Technology Development for NASA Mars Missions

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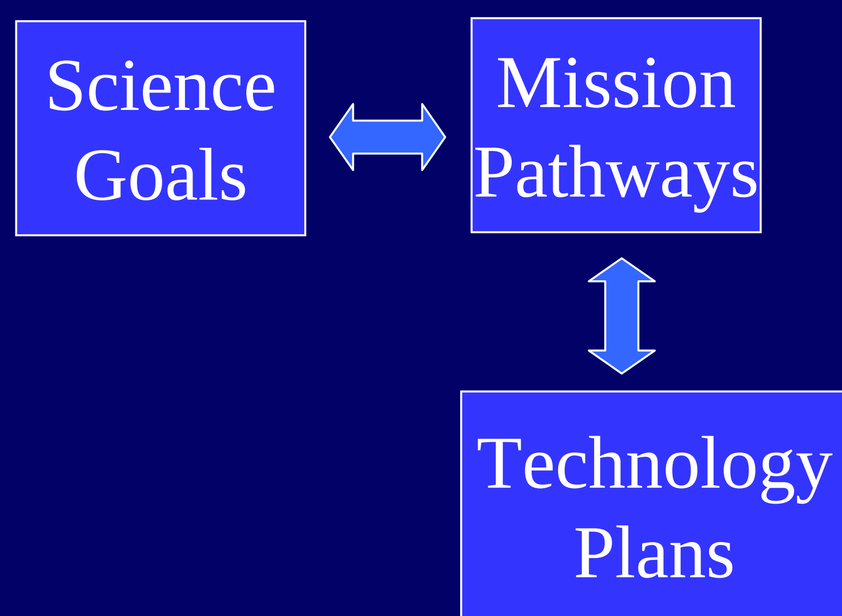
Presentation Content

- *Mars mission roadmaps*
- *Focus and Base technology programs*
- *Technology infusion*
- *Feed forward to future missions*

Mars Technology Program (MTP)

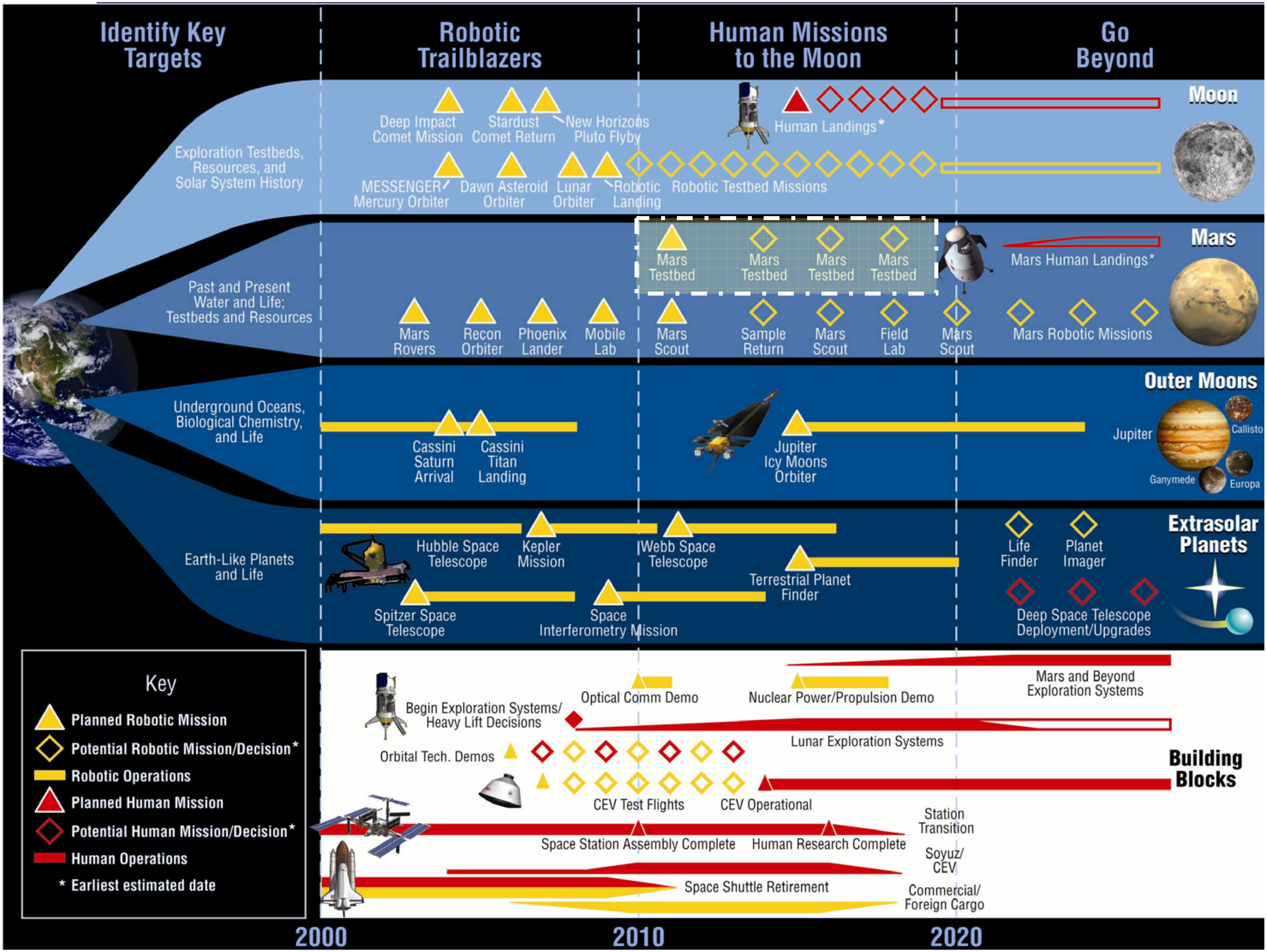
- *Code S determined that the Mars Exploration Program must have a strong technology component to enable increasingly more capable missions and science*
- *Accordingly the restructured program contains an average technology investment of ~ 10% over a decade*

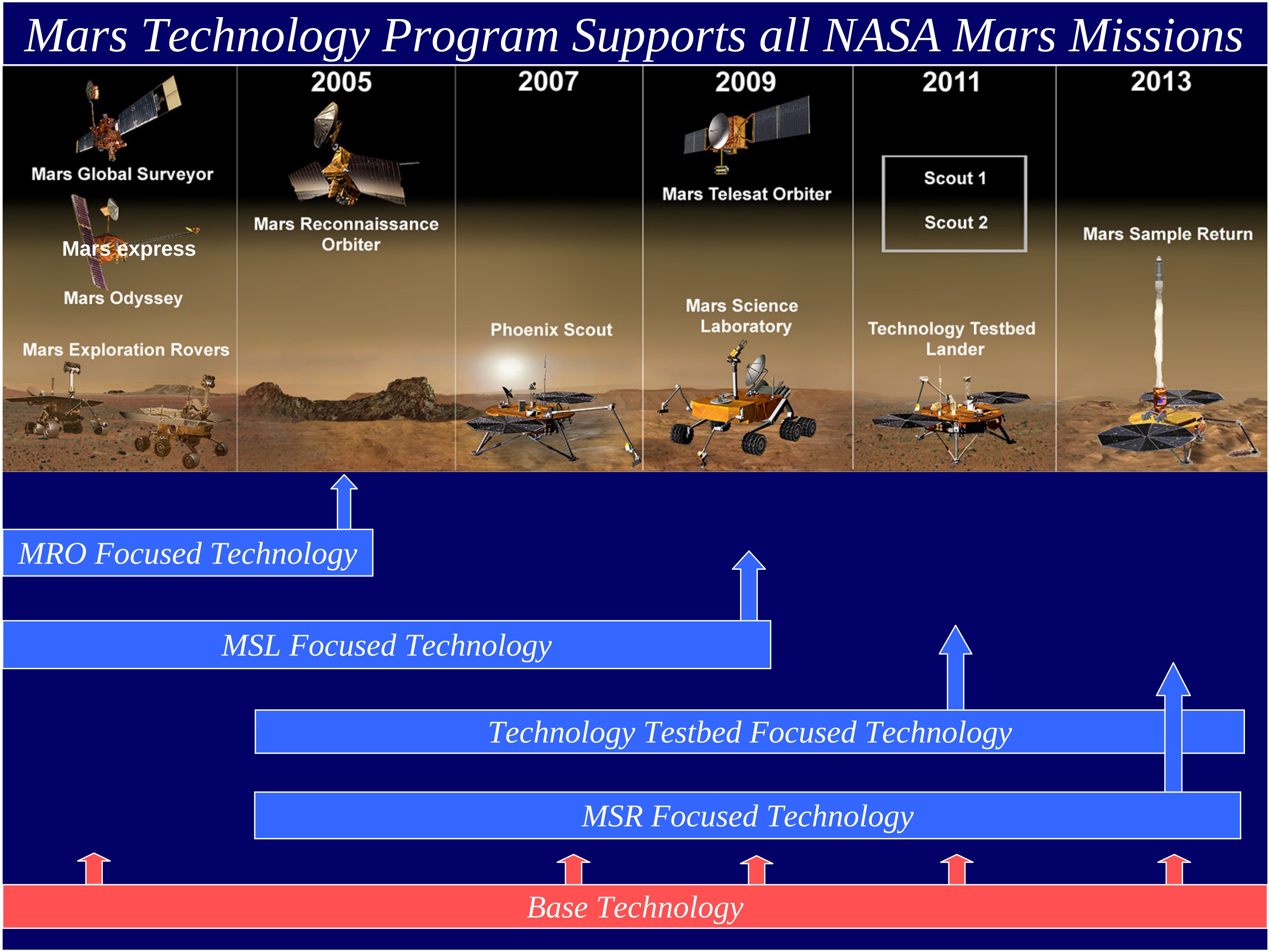


Mars Exploration Pathways Missions 2009 - 2020

Pathway	2009	2011	2013	2016	2018	2020	NOTES
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 →


Identify Key Targets
Robotic Trailblazers
Human Missions to the Moon
Go Beyond
Moon
Deep Impact Comet Mission
Stardust Comet Return
New Horizons Pluto Flyby
Human Landings*
Exploration Testbeds, Resources, and Solar System History
MESSENGER Mercury Orbiter
Dawn Asteroid Orbiter
Lunar Orbiter
Robotic Landing
Robotic Testbed Missions
Mars
Mars Testbed
Mars Testbed
Mars Testbed
Mars Testbed
Mars Human Landings*
Past and Present Water and Life; Testbeds and Resources
Mars Rovers
Recon Orbiter
Phoenix Lander
Mobile Lab
Mars Scout
Sample Return
Mars Scout
Field Lab
Mars Scout
Mars Robotic Missions
Outer Moons
Underground Oceans, Biological Chemistry, and Life
Cassini Saturn Arrival
Cassini Titan Landing
Jupiter Icy Moons Orbiter
Jupiter
Callisto
Ganymede
Europa
Extrasolar Planets
Earth-Like Planets and Life
Hubble Space Telescope
Kepler Mission
Webb Space Telescope
Terrestrial Planet Finder
Spitzer Space Telescope
Space Interferometry Mission
Life Finder
Planet Imager
Deep Space Telescope Deployment/Upgrades
Key
Planned Robotic Mission
Potential Robotic Mission/Decision*
Robotic Operations
Planned Human Mission
Potential Human Mission/Decision*
Human Operations
* Earliest estimated date
Optical Comm Demo
Nuclear Power/Propulsion Demo
Mars and Beyond Exploration Systems
Begin Exploration Systems/ Heavy Lift Decisions
Lunar Exploration Systems
Orbital Tech. Demos
Building Blocks
CEV Test Flights
CEV Operational
Station Transition
Space Station Assembly Complete
Human Research Complete
Soyuz/ CEV
Space Shuttle Retirement
Commercial/ Foreign Cargo
2000
2010
2020



Mars Technology Program Supports all NASA Mars Missions
2005
2007
2009
2011
2013
Mars Global Surveyor
Mars express
Mars Odyssey
Mars Exploration Rovers
Mars Reconnaissance Orbiter
Phoenix Scout
Mars Telesat Orbiter
Mars Science Laboratory
Scout 1
Scout 2
Technology Testbed Lander
Mars Sample Return
MRO Focused Technology
MSL Focused Technology
Technology Testbed Focused Technology
MSR Focused Technology
Base Technology

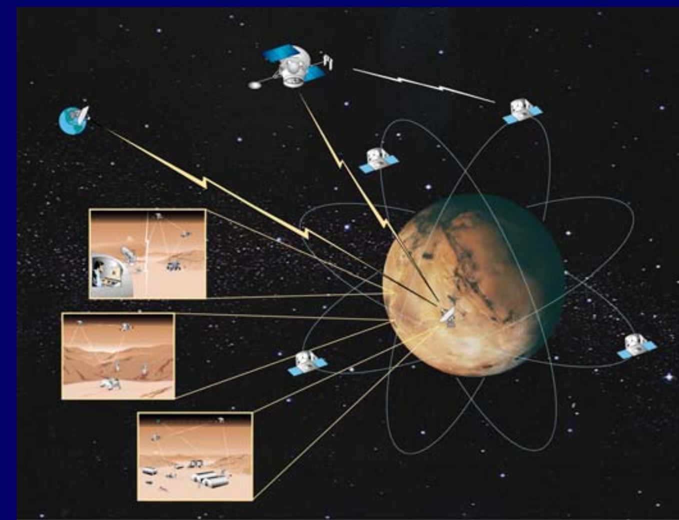
Mars Technology Program Elements

- ***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*

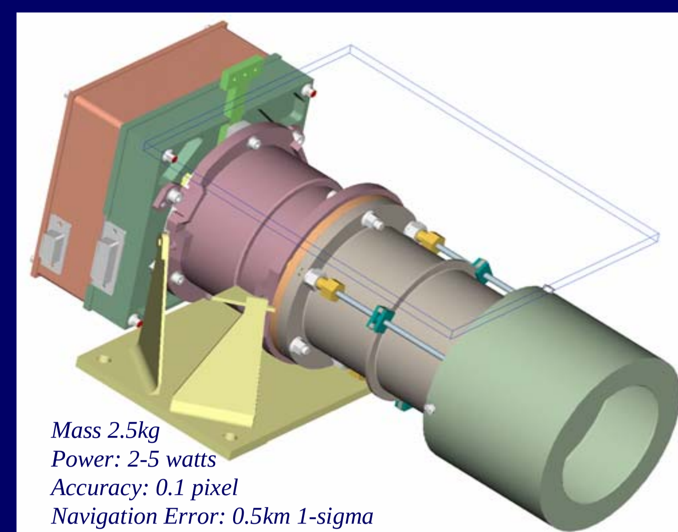
- ***Base Technology***
  - *Is exploratory in nature*
  - *Provides seed corn for future mission technologies*
  - *Includes push technology development*
  - *Enables new types of missions*
  - *100% competed via NASA NRA process*

MRO Focused Technology

- *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*

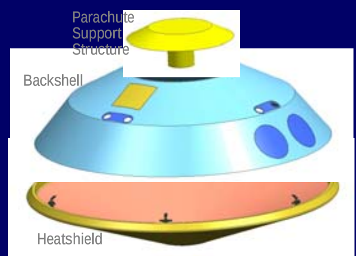


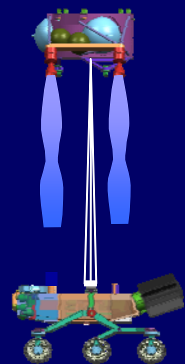
- *Optical Navigation Camera:*
  - *Lightweight, low power, high resolution navigation camera for all future Mars missions*
  - *Instrument development and flight test validation is funded by MTP*
  - *Protoflight unit delivery 9/04*

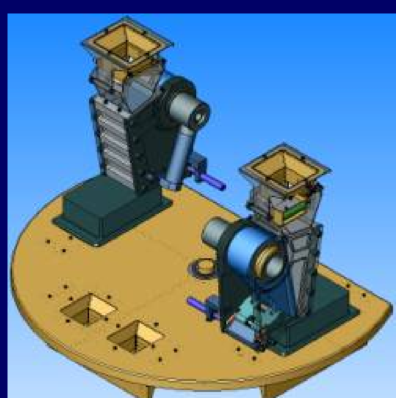


Mars Science Laboratory (MSL, 2009)

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/Abrading*
- *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*

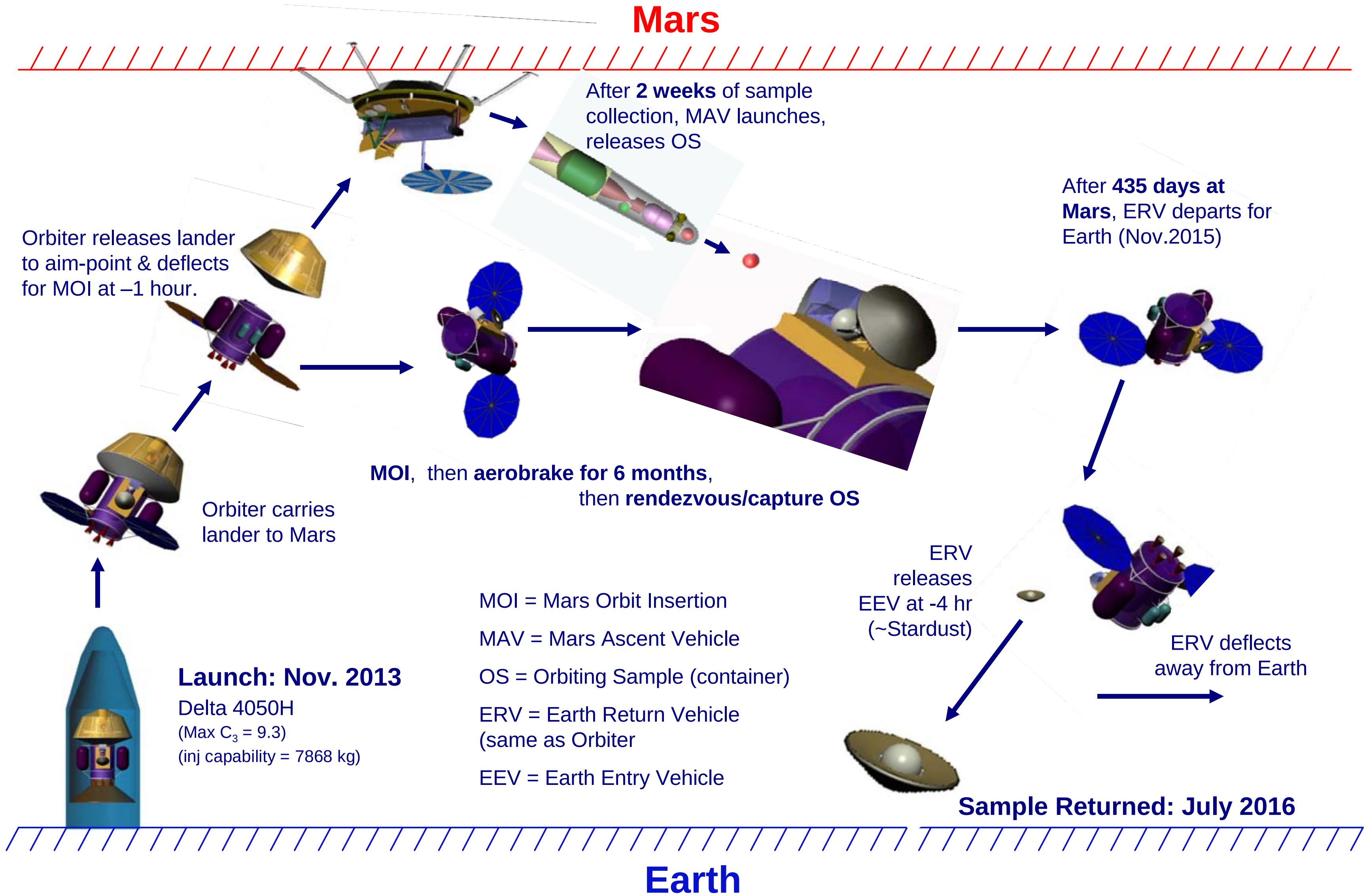
** No longer in the mission baseline*

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*

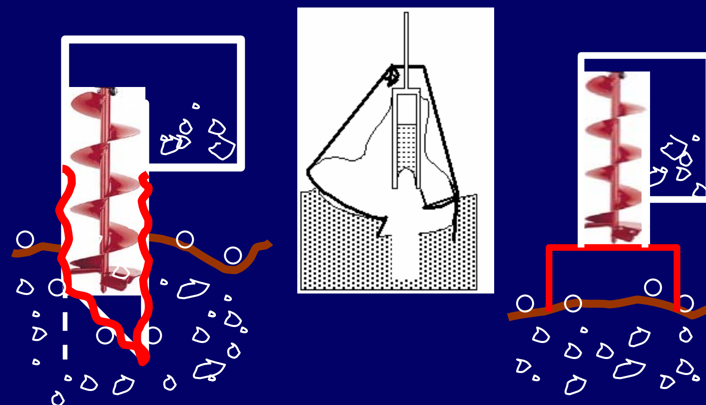
Mars Sample Return (MSR, 2013, or 2016)

Mars Sample Return Mission Scenario



MSR Focused Technology

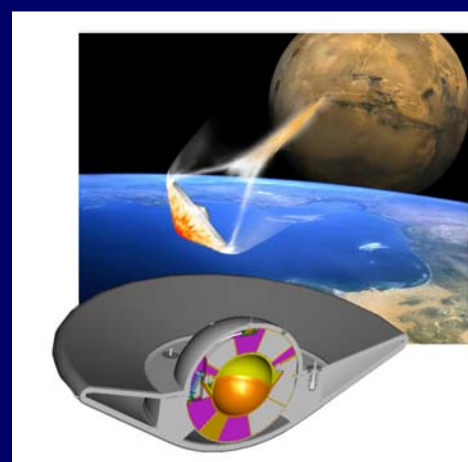
Forward and Back Planetary Protection



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*

Proximity Telecom/Navigation

Subsurface Access

Advance EDL

Rover Technology

Planetary Protection

Low Cost Mission Technologies

Mars Science Instruments

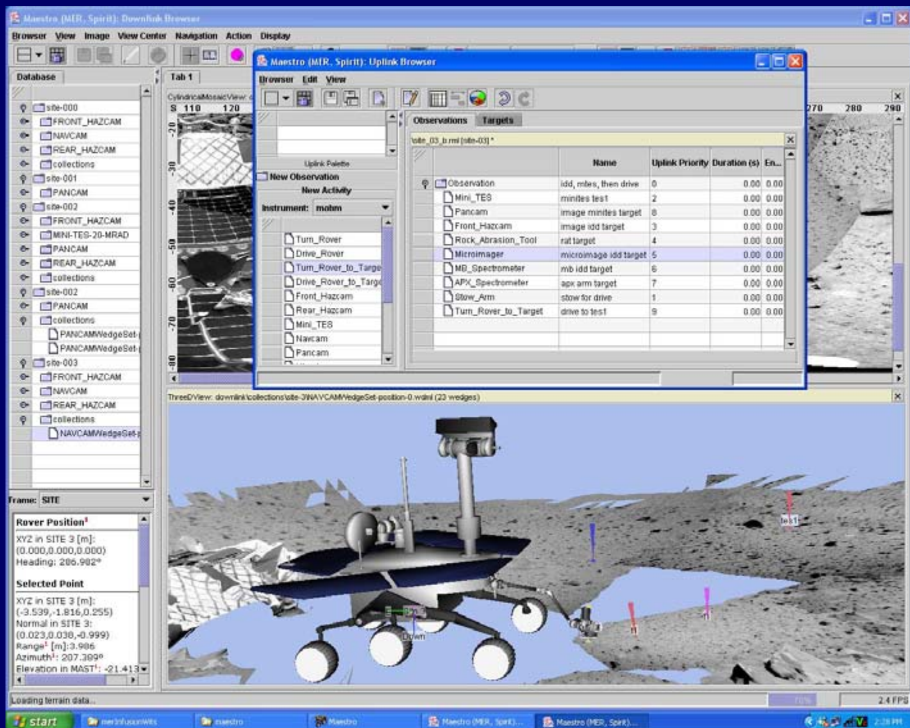
Technology Infusion

- *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*
- *MRO mission will fly two new technologies:*
  - *Electra UHF proximity radio*
  - *Optical Navigation Camera (ONC)*

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

Technology Infusion into MER Science Activity Planner (SAP)



- *SAP is the primary science operation tool for MER and is used on 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*

- ***Winner of NASA's best software award for FY '04***

- *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*

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)