Technology Development for NASA Mars Missions

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Presentation Content

- Mars mission roadmaps
- Focus and Base technology programs
- Technology infusion
- Feed forward to future missions
Mars Technology Program (MTP)

- Code S determined that the Mars Exploration Program must have a strong technology component to enable increasingly more capable missions and science.
- Accordingly, the restructured program contains an average technology investment of ~ 10% over a decade.
# Mars Exploration Pathways Missions 2009 - 2020

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Search for Evidence of Past Life</td>
<td>MSL to Low Lat.</td>
<td>Scout</td>
<td><strong>Ground-Breaking MSR</strong></td>
<td>Scout</td>
<td>Astrobiology Field Lab or Deep Drill</td>
<td>Scout</td>
<td>All core missions to mid-latitudes. Mission in ‘18 driven by MSL results and budget.</td>
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<tr>
<td>Explore Hydrothermal Habitats</td>
<td>MSL to Hydrothermal Deposit</td>
<td>Scout</td>
<td><strong>Astrobiology Field Laboratory</strong></td>
<td>Scout</td>
<td>Deep Drill</td>
<td>Scout</td>
<td>All core missions sent to active or extinct hydrothermal deposits.</td>
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<tr>
<td>Search for Present Life</td>
<td>MSL to N. Pole or Active Vent</td>
<td>Scout</td>
<td>Scout</td>
<td>MSR with Rover</td>
<td>Scout</td>
<td>Deep Drill</td>
<td>Missions to modern habit. Path has highest risk.</td>
</tr>
<tr>
<td>Explore Evolution of Mars</td>
<td>MSL to Low Lat.</td>
<td>Scout</td>
<td><strong>Ground-Breaking MSR</strong></td>
<td>Aeronomy</td>
<td><strong>Network</strong></td>
<td>Scout</td>
<td>Path rests on proof that Mars was never wet.</td>
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</table>

**NOTES**
- **Network**: replacement Telecom
- **Ground-Breaking MSR**: telecom
Mars Technology Program Supports all NASA Mars Missions

- Mars Global Surveyor
- Mars Odyssey
- Mars Exploration Rovers
- Mars Reconnaissance Orbiter
- Phoenix Scout
- Mars Telesat Orbiter
- Technology Testbed Lander
- Mars Sample Return

Focused Technologies:
- MSL Focused Technology
- MRO Focused Technology
- Technology Testbed Focused Technology
- MSR Focused Technology
- Base Technology
Mars Technology Program Elements

- **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

- **Base Technology**
  - Is exploratory in nature
  - Provides seed corn for future mission technologies
  - Includes push technology development
  - Enables new types of missions
  - 100% competed via NASA NRA process
**Electra Payload:**
- Software reconfigurable radio system for near- and far-term Mars missions
- Electra will be used on all Mars missions including appropriate scout missions.
- EM delivered

**Optical Navigation Camera:**
- Lightweight, low power, high resolution navigation camera for all future Mars missions
- Instrument development and flight test validation is funded by MTP
- Protoflight unit delivery 9/04
Mars Science Laboratory (MSL, 2009)
MSL Focused Technology

**Entry, Descent, and Landing:**
- Guided entry
- Engine development
- Soft landing (Skycrane)

**Surface System Technology:**
- Increased autonomy
- Longer lived actuators
- Realistic rover simulation

**Sample Acquisition & Distribution:**
- Coring/Abraiding
- Sample acquisition/transfer
- Rock crushing
- Sample distribution
- Planetary protection
MSL Entry, Descent, and Landing Technologies

- Aeroshell
- Descent Engine
- EDL Guidance, Navigation, and Control
- EDL Modeling and Simulation
- High Flow Regulator for Descent Engine
- Subsonic Parachute*
- Phased Array Terrain Radar*
- POST-based End-to-End EDL Engineering Simulation for MSL
- Safe Landing and Descent Stage

*No longer in the mission baseline
Mars Testbed -1
(2011)

- Testbeds will be used to develop and test those technologies that will enable human missions to Mars
- NASA is currently developing requirements for these missions
- Some of the candidate technologies are:
  - Aerocapture
  - pin-point landing
  - ISRU
  - Instruments to characterize Martian environment for safety for human missions
  - Subsurface access
  - Water extraction
  - Engineering instrumentation to characterize the atmosphere
  - Mach 3 parachute
  - Mid L/D probes
Mars Sample Return (MSR, 2013, or 2016)
Mars Sample Return Mission

Scenario

Launch: Nov. 2013
Delta 4050H (Max C3 = 9.3) (inj capability = 7868 kg)

Orbiter carries lander to Mars

After 435 days at Mars, ERV departs for Earth (Nov. 2015)

Orbiter releases lander to aim-point & deflects for MOI at –1 hour.

MOI = Mars Orbit Insertion
MAV = Mars Ascent Vehicle
OS = Orbiting Sample (container)
ERV = Earth Return Vehicle
EEV = Earth Entry Vehicle

After 2 weeks of sample collection, MAV launches, releases OS

MOI, then aerobrake for 6 months, then rendezvous/capture OS

Orbiter carries lander to Mars

Sample Returned: July 2016

After 435 days at Mars, ERV departs for Earth (Nov. 2015)

ERV releases EEV at –4 hr (~Stardust)

ERV deflects away from Earth

Sample Returned: July 2016

OS captured by ERV, placed in EEV

After 435 days at Mars, ERV departs for Earth (Nov. 2015)

OS captured by ERV, placed in EEV

After 2 weeks of sample collection, MAV launches, releases OS

MOI = Mars Orbit Insertion
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After 435 days at Mars, ERV departs for Earth (Nov. 2015)
MSR Focused Technology

Forward and Back
Planetary Protection

Covered sampling tool

Mars Ascent Vehicle

Rendezvous and Capture

Earth Entry Vehicle

Mars Returned Sample Handling
Astrobiology Field Laboratory
(AFL, 2013 or 2018)

**Technology:**
- More autonomy in rover technology
- More autonomy and functionality for sample preparation and distribution

**Exploration Metrics**
- 800-1000 day landed mission
- 25 km linear traverse capability @ 0.25 km/sol (4 hours)
- Repeatable 4 (rock corer) and 25 (drill) day cycles
- 2.5 m drilling depth (3-5 holes) @ 0.3 m/sol
- 100 samples for the organic analysis/biosignature detection suite (pyrolysis and liquid phase organic extraction systems)
Base Technology

• These are “push” technologies to enable increased capability in future missions
• 100% competed
• Seven areas have been identified as high priority technology areas for Mars missions
• Currently, 87 tasks are within the Base Program
Technology Infusion

MTP’s effectiveness is measured by its success in technology infusion into Mars missions.

Factors enabling technology infusion are:

- Careful selection of technologies based on future mission needs
- Technology funding contingent upon well defined and measured performance matrices
- Technology integration/validation to demonstrate capabilities

Ten technologies were successfully infused into Mars Exploration Rover (MER) mission:

- Electra UHF proximity radio
- Optical Navigation Camera (ONC)

MRO mission will fly two new technologies:

- Electra UHF proximity radio
- Optical Navigation Camera (ONC)
<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
<th>Funding Source</th>
<th>PI/Technologist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereo Vision</td>
<td>Provides 3-D terrain maps for rovers, manipulators, and human operators</td>
<td>NASA, Caltech, DRD,</td>
<td>Larry Matthies</td>
</tr>
<tr>
<td>Long Range Science Rover</td>
<td>Provides increased traverse range of rover operations, improved traverse accuracy, landerless and distributed ground operations with a large reduction in mass</td>
<td>NASA (Code R and MTP)</td>
<td>Samad Hayati</td>
</tr>
<tr>
<td>Science Activity Planner</td>
<td>Provides downlink data visualization, science activity planning, merging of science plans from multiple scientists</td>
<td>NASA (Code R)</td>
<td>Jeff Norris</td>
</tr>
<tr>
<td>Viz - 3D Terrain</td>
<td>Enables the science team to operate a rover simulation with an interactive time of day shadow command and specification</td>
<td>NASA (MTP)</td>
<td>Chris Leger</td>
</tr>
<tr>
<td>Long Range Science Rover</td>
<td>Software and hardware system for measuring horizontal velocity during descent, Algorithm combines image feature correlation with gyroscopic attitude and radar altitude measurements.</td>
<td>NASA (Code R and MTP)</td>
<td>Larry Matthies</td>
</tr>
<tr>
<td>3D Terrain Visualization</td>
<td>Enables the Science team to operate a rover simulation with an interactive time of day shadow command and specification</td>
<td>NASA (MTP)</td>
<td>Eric Baumgartner</td>
</tr>
<tr>
<td>FIDO: Field Integrated Design and Operations Rover</td>
<td>Developed an enhanced Mars rover system design; advanced NASA capabilities for Mars exploration; demonstrated high-mission interest, integrated multiple instruments</td>
<td>NASA (MTP)</td>
<td>Paul Schenk &amp; Eric Baumgartner</td>
</tr>
<tr>
<td>Manipulator Collision Prevention Software</td>
<td>Computationally efficient algorithm for predicting and preventing collisions between manipulator and rover/terrain.</td>
<td>NASA (MTP)</td>
<td>Eric Baumgartner</td>
</tr>
<tr>
<td>Descent Image Motion Estimation System (DIMES)</td>
<td>Software and hardware system for measuring horizontal velocity during descent, Algorithm combines image feature correlation with gyroscopic attitude and radar altitude measurements.</td>
<td>NASA (Code R and MTP)</td>
<td>Larry Matthies</td>
</tr>
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<td>Parallel Telemetry Processor (PTeP)</td>
<td>Used in the MER mission to catalog database files for the Science Activity Planner</td>
<td>NASA (Code R and MTP)</td>
<td>Mark Powell</td>
</tr>
<tr>
<td>Rover Localization and Mapping</td>
<td>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.</td>
<td>NASA (MTP)</td>
<td>Ron Li</td>
</tr>
<tr>
<td>Grid-based Estimation of Surface Traversability (GESTALT)</td>
<td>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.</td>
<td>NASA (Code R and MTP)</td>
<td>Yang Chen et al.</td>
</tr>
<tr>
<td>Collaborative Information Portal (CIP)</td>
<td>An enhanced situational awareness tool to provide mission management, scientists and engineers with insight into the status of mission operations</td>
<td>NASA (Code R)</td>
<td>Joan Walton</td>
</tr>
<tr>
<td>MAPGEN and Constraint Editor</td>
<td>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</td>
<td>NASA (Code R)</td>
<td>Kanna Rajan</td>
</tr>
<tr>
<td>MERboard</td>
<td>Replaced flip charts based manual So Tree process with computer tool, capability for re-planning, calculation of mission success criteria for different planning options</td>
<td>NASA (Code R)</td>
<td>Jay Trimble</td>
</tr>
<tr>
<td>Lithium-Ion Batteries</td>
<td>Significant mass and volume savings (3-4X) compared to the SOA Ni-Cd and Ni-H2 batteries.</td>
<td>NASA (Code R and MTP), Air Force (AFRL)</td>
<td>Richard Ewell</td>
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Technology Infusion into MER
Science Activity Planner (SAP)

- SAP is the primary science operation tool for MER and is used on a daily basis
  - Developed as a ground operations software, started in 1995
  - Provides downlink data visualization, science activity planning, merging of science plans from multiple scientists
  - Public outreach version, called Maestro, along with actual Spirit and Opportunity data sets, is available for download from MER mission main web page; hundreds of thousands of public downloads in first month of the mission

- FUTURE USERS and APPLICATIONS
  - ’07 Phoenix – downlink data visualization and robotic arm command generation
  - ’09 Mars Science Laboratory – downlink data visualization and science goal specification

Winner of NASA’s best software award for FY ‘04
Technology Feed Forward to Mars Missions
Entry, Descent, and Landing Example

- **MRO (’05)**
  Optical Navigation Camera is used to perform Optical Navigation - Demonstrates improved entry accuracy

- **MSL (’09)**
  Guided Entry technology improves landing accuracy by an order of magnitude. Skycrane technology enables robust landing of larger payloads than MER rover

- **Testbed Mission (’11)**
  Terrain based navigation and optimized descent in conjunction with optical navigation and guided entry demonstrates 100 meter pin-point landing capability

- **MSR (’13)**
  Above technologies provide ability to return samples from very specific regions of Mars or samples cached by MSL
New MTP Website
(http://marstech.jpl.nasa.gov)

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 interest.
- Longer-lived surface systems to allow for year-long surface exploration.
- Technologies to access the subsurface and acquire samples for in situ analysis.
- New and improved science instruments.
- In situ sample acquisition, preparation, and distribution systems.
- Increased autonomy to enable increased science return.
- Planetary protection techniques.
- Sample-return technologies for bringing samples to Earth for analysis.

The Mars Technology Program (MTP) is responsible for technology-development...