Mars Technology Program (MTP)

http://marstech.jpl.nasa.gov

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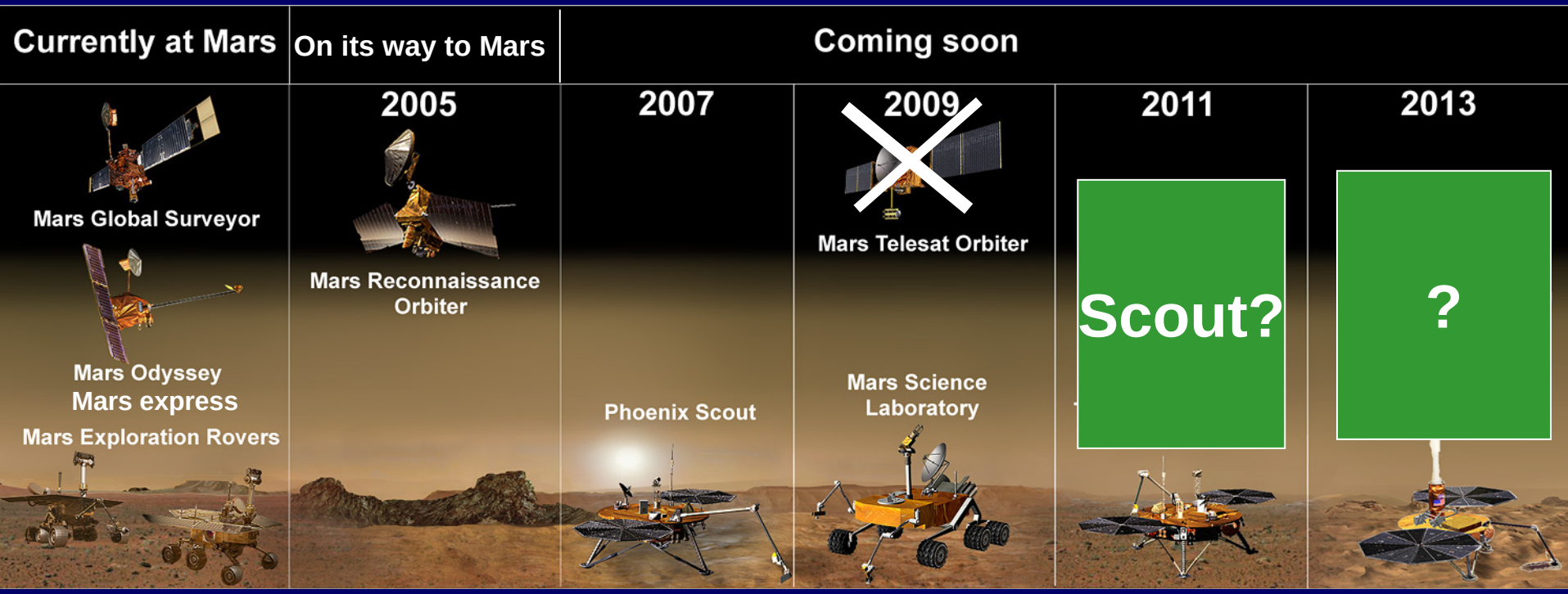
i-SAIRAS 2005
Munich, Germany
September 5-8, 2005

Outline

- *Review of Mars Missions*
- *Overview of Mars Technology Program (MTP)*
- *Technology Infusion*

Current and future Mars Missions



Phoenix Scout Mission (2007)

Designed to measure volatiles (especially water) and complex organic molecules in the arctic plains of Mars, where the Mars Odyssey orbiter has discovered evidence of ice-rich soil very near the surface.

Robotic Arm is designed to dig trenches, scoop up soil and water ice samples, and deliver these samples to the TEGA and MECA instruments for detailed chemical and geological analysis

Mars Science Laboratory (2009)

- ***Twice as long and three times as heavy as the Mars Exploration Rovers Spirit and Opportunity***
- ***Collects Martian soil samples and rock cores and analyze them for organic compounds and environmental conditions***
- ***Uses many new technologies***
- ***International participations:***
  - ***Neutron-based hydrogen detector for locating water provided by the Russian Federal Space Agency***
  - ***Meteorological package provided by the Spanish Ministry of Education and Science***
  - ***A spectrometer provided by the Canadian Space Agency with participation by the Max Planck Institute for Chemistry in Germany.***

Technology Program tightly integrated to Mars Exploration Pathways

Pathway	2009	2011	2013	2016	2018	2020	NOTEΣ
Search for Evidence of Past Life	MSL to Low Lat.	Scout	Ground-Breaking MSR	Scout	Astrobiology Field Lab or Deep Drill	Scout	All core missions to mid-latitudes. Mission in '18 driven by MSL results and budget.
Explore Hydrothermal Habitats	MSL to Hydrothermal Deposit	Scout	Astrobiology Field Laboratory	Scout	Deep Drill	Scout	All core missions sent to active or extinct hydrothermal deposits.
Search for Present Life	MSL to N. Pole or Active Vent	Scout	Scout	MSR with Rover	Scout	Deep Drill	Missions to modern habitat. Path has highest risk.
Explore Evolution of Mars	MSL to Low Lat.	Scout	Ground-Breaking MSR	Aeronomy	Network	Scout	Path rests on proof that Mars was never wet.

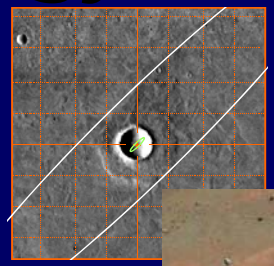
telecom → replacement Telecom →

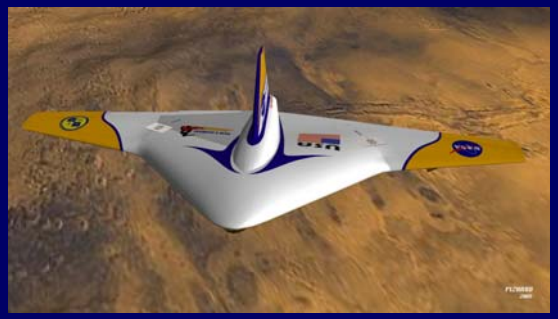
Some Candidate Future Missions

- *Scout: PI led, cost capped per NASA announcement of Opportunity*
- *More MSLs and MERs: Same or new science instruments*
- *MSR: Variety of architectures: ground breaking (no mobility); with a fetch rover; in coordination with other missions*
- *AFL: MSL with life detection instruments and more rover and sample processing capabilities*
- *Deep Drill: > 0.5 m and <20m*
- *Network*
- *Aeronomy*

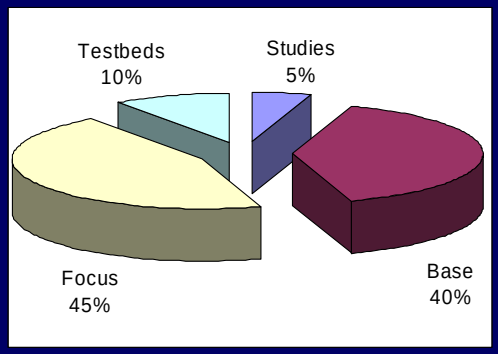
Mars Technology Goals

- *Land more payload mass on higher altitudes more accurately*
- *Access higher latitudes*
- *Access to sites with terrain too complex for landing current rovers*
- *Increase mobility and autonomy*
- *Access the subsurface and acquire samples for in situ analysis*
- *Enable improved science instruments*
- *In situ sample acquisition, preparation, and distribution systems*
- *Planetary protection techniques*
- *Technologies for return of samples to Earth for analysis*





Technology Development Strategy



- ***Studies***
  - *Studies are conducted when technology development path is not clear*
- ***Base Technology***
  - *Lower TRL*
  - *Provides seed corn for future mission technologies*
  - *Enables new types of missions*
  - *100% competed via NASA NRA process*
- ***Focused Technology***
  - *Driven by requirements of missions (such as MSL and MSR)*
  - *Technology development is strongly coupled and interactive with the project early in the design phase*
  - *Technology must reach maturity (TRL 6) by Project PDR*
  - *Directed or competed*
  - *Day-to-day management is done by projects*
- ***Validation Testbeds***
  - *Integrates component technologies and validates capabilities*

Base Technology

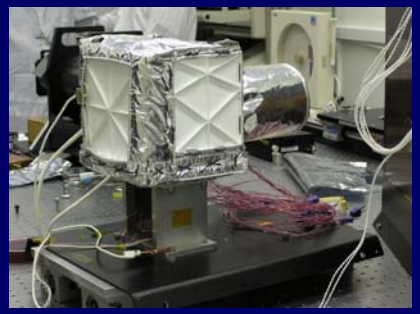
Seven areas have been identified as high priority technology areas for Mars missions

- Proximity Telecom/Navigation
- Rover Technology
- Subsurface Access
- Planetary Protection
- Advance EDL
- Low Cost Mission Technologies
- Mars Science Instruments

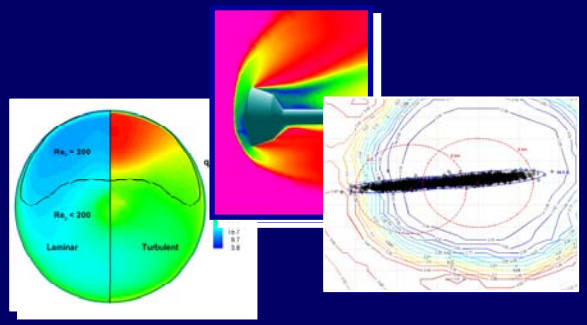
Currently, 95 tasks are within the Base Program

EDL Technologies

- *Increase landing accuracy at higher altitudes for larger payloads*
- *EDL remains as one of the most challenging elements of Mars Missions*

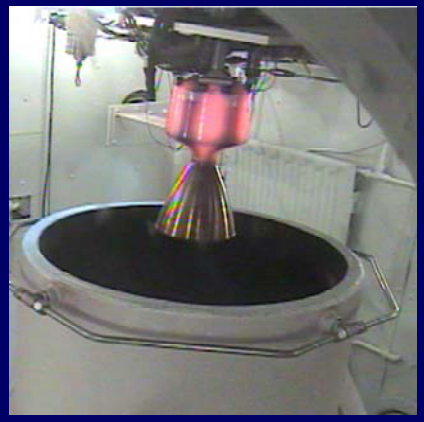


MRO Optical Navigation Camera (FY '05)

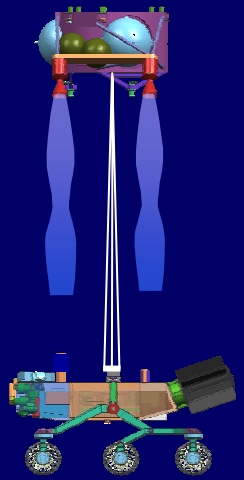


MSL Guided Entry and Thermal Analysis and simulation (FY '09)

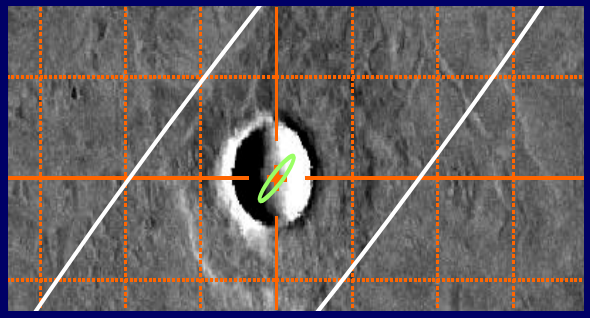
Subsonic Parachute, MSL or MSR



MSL Descent Engine and Throttle Valve (FY '09)



MSL Sky Crane (FY '09)



Pin-point Landing Technology, post MSL

Surface Systems (Rovers)

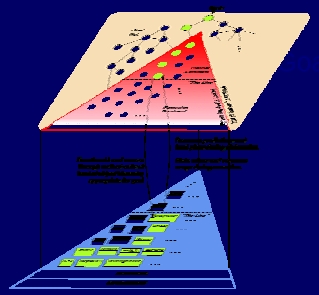
- *NASA has been involved in planetary rovers for several decades (TRIWG)*
- *There has been only two autonomous planetary rover missions (both to Mars)*
- *NASA and government investments have paid off well via the successful Sojourner and MER rovers*
- *Many new technologies were infused into MER mission*
- *NASA, Academia, and Industry contributed to technology infusion*

Technologies Infused to MER

	Technology	Funding Source	Description	PI/Technologist
1	Stereo Vision	NASA, caltech DRD, Army, DARPA	Provides 3-D terrain maps for rovers, manipulators, and human operators	Larry Matthies Mark Maimone
2	Long Range Science Rover	NASA (Code R and MTP)	Provides increased traverse range of rover operations, improved traverse acuracy, landerless and distributed ground operations with a large reduction in mass	Samad Hayati Richard Volpe
3	Science Activity Planner	NASA (Code R and MTP)	Provides downlink data visualization, science activity planning, merging of science plans from multiple scientists	Paul Backes Jeff Norris
4	Viz - 3D Terrain Visualization	NASA (Code R)	Enables the Science team to operate a rover simulation with an interactive time of day shadow simulation, provides multiple views onto the visualization, demonstrates a proof of concept rover command specification	Larry Edwards
5	FIDO: Field Integrated Design and Operations Rover	NASA (MTP)	Developed TRL 4-6 rover system designs, advancing NASA capabilities for Mars exploration; demonstrated this in full-scale terrestrial field trials, Integrated/operated miniaturized science payloads of mission interest, coupling terrestrial field trials to flight requirements	Paul Schenker Eric Baumgartner
6	Manipulator Collision Prevention Software	NASA (MTP)	Computationally efficient algorithm for predicting and preventing collisions between manipulator and rover/terrain.	Eric Baumgartner Chris Leger
7	Descent Image Motion Estimation System (DIMES)	NASA (Code R and MTP)	Software and hardware system for measuring horizontal velocity during descent, Algorithm combines image feature correlation with gyroscope attitude and radar altitude measurements.	Andrew Johnson Yang Cheng et al.
8	Parallel Telemetry Processor (PTeP)	NASA (Code R and MTP)	Data cataloging system from PTeP is used in the MER mission to catalog database files for the Science Activity Planner science operations tool	Mark Powell Paul Backes
9	Visual Odometry	NASA (MTP)	Onboard rover motion estimation by feature tracking with stereo imagery, enables rover motion estimation with error < 2% of distance traveled	Larry Matthies Yang Cheng
10	Rover Localization and Mapping	NASA (MTP)	An image network is formed by finding correspondences within and between stereo image pairs, then bundle adjustment (a geometrical optimization technique) is used to determine camera and landmark positions, resulting in localization accuracy good for travel up 1 km	Ron Li Clark Olson et. al.
11	Grid-based Estimation of Surface Traversability Applied to Local Terrain (GESTALT)	NASA (Code R and MTP)	Performs traversability analysis on 3-D range data to predict vehicle safety at all nearby locations; robust to partial sensor data and imprecise position estimation. Configurable for avoiding obstacle during long traverse or for driving toward rocks for science analysis	Mark Maimone
12	Collaborative Information Portal (CIP)	NASA (Code R)	An enhanced situational awareness tool to provide mission management, scientists and engineers with insight into the status of mission operations.	Joan Walton John Schreiner
13	MAPGEN and Constraint Editor	NASA (Code R)	Provides mixed initiative decision support system for complex activity planning with constraints, activity plan development and what-if analysis, automated activity and resource conflict resolution to improve resource management for the rover, enabling increased science activities	Kanna Rajan John Bresina
14	MERboard	NASA (Code R)	Replaced flip chart based manual Sol Tree process with computer tool, capability for re-planning, calculation of mission success criteria for different planning options	Jay Trimble
15	Science Process Design and Evaluation	NASA (Code R)	Created a system to capture and handover science intent information across multiple shifts - previous process required continuous team member presence of same people in long monolithic uplink shift - not sustainable from a human factors standpoint	Roxana Wales Jay Trimble
16	Fatigue Countermeasures	NASA (Code R)	Procedures, scheduling techniques and countermeasures for Operating on “Mars-time”	Melissa Mallis
17	Static Analysis of MER Flight Software	NASA (Code R)	Static analysis, based on abstract interpretation, offers compile-time techniques used to exhaustively check for runtime errors (e.g., out-of-bound array accesses) in large software systems (~500 KLOC).	Guillaume Brat
18	Lithium-Ion Batteries	NASA (Code R and MTP), Air Force (AFRL)	Significant mass and volume savings (3-4 X) compared to the SOA Ni-Cd and Ni-H2 batteries.	Richard Ewell

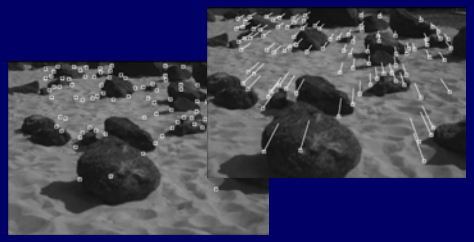
Rover Technologies

- *GESTALT rover navigation has been used successfully to drive ~10km on the surface of Mars*
- *Science Activity Planner (SAP) has been used to develop science plans for MER rovers*



CLARAty (JPL/Ames/CMU)

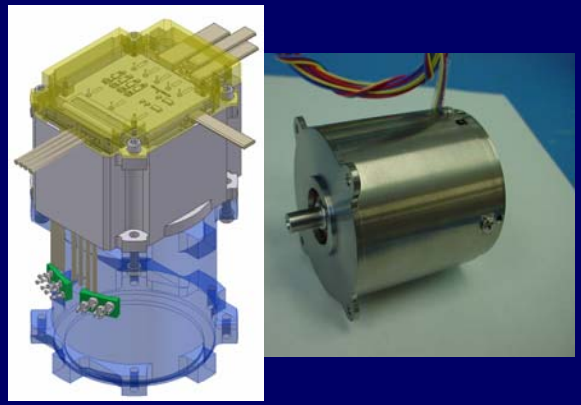
Improved autonomy for instrument placement and long traverse, MSL, 09



Visual Odometery, MSL, '09

Driving on slops

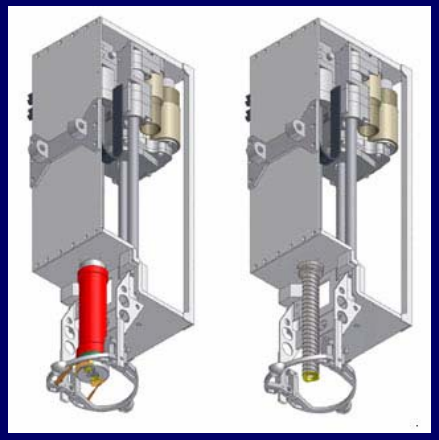
Rigorous validation of selected technologies



Long lived actuators for Martian Temperatures, MSL, '09

Rover Design, MSL, 09

Sampling and Subsurface Access

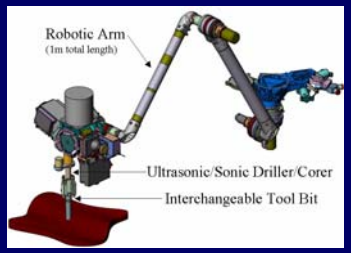


Corer/Abrader by Honeybee Robotics , MSL' 09

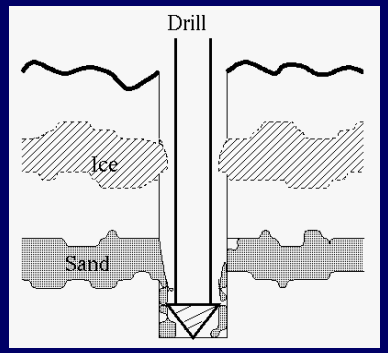
Rock Crusher, MSL' 09

Arm design and force sensing alternatives for coring, MSL, '09

Deep Drill, Swales , Second decade missions



Shallow Drills, Second decade missions

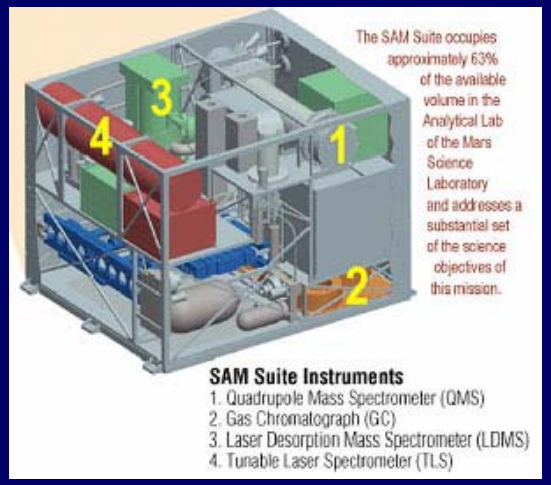


Automated Drilling for Subsurface Sample Acquisition

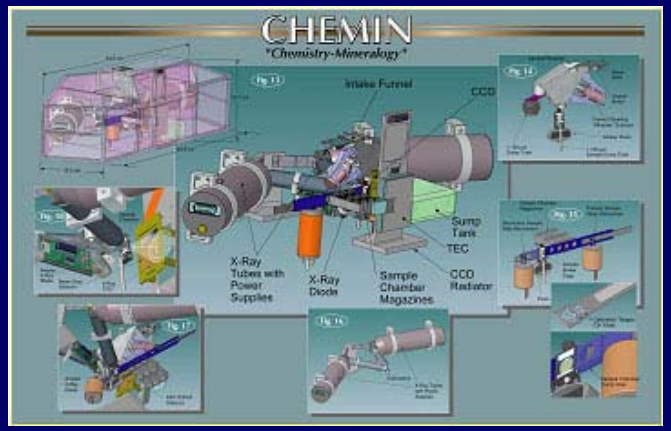
Mars Science Instrument Development (MIDP)

- Program develops science instruments, particularly at TRLs 4-6
- Last MSL AO selected three of the instruments developed within this program
- Program emphasis has been on in-situ instruments

ChemCam
Laser Induced Remote Sensing for Chemistry and Micro-Imaging (Elemental composition)

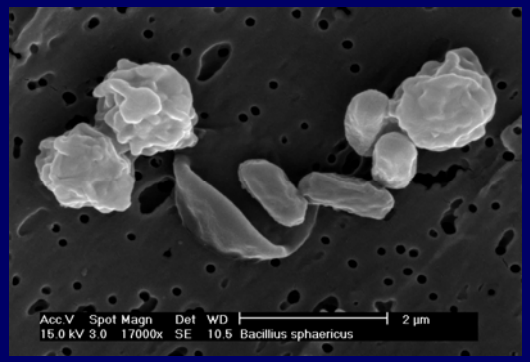


Sample Analysis at Mars (SAM) :
With integrated suite consisting of a gas chromatograph mass spectrometer, and a tunable laser spectrometer (Organic compounds)

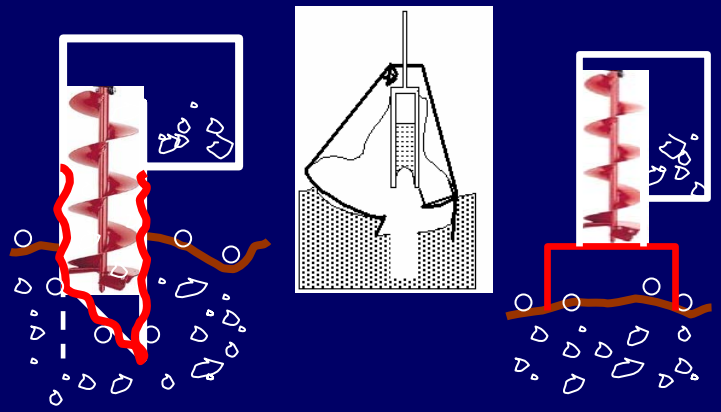


CheMin: An X-ray Diffraction/X-ray Fluorescence (XRD/XRF) instrument for definitive mineralogical analysis in the Analytical Laboratory of MSL (minerals)

Sample Return Technologies

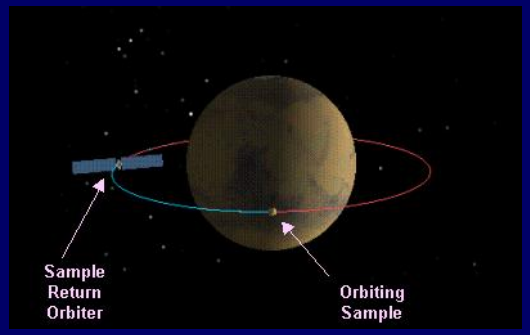


Forward and Back Planetary Protection

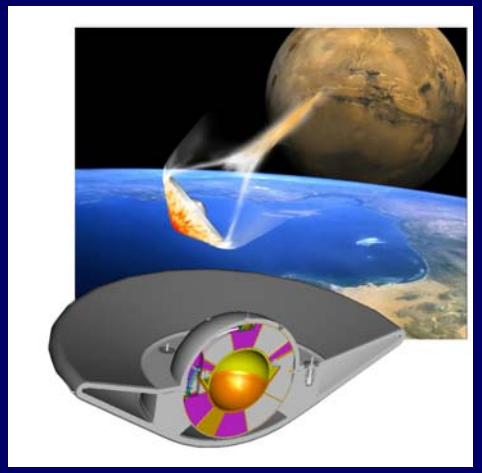


Covered sampling tool

Mars Ascent Vehicle



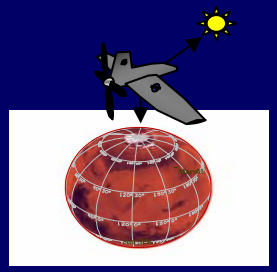
Rendezvous and Capture



Earth Entry Vehicle

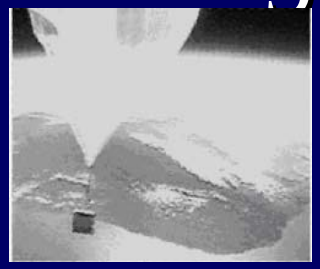
Mars Returned Sample Handling

Examples of Low Cost Mission Technologies



low-mass, low-cost avionic components in (FPGA).

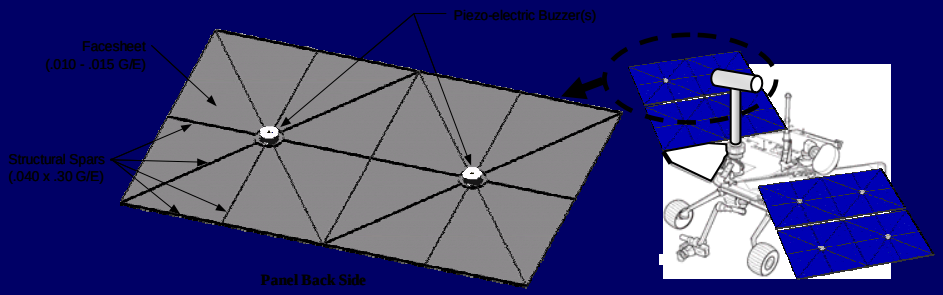
Ultralight Diaphragm Propellant Tank



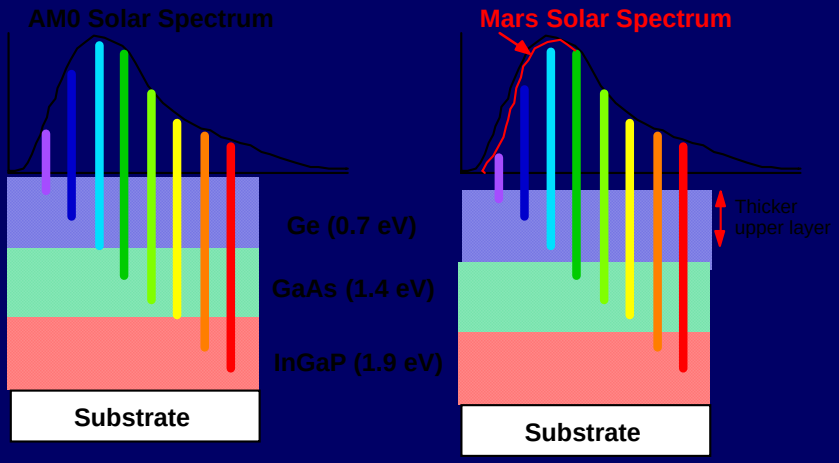
Superpressure Balloons

Montgolfiere Balloons

Mars Airplanes



Dust Removal Technologies



MARS OPTIMIZED SOLAR CELL TECHNOLOGY

New Public Website
www.marstech.jpl.nasa.gov

Jet Propulsion Laboratory
California Institute of Technology

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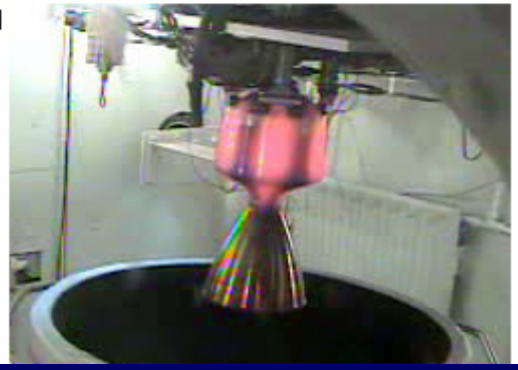
    - Mars Exploration Rover
    - Mars Reconnaissance Orbiter
    - Mars Science Laboratory
      - EDL Systems
      - Flight Software Systems
      - Long Life Systems
      - Payload Systems
      - Rover Technology

OVERVIEW

NASA is pursuing an aggressive, science-driven agenda of robotic exploration of Mars with a series of orbiters and landers. These missions carry science instruments selected to answer questions the planetary science community has posed to better characterize the planet (See Mars Exploration Program Analysis Group, MEPAG). The overarching objective is increased understanding with regard to Life, Climate, Geology, and Preparation for Human Exploration.

Many new technologies need to be developed and infused into future Mars missions, which demand the following capabilities:

- Better landing accuracy, with active hazard-detection-and-avoidance capability.
- Access to high-priority sites with terrain too complex for landing current rovers.
- Increased mobility to sample diverse geological sites and reach targets of