

National Aeronautics and Space Administration



Mars Exploration Program Status

Science Subcommittee of NAC

15 July 2009



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Mars Exploration Program, Director



Agenda

- **MSL–A Short History**
- **MSL Status and Path Forward**



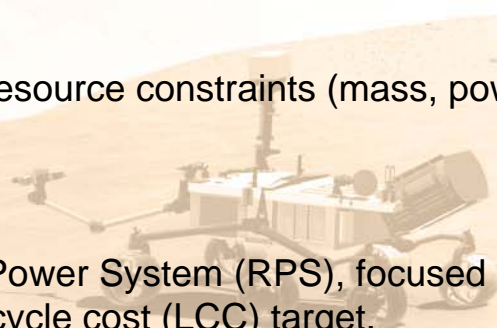
The background of the slide is a photograph of a Mars rover on a desert landscape. The rover is positioned in the lower right quadrant, facing left. The terrain is a vast, flat, orange-brown desert with subtle ripples in the sand. In the top left corner, there is a small, semi-transparent image of the planet Mars. The overall color palette is warm and monochromatic, dominated by shades of orange and brown.

MSL

A Short History



MSL Development Timeline

- Science Definition Team (2001)
 - Mars Smart Lander was envisioned as a technology mission in preparation for Mars Sample Return
 - Surface science focus had both biological and environmental goals.
 - Decadal Survey: “*New Frontiers in the Solar System: An Integrated Exploration Strategy*”, National Research Council (2003)
 - “The Mars Exploration Program (MEP) projects development of a Mars Science Laboratory^b (MSL), presumably a moderate-cost mission, for launch in 2009. Its instrument payload has been stated only in the most general terms. The mission may be important, indeed essential, as a technology-demonstration precursor mission to MSR.”
 - ^bAlso known as the Mars Smart Lander or the Mobile Science Laboratory.
 - Categorized as a medium-class mission, defined as costing <\$650M (launch vehicle assumed included).
 - Project Science Integration Team (April 2003)
 - Refined and focused results from the SDT.
 - Defined a strawman payload for a Mars habitability mission.
 - Mission Concept Review (October 2003)
 - Basis for Formulation Authorization, and established preliminary resource constraints (mass, power, volume) for instruments.
 - Formulation Authorization (November 2003)
 - Development-only cost target \$865M not including Radioisotope Power System (RPS), focused technology, and launch vehicle. The FAD did not establish a life-cycle cost (LCC) target.
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MSL Development History

- Announcement of Opportunity (April 2004)
 - “The overall science objective of the MSL mission is to explore and quantitatively assess a potential habitat on Mars.”
 - Solicited instruments and investigations within established science goals and mission constraints.
- Delta-Mission Concept Review (December 2004)
 - Instruments selections announced.
 - Development-only cost estimate \$895M including accommodation of RPS, but still not including RPS development, focused technology, or launch vehicle.
 - Life Cycle Cost (LCC) estimate of \$1,439M included above items.
- Focused Technology Development (FY03-05)
 - Total of \$84.2M
 - Significant investments in throttled engines, high-flow regulator, precision guided entry, sample acquisition (corer), sample processing (rock crusher), mobility and navigation software, planetary protection, and organic cleanliness.
- Preliminary Non-Advocate Review/Initial Confirmation (February 2006)
 - Approved to start the preliminary design, Phase B.
 - LCC estimate: \$1,543M included increases for NASA Full Cost Accounting
 - Top project challenges: Entry, Descent, & Landing (EDL) design; Sample Acquisition & Processing development; and Analytical Instrument development.





MSL Development History

- Preliminary Design Review/Non-Advocate Review/Confirmation (August 2006)
 - Approved to start the detailed design, Phase C.
 - Established the project baseline for Congressional reporting.
 - LCC estimate \$1,634M
 - New estimates for Phase E operations considering MER experience.
 - Launch vehicle contract price included.
 - Increased reserves to 70% confidence level (~\$100M split between project and program—program funding later deleted)
- Critical Design Review (June 2007)
 - Significant design changes
 - Redundant avionics added in the rover
 - Mars Entry, Descent, and Landing Instrumentation (MEDLI) added (ESMD-funded)
 - Corer replaced by a powdering drill, rock crusher deleted.
 - Deleted Tunable Laser Spectrometer (subsequently added back by JPL IRAD funding) due to cost overruns
 - Deleted X-ray fluorescence from Chemistry-Mineralogy (CheMin) instrument.
 - Increased descent stage propellant tank capacity to improve margins.
 - Design problems became evident
 - Heatshield material, SLA-561, test failure. Design change to Phenolic-Impregnated Carbon Ablater (PICA).
 - Actuator titanium gear-dry lube test failures. Design change to stainless steel gears and wet lube.
 - Mechanism design delays impacting delivery schedules, causing schedule compression.
 - Project within budget, but SRB estimates that a reserve augmentation of \$50M to \$100M may be required.
- Descoping effort to reduce cost provided \$36M of requested \$75M (November 2007)
- Program progress reviews conducted by NASA HQ in May and October 2008
 - Included increasing requests from JPL for additional funding

MSL Current History

- Decision to slip to 2011 Mars launch opportunity (December 2008)
 - Schedule no longer viable for 2009 LRD
- Replan first-order cost estimates for a 2011 launch (February 2009)
 - No additional funding required in FY09 (\$223M)
 - FY'10—FY'14 budget increase in the range of \$400M
- Replan presented to DPMC and APMC (June 2009)
 - Additional resource needs predicted by several different cost models to restore reserves to adequate levels for ATLO
- Submit MSL Cost and Schedule Analysis Report (“Breach Report”) to Congress by the end of July '09
 - Development = \$1,631M (68% development overrun); LCC = \$2,286M
 - Report states that additional reserves may be needed (\$15M to \$115M range)
- HQ/SMD continuously track progress through weekly meetings and metrics (resolution of technical issues, reserve burn rates, PFR closure rates, workforce profile, etc.)
- DPMC reviews of SAM and overall project progress recently scheduled for July and Sept, respectively
- Conduct a “Readiness to Proceed” Review in November 2009—actuators, avionics, power, etc.
 - Project must stabilize these key technical issues for meaningful CTG estimates
 - Include updated cost estimate
- After “Readiness to Proceed” Review, assess the need for added funding reserves
 - APMC approval required
- Bring back to PSS and NAC-SC for review after DPMC and/or Readiness to Proceed Review

The image features a Mars rover on a desert landscape. The rover is positioned in the lower right quadrant, facing left. The background consists of rolling sand dunes under a hazy, orange sky. In the top left corner, there is a small, semi-transparent globe of the Earth. The overall color palette is dominated by warm, earthy tones of orange, tan, and brown.

MSL Current Status

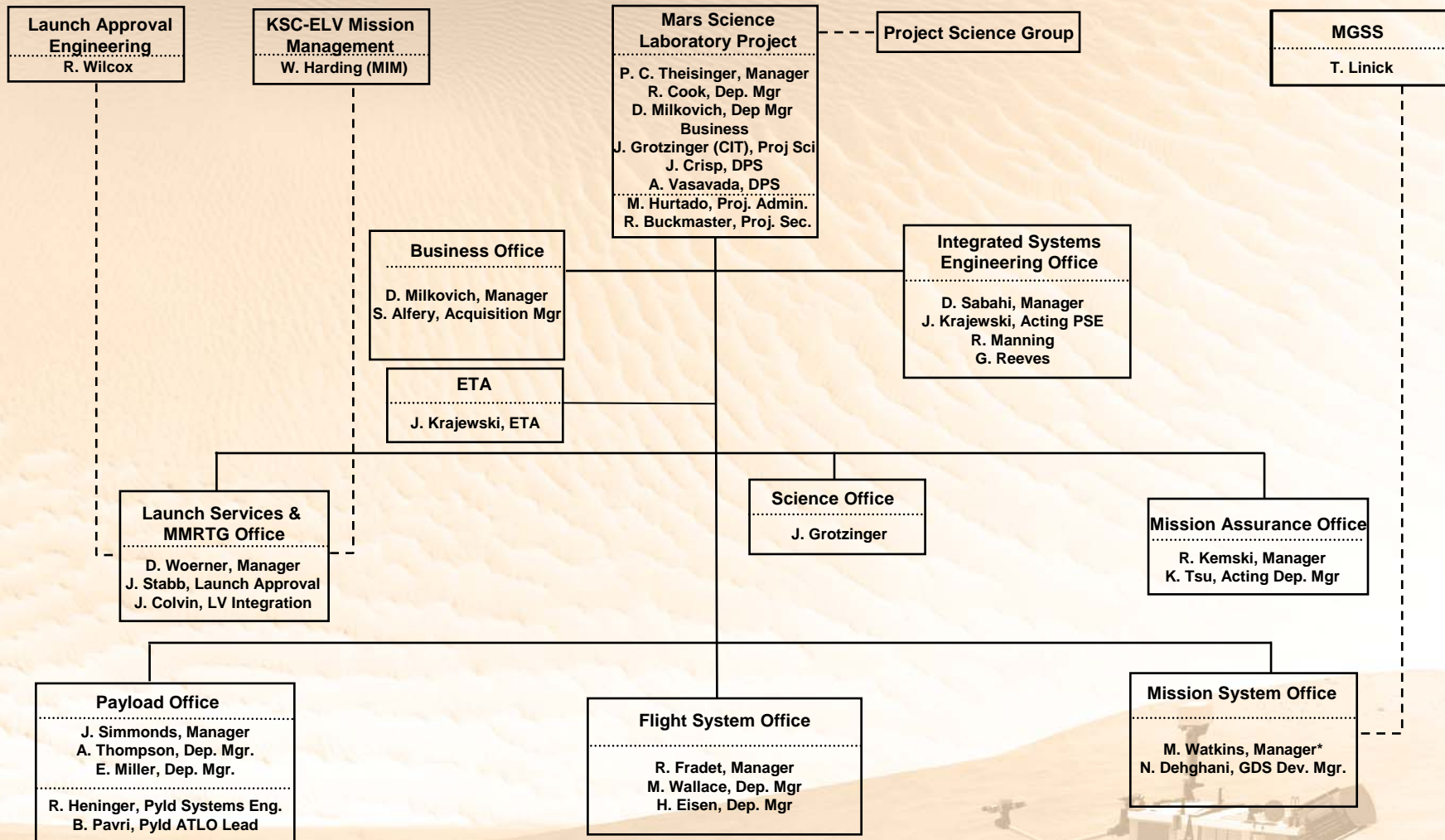


Recent Activities

- After the decision to slip the MSL launch to 2011:
 - MSL status presented to PSS in December 2008
 - Presented interim report to SMD in February, completed the re-plan activity, and started baselining the new implementation plan in March.
 - SRB Re-Baseline Review was held May 13 – 15, 2009, and the JPL CMC on May 27, 2009
- SMD DPMC on June 11, 2009 approved MSL to proceed to APMC
- APMC on June 18, 2009 approved MSL to continue, knowing that:
 - Current reserves are low (~13%) and budget challenges remain
 - Additional reserves may be necessary based on several different cost estimate models



New MSL Project Organization



* Additional Duty

Project Overview and Status

- Key technical and management issues that delayed the 2009 launch are being addressed
 - System and Subsystem design assessment and closure
 - Broad based design assessment performed

Fault Protection and redundancy	Actuator Recovery Team
Grounding, EMI/EMC	Surface Energy Augmentation
E-Bridle bridge	Actuators
Motion Control	Surface resources
Sample Transfer	CHEMCAM TEC
Functionality description, flight S/W, V&V	

- Actuators
 - Focusing on:
 - Anomaly resolution (thermal backdrive torque, bi-stability)
 - Life test completion
 - Flight Unit Production
 - Project initiated an Actuator Evaluation and Recovery Task in March
 - “Path to flyability”--Analyses and tests that would permit flying existing Aeroflex WSA and LPHTA actuators
 - As an insurance policy, initiated a study of the feasibility of alternate supplier



Project Overview and Status - 2

- Avionics
 - Design Finalization, including resolution of open design issues, maturing of FPGA designs, and resolving Problem Failure Reports (PFR's)
 - Major progress in completion of test infrastructure and maturing of FPGA designs.
 - Rover Computer (RCE) #101 PFR diagnosis proceeding acceptably, including repeat of environmental testing
 - Start of hardware rework and deliveries scheduled for later in FY.
- FSW development and V&V implementation planning
 - Four month S/W development schedule; personnel assignments, including margin, in place
 - FSW capabilities and deliveries synchronized with ATLO needs,
 - Testbed schedule for V&V generated and synchronized with FSW deliveries – substantial margin exists.



Overall Integration Status

	SN	Elect Int	Funct Test	Mech Int
ROVER				
AVS RCE-A	FM 101			
AVS RCE-B				
AVS RPAM-A	FM 102			
AVS RPAM-B	FM 103			
AVS RMCA				
AVS RPA	FM 101			
AVS RPF A				
AVS RBAU	NF 001			
RPS MMRTG	Qual			
GNC NavCams-A [pair]				
GNC NavCams-B [pair]				
GNC HazCams, front-A [pair]				
GNC HazCams, rear-A [pair]				
GNC HazCams, rear-B [pair]				
GNC RIMU-A (LN200)	FM 404448			
GNC RIMU-B (LN200)	FM 404471			
MECH RVR Chassis	FM 101	N/A	N/A	
MECH RVR Heat Exchanger	FM 004	N/A	N/A	
MECH Mobility				
MECH Remote Sensing Mast				
MECH Robotic Arm Assembly				
MECH PADS Drill				
MECH CHIMRA				
MECH SAM Inlet Covers Assembly				
MECH Chemin Inlet Cover Assembly				
MECH Pyro Circuits				
PLD MSSS DEA	EM-MARDI			
PLD MastCam Heads				
PLD MAHLI Camera Head				
PLD MARDI Camera Head	FM 00001			
PLD ChemCam				
PLD APXS				
PLD CheMin				
PLD SAM				
PLD RAD				
PLD DAN				
PLD REMS				
PLD Cal Targets				
TEL RVR X-band	Numerous			
TEL High Gain Antenna System				
TEL UHF-A (Electra)	EM001			
TEL UHF-B (Electra)				
THM RIPA (Rover IPA)	FS* 001			
THM Rover Shunt Radiator (RSR)				
THM Thermal Circuits	N/A			

	SN	Elect Int	Funct Test	Mech Int
DESCENT STAGE				
AVS DPAM-A	FM 104			
AVS DPAM-B	FM 105			
AVS DPA	FM 101			
AVS BLRA	EM 101			
AVS DMCA				
AVS PWTB				
AVS PYTB				
GNC DIMU				
GNC TDS	FM 002			
MECH Pyro Circuits	N/A			
MECH BUD				
MECH DS Structure		N/A	N/A	
PROP Descent RCS	Various			
PROP Descent MLE	Various			
TEL DS X-Band	Numerous			
THM Thermal Circuits	N/A			
CRUISE STAGE				
AVS CPAM-A	FM 106			
AVS CPAM-B	FM 107			
AVS CPA	FM 101			
AVS CSA	Numerous			
GNC DSE-A	FM 003			
GNC DSH-A (x4)	Numerous			
GNC DSE-B	FM 004			
GNC DSH-B (x4)	Numerous			
GNC SSA	FM 009			
MECH CS Structure		N/A	N/A	
PROP Cruise RCS				
THM CIPA (Cruise IPA)	Test 001			
THM Cruise Shunt Radiator (CSR)				
THM Thermal Circuits	N/A			
AEROSHELL				
Mech Backshell		N/A	N/A	
Mech Heatshield		N/A	N/A	
MEDLI MEDLI	FM 006			





New Technical Issues

- Rover power system design does not meet present mission requirements, requiring additional battery capacity, and possibly solar array
 - Increased energy requirements to keep actuators above safe operating temperature
 - Almost double energy requirement to operate/conduct SAM instrument science/sample analysis scenarios
- The SAM instrument has not completed its environmental qualification program, and the wide range pump has not demonstrated life qualification (hours of operation and start/stop) requirements.



Budget Status and Impacts

- MSL overall budget needs remain around \$400M at PMC, but reserves were unacceptably low (~13% cost-to-go)
- Expect a requirement for additional resources to restore reserves to adequate levels (\$15-115M), predicted by several different cost models
 - Amount to be determined this calendar year after more progress has made on technical issues
- Impacts must be contained in Planetary Division
 - The Mars Program will cover non-Mars rephasings to cover MSL in FY10-11 as needed
- Impacts to cover low- to mid-range budget needs, in order:
 - Reduce or eliminate Mars Program APA in FY10 and FY11
 - Reduce US portion of Mars-16/18/20 missions
 - Reduce Discovery future and New Frontiers mission lines (no impact to current schedules)
- Impacts increase to cover mid- to upper-range budget needs, in order:
 - Further reduce US portion of Mars-16/18/20 missions
 - Delay LADEE and ILN missions
 - Delay New Frontiers 3 phase B selection



The Path Forward

- MSL Project's Baseline readjusted w/additional \$400M in President's 2010 budget
- Submit MSL Project Cost and Schedule Analysis Report ("Breach Report") to Congress by the end of July
 - Development = \$1,631M (68% development overrun); LCC = \$2,286M
 - Report states that additional reserves may be needed (\$15M to \$115M range)
- HQ/SMD will continue tracking progress through weekly meetings and metrics (resolution of technical issues, reserve burn rates, PFR closure rates, workforce profile, etc.)
- Conduct targeted reviews with the AA
 - SAM—late July
 - Progress report on key technical and budget issues—September
- Conduct a "Readiness to Proceed" Review in November 2009
 - Project must stabilize these key technical issues for meaningful CTG estimates
 - Include updated cost estimate
 - Assess the need for added reserve funding
 - APMC approval
- Review with NAC-SC and PSS as the above activities proceed

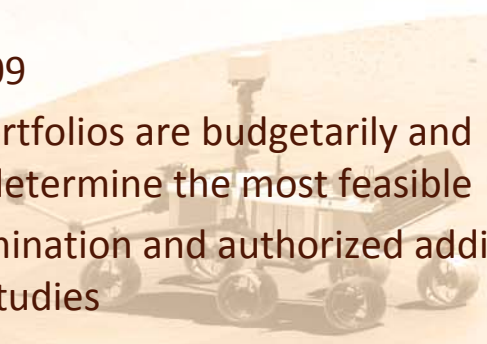


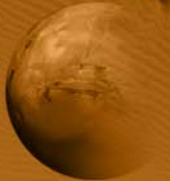
A wide-angle photograph of a Mars landscape. The foreground and middle ground are dominated by rolling sand dunes with fine, wavy ripples. The sky is a pale, hazy orange. In the bottom right corner, a Mars rover is parked on the sand. In the top left corner, a small, dark, spherical object, possibly a meteorite or a small planet, is visible against the sky.

Backup Future Mars Program Planning



ESA and NASA are Forming a Joint Mars Exploration Initiative

- Joint studies began the first week of January, 2009
 - Joint ESA-NASA Engineering Working Group (JEWG)
 - Developed cooperative architecture options for shared mission responsibilities
 - Joint Instrument Definition Team (JIDT)
 - Defined minimum investigation capabilities for orbital science, to focus EWG studies
 - Focused on orbital measurements: Trace Gas Detection and mapping, aerosols, surface mapping
 - Joint Executive Board
 - JEWG and JIDT reported to an Executive Board made up of senior ESA and NASA Managers
 - NASA: McCuiston, Meyer
 - ESA: Coradini, Ellwood
 - In-depth analyses and meetings occurred, January –June 2009
 - The Board's determined that multiple options for mission portfolios are budgetarily and technically feasible, but additional analyses are required to determine the most feasible
 - June 2009 ESA-NASA Bi-lateral meeting endorsed the determination and authorized additional studies encompassing a broader range of mission portfolio studies
- 



Study Principles Established for an ESA/NASA Collaboration

NASA Principles

ESA Principles

- | | | |
|--|---|---|
| 1. Partnership must address NASA/MEP/NRC, as well as ESA, science goals | → | 4. ESA science priority for ExoMars—Exobiology |
| 2. NASA-ESA establish a strategic partnership for Mars exploration in 2016/18/20 and beyond, with immediate focus on ExoMars and 2016-18 | → | 1. ESA-NASA establish a strategic partnership for Mars exploration in 2016/18/20 and beyond, with immediate focus on ExoMars and 2016-18 |
| <i>3. Plans must be budgetarily and technically realistic</i> | | |
| <i>3a. Develop two plans: what we can afford to do, and the "best" partnership</i> | | |
| 4. Shared science and science efforts on all missions, including sharing science data | → | 2. Shared science and science efforts on all missions, including sharing science data |
| 5. Substantial collaboration will create dependencies, and must build on both party's strengths and strategic interests | → | 5. ESA technology tenants for ExoMars-EDL, rover, drilling, sample preparation and distribution |
| 6. Missions should be segmented with clean interfaces (ITAR requirements must be complied with as well) | → | 7. Missions should be segmented with clean interfaces |
| 7. US does EDL in at least one opportunity of 2016-18 (NASA core competency) | } | <i>6. Lead agency to be defined for each mission. For ExoMars (2016), ESA would like to be the lead agency</i> |
| 8. US has a surface system in at least one opportunity of 2016-18 (NASA core competency) | | |
| 9. US provides an ELV in no more than one opportunity of 2016-18 | | |
| 10. Shared opportunities require shared credit for outreach, public relations and national/organizational prestige | → | 9. Shared opportunities require shared credit for outreach, public relations and national/organizational prestige |
| 11. Missions must show identifiable progress toward Mars Sample Return | → | 3. Missions must show identifiable progress toward Mars Sample Return |
| | | <i>8. Need a communications data relay orbiter for 2016 opportunity which could be used as a science opportunity as a secondary objective</i> |

NOTE: Red/italics items do not have a specific cross-reference

Leading Elements for Future Architectures



Trace Gas & Telecomm Orbiter

- Detect a suite of trace gases with high sensitivity (ppt)
- Characterize their time/space variability & infer sources
- Replenish orbiter infrastructure support for the Program



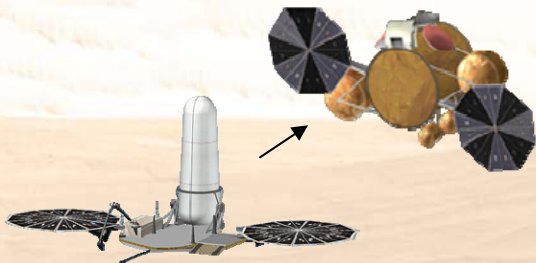
Rovers

- Explore Mars habitability in the context of diverse aqueous environments provided by a new site
- Begin process of preparing samples for return



Geophysical Surface Science

- Determine the planet's internal structure and composition, including its core, crust and mantle
- Collect simultaneous network meteorological data on timescales ranging from minutes to days to seasons



Mars Sample Return

- Make a major advance in understanding Mars, from both geochemical and astrobiological perspectives, by the detailed analysis conducted on carefully selected samples of Mars returned to Earth



Joint ESA-NASA Mars Exploration Initiative

- The Initiative's mission portfolio will span 2016 through 2020 opportunities, with goal of Mars Sample Return in the 2020's
- Follow-up on the recent methane discovery, and emplacement of long-term telecommunications relay capability, are important (a NASA-priority)
- Completion of the ExoMars mission is important (an ESA-priority)
- Studies begin this week for 2016-2020 mission queue:
 - Astrobiology is the overall scientific focus
 - Geological, geophysical and geochemical sciences are a high priority
 - Surface systems are expected to predominate mission types
 - Sample return technologies will factor prominently in mission design, such as
 - Precision sample handling
 - Sample preparation and caching
 - Precision landing
- A new series of intense studies are being initiated under these premises
 - Results timed to provide more detail on mission queue to the Decadal's Mars Panel in September, and the ESA Council Meeting in October