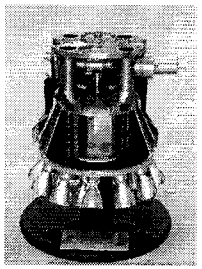


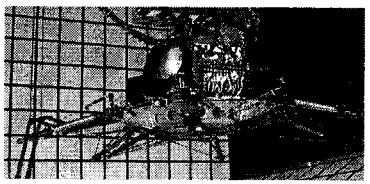
- **Complete the 2007 Scout AO Proposal Evaluation by end-of-year.**
- **Downselect to 3 or 4 proposals in December 2002.**
- **Phase A studies for the selected proposals anticipated to be for a duration of 5 to 6 months.**
- **This 2-step process will culminate in a mission selection by NASA in August 2003.**
- **The selected Mars Scout mission will be launched during the 2007 opportunity.**
- **Begin advanced planning for possible 2011 Scout mission.**

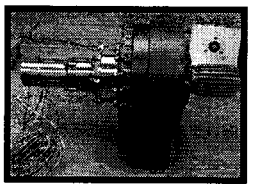
MARS EXPLORATION PROGRAM

MSL Focused Technology



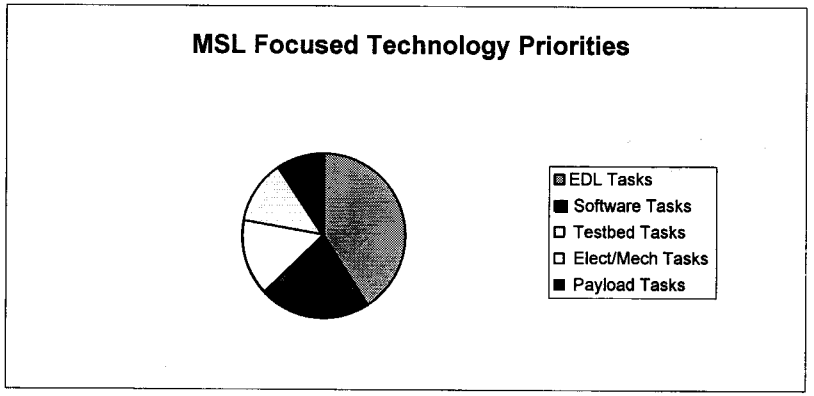


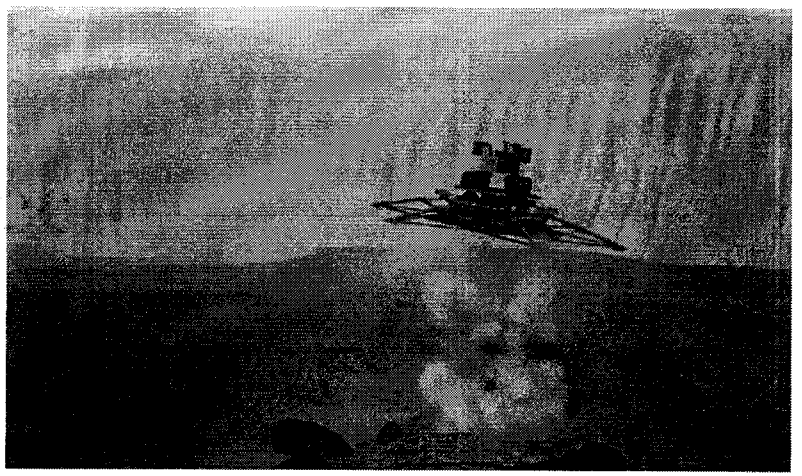




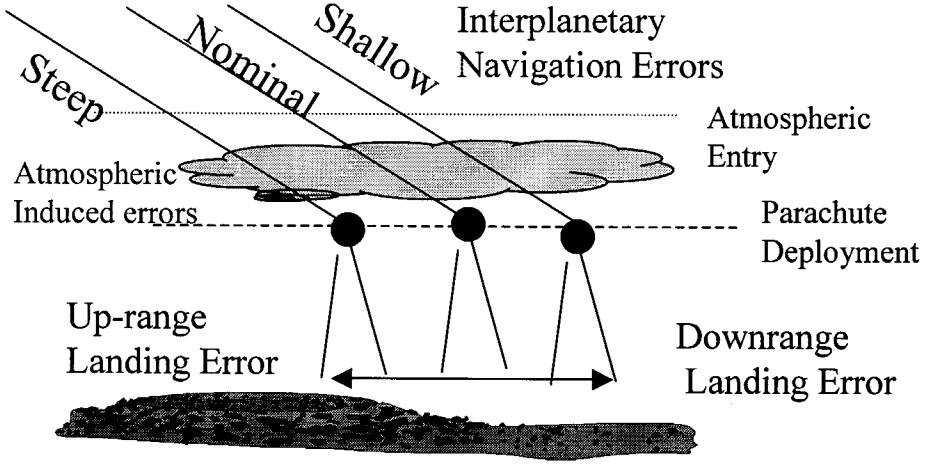
Objectives:

This 3-year program develops technology to improve performance, reduce cost, and reduce risk to the MSL project. The technologies will demonstrate a technology readiness level (TRL) 6 by the PDR.. Where TRL 6 means a system or subsystem model or prototype is demonstrated in a relevant environment





Guided Entry Technology

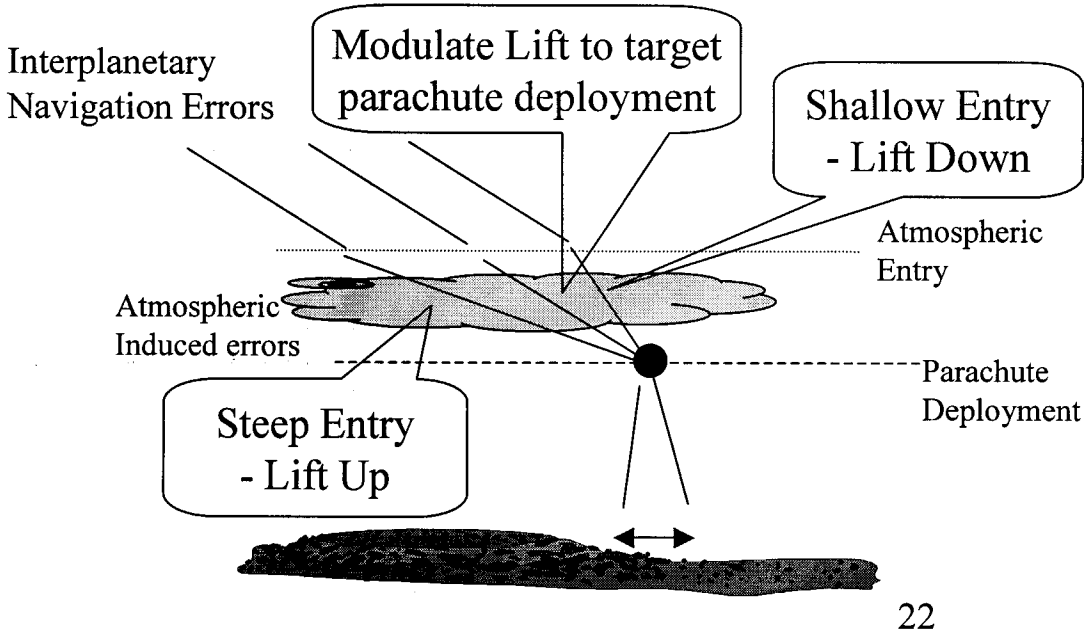


Ballistic or Unguided Lifting Entry

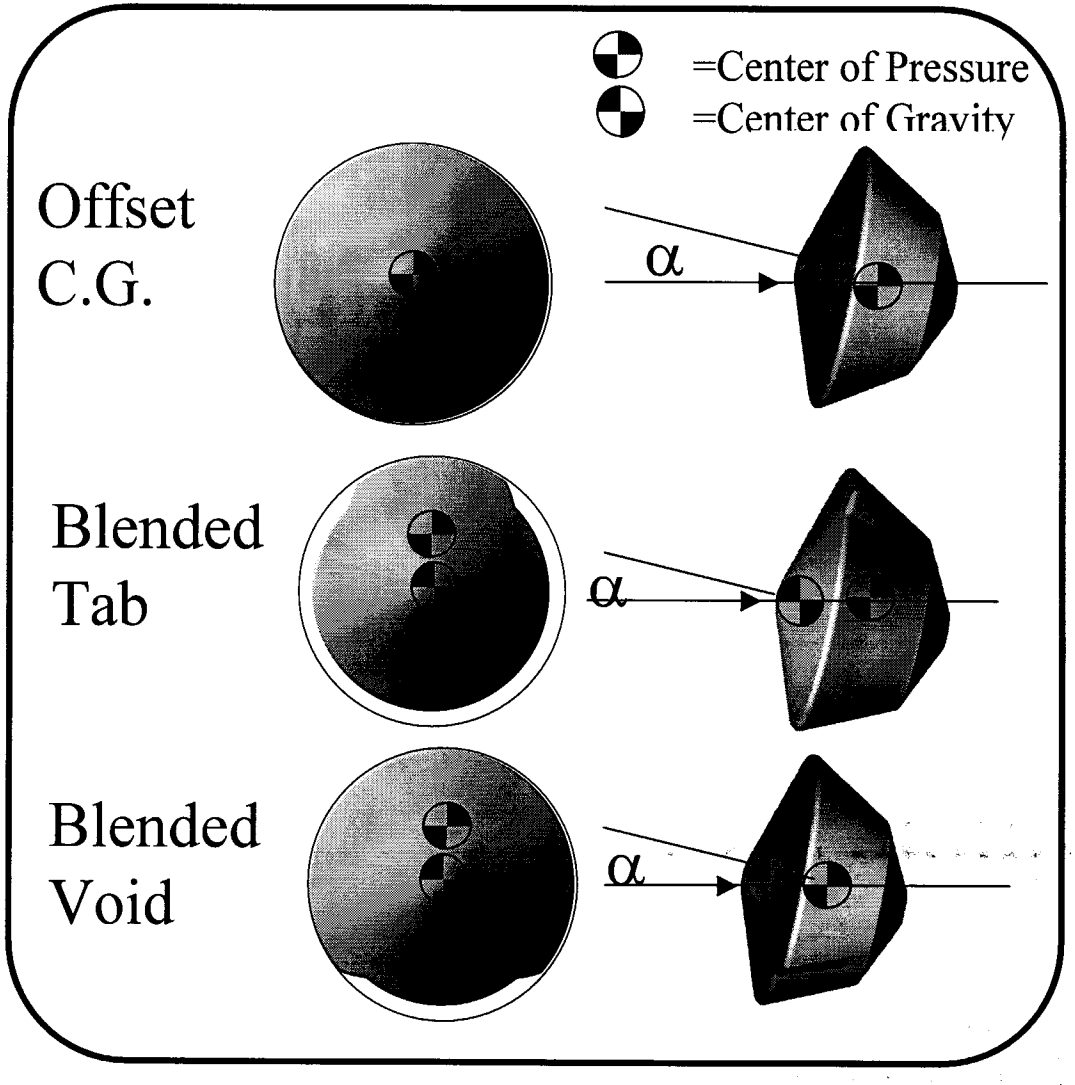
- Arrival/Entry Navigation errors uncorrected

Guided Lifting Entry

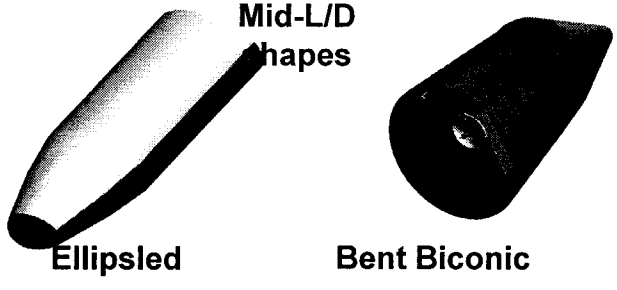
- Arrival/Entry Navigation "flown-out" with modulated lift guidance strategy



Entry Body Aerodynamics

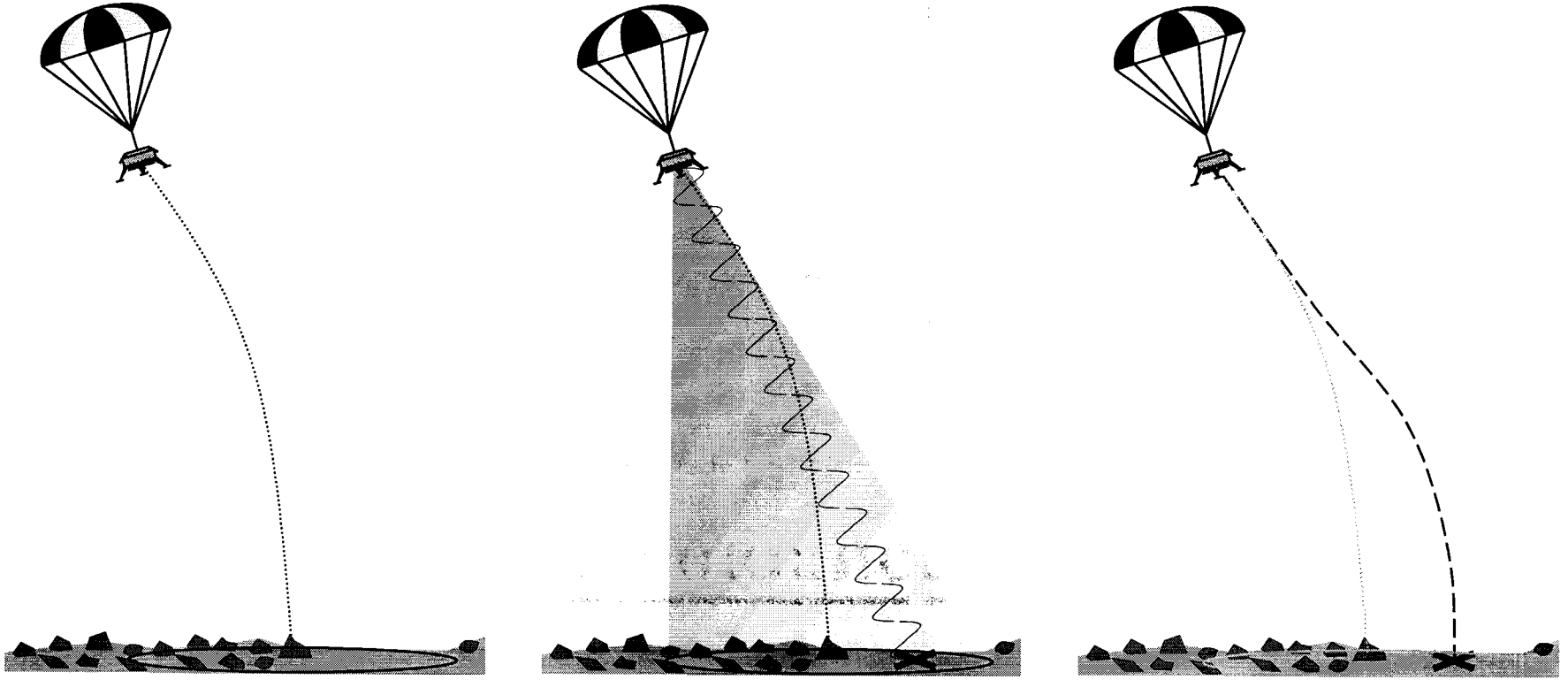


- Different options available to induce angle of attack/lift within family of Viking heritage for low L/D
- Other shapes require future flight qualification for higher L/D



Active Hazard Avoidance Landing

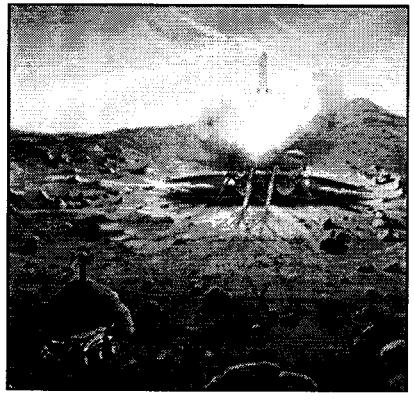
Key Areas For this Technology:
Sensor Technology, Feature Recognition, and Maneuverability



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

Sample Return Technologies

Forward Planetary Protection

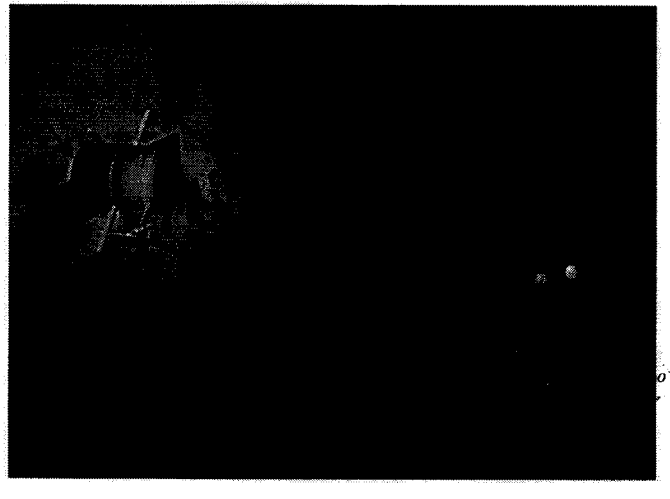


Mars Ascent Vehicle

Objectives:

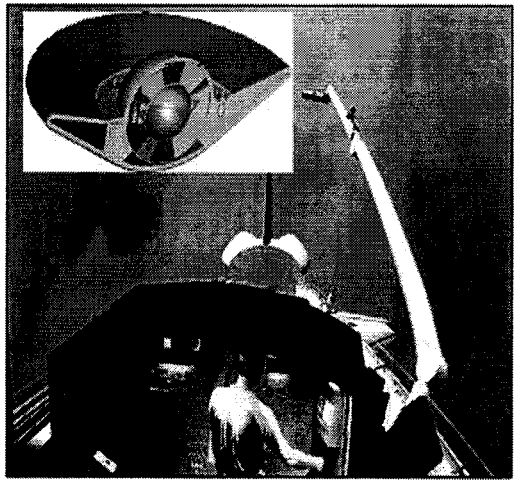
Develop and validate enabling technologies for

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



Rendezvous and Sample Capture

Returned Sample Handling

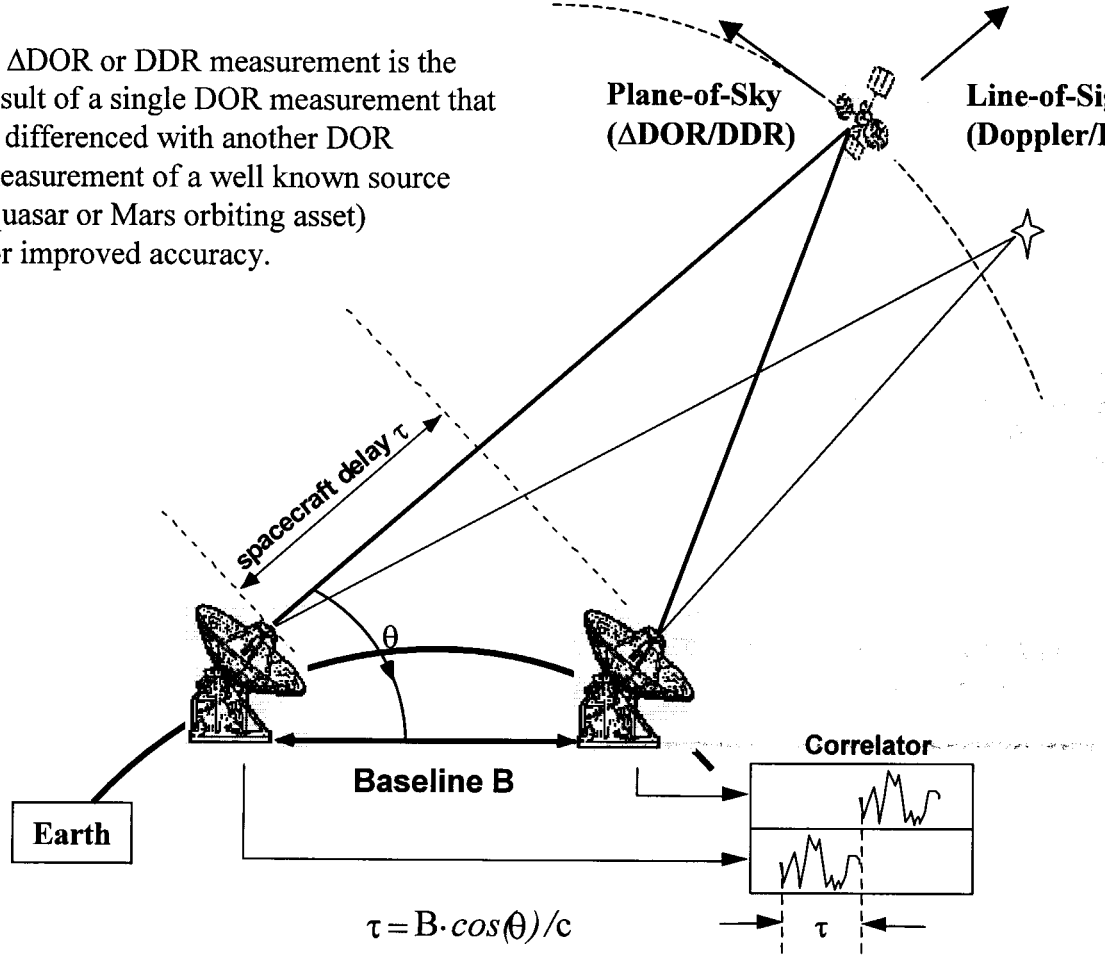


Sample Containment and Earth Return

Complementary Nav Data Type: Definitions

ΔVLBI (delta Very Long Baseline Interferometry) is a general term that covers both ΔDOR and DDR.
ΔDOR (delta Differenced One-Way Range)
DDR (Doubly Differenced Range)

A ΔDOR or DDR measurement is the result of a single DOR measurement that is differenced with another DOR measurement of a well known source (quasar or Mars orbiting asset) for improved accuracy.



- **Doppler and Range measure the position and velocity of the spacecraft along the Line-of Sight.**
- **ΔDOR and DDR are complementary data types because they directly measure the spacecraft position in a direction orthogonal to the Line-of-Sight Doppler and Range measurements.**
- ΔDOR measures the angular difference in the Plane-of-Sky between the spacecraft and a quasar reference.
- DDR measures the angular difference in the Plane-of-Sky between the spacecraft and another reference spacecraft (Mars orbiting asset, not shown in figure).