National Aeronautics and Space Administration

Mars Exploration Program Status Briefing to the Decadal Survey Committee

6 July 2009

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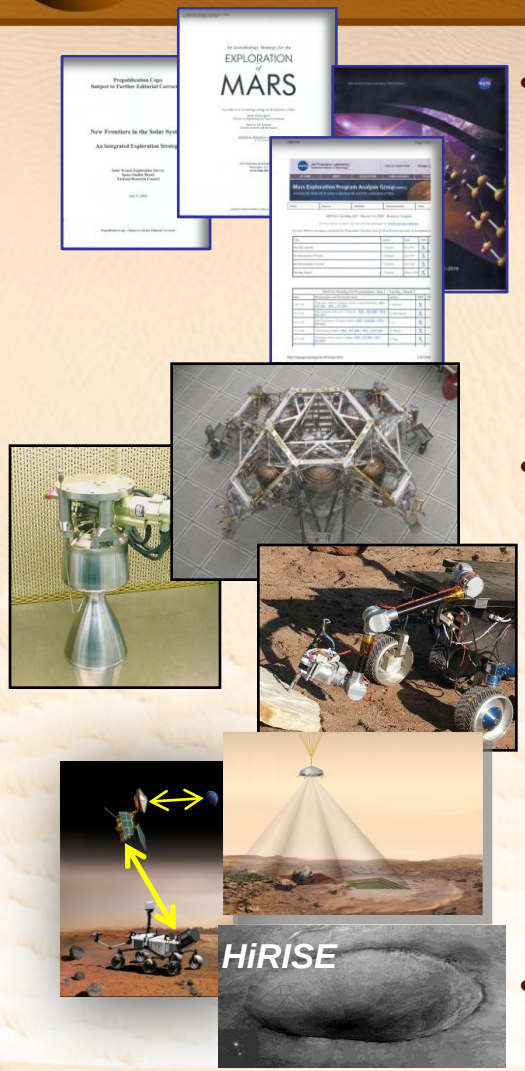
Mars Exploration Program, Director

Agenda

- A Little History, then Program Accomplishments/Status
- Science Highlights
- Science Goals and Progress on ’02 Decadal Survey Themes
- Future Program Plans

Fundamentals of the Mars Exploration Program



- **Approach challenging goals in a step-by-step manner**
  - Pursue high-priority science objectives
  - Exploit accessibility of Mars (a combination of proximity and manageable environment) to reduce scientific, technical, and cost profile risks
  - Provide opportunities to respond to new discoveries
  - Enable cost-effective development of required technologies
- **Use mix of flight platforms to reduce risk and increase science**
  - Adapted to each mission's environment and purpose
    - Orbiters provide global reconnaissance; landers provide ground truth
  - Leverage capabilities to augment science and reduce risk
    - Orbiter relay of lander data
    - Site reconnaissance and certification for safety
    - Critical event coverage
    - Complementary science payload
    - Operations support
- **Provide opportunities for international collaboration at the flight and flight subsystem (in addition to payload) level**

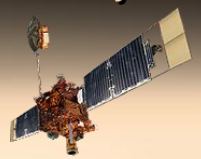
Integrated Program Approach Leads to Greater Scientific Progress

Mars Exploration Program Accomplishments/Status

Year of Launch

1996

Mars Global Surveyor

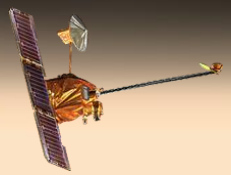


Mars Pathfinder

- Global topography
- Extended layering
- Magnetic crustal zones
- Ionosphere
- Atmospheric profiling
- Relay

2001

Mars Odyssey



- Elemental abundances
- Water ice in top meter of crust
- Atmospheric dust monitoring
- Aqueous minerals
- Relay

2003

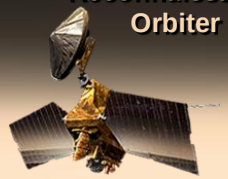
Opportunity

Spirit

- Exploring different environments on opposite sides of Mars
- Diverse effects of surface water and ground water

2005

Mars Reconnaissance Orbiter



- Aqueous minerals, clays, compositional stratigraphy
- Surface texture & surface change
- Ice detection and cap profiling
- Atmospheric monitoring
- Site certification
- Relay

2007

Phoenix

- In situ ice detection
- Surface material properties and composition (e.g., perchlorates)
- Atmospheric phenomena (e.g., ice fall)

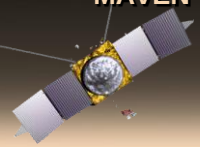
2011

Curiosity

In Development

2013

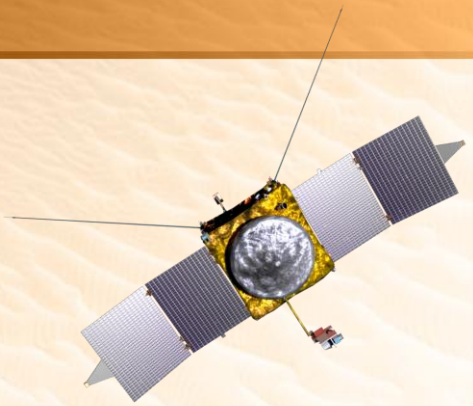
MAVEN

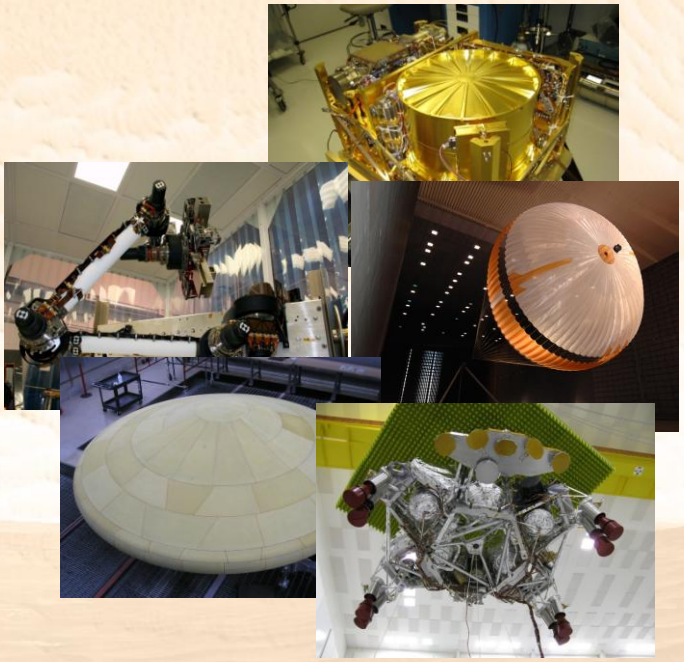


Status of Curiosity and MAVEN

Mars Atmosphere and Volatile EvolutioN (MAVEN)

- Second Mars Scout selection (Bruce Jakosky, PI) slotted for 2013 launch
  - Partnership between U. Colorado, GSFC, LMSS
- High –priority NAS aeronomy mission--Characterize atmosphere response to solar forcing & quantify loss to space
- In risk-reduction phase awaiting restart of Phase B activity
  - System requirements assessment in August 2009
- Will carry Electra package for relay for future landers/rovers





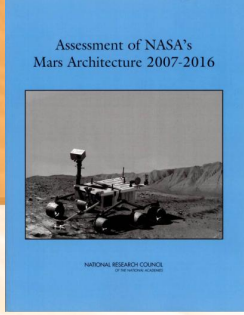
Mars Sceince Laboratory Mission; Curiosity Rover

- In Dec'08, launch delayed from 2009 to 2011
- Cruise & Descent Stages near completion: some rework in progress
- Key technical subsystem development to-go:
  - Avionics, including flight software
  - Actuators
- Schedule highlights
  - FY09 - Risk Reduction/Design Completion
  - FY10 - Delivery & Test
    - Complete remaining hardware builds
    - Start Environmental Test Program
  - FY11 - Test & Margin
    - Complete Environmental Test Program
    - Complete ATLO ~ 2 ½ months prior to earliest launch
    - KSC Operations
- All key science capabilities retained; e.g., organics detection, mineralogy, morphologic and textural imaging, roving range

Mars Science Highlights

- **Mars crust has exposed surface materials that were formed in all major periods of history.**
  - *This includes an ancient crust whose counterpart on Earth disappeared long ago.*
- **Impacts have played a major role in Mars history.**
  - The north-south hemispheric dichotomy may be due to an early impact that formed the Solar System's largest crater.
- **A major change occurred in the Martian climate and environment early in its history with water activity decreasing over time.**
  - Some water activity extended into later geologic periods (Hesperian and even Amazonian).
  - Internal processes may have played an important role, as reflected in the loss of the global magnetic field.
- **There was a diversity of water-related environments (in terms of duration, acidity, etc.) early in Mars history which are accessible today.**
  - These have formed and preserved physical records of climate change and planetary evolution.
  - *Some of these have the potential to have preserved evidence of ancient life.*
- **Water has been redistributed on Mars in recent geologic times (I.e., last few million years).**
  - North polar residual ice cap is rhythmically layered throughout and is geologically young.
  - Remnant ice deposits, insulated today by debris cover, are found outside the polar regions.
- **Mars remains a dynamic planet today.**
  - Impacts still occur; gullies still form
  - Short-lived trace gases are generated by subsurface processes (geochemical or biochemical?)

Today's Mars Exploration Program Science Goals & Drivers



Solar System Exploration Decadal Survey

Solar System Themes

- *The First Billion Years of Solar System History*
- *Volatiles and Organics: The Stuff of Life*
- *The Origin and Evolution of Habitable Worlds*
- *Processes: How Planetary Systems Work*

Themes for Mars: 2007-2016

- Mars as a Potential Abode of Life
- Water, Atmosphere & Climate on Mars
- Structure and Evolution of Mars

- *Mars Science Laboratory*
- *Mars Aeronomy*
- *Mars Landed Network*
- *Mars Sample Return*

Mars Exploration Program

LIFE

CLIMATE

GEOLOGY

Prepare for Human Exploration

Follow the Water

MEPAG: Goals, Objectives & Investigations

MEP Missions for 2005-2013

Reconnaissance
- *ODY, MRO, MAVEN*

Ground Truth
- *MER, PHX, Curiosity*

Missions build capability and knowledge for sample return

Progress on SSE Decadal Survey Science Goals

MEP has made the following progress despite significant implementation challenges.

- **Mars Sample Return -- *Major Progress***
  - ✓ Returned data have reinforced the need to return samples to Earth for detailed and repeated geological, climatological and biological analyses
  - ✓ Identified several kinds of water-related environments on Mars
  - ✓ Identified potentially habitable environments, some possibly able to preserve biosignatures
  - ✓ Developed the MSL ("Skycrane") delivery system which can be the basis during the next decade (or more) for landing sample caching and sample return flight systems
  - – Plans to follow with a system to prepare retrievable cache (now the subject of a MEPAG analysis group); further technology work being planned into follow-on missions

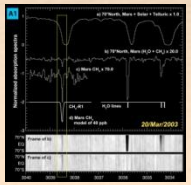
- **Mars Aeronomy -- *Major Progress***
  - ✓ MAVEN Mars Scout -- Will characterize upper atmosphere response to solar inputs and characterize mechanisms for atmospheric loss to space
  - – Trace Gas Orbiter -- Inventory and mapping of lower atmosphere trace gases; in study for 2016

- **Habitability (Mars as an abode of life) -- *Major Progress***
  - ✓ Identified several kinds of water-related environments on Mars; placed in global context
  - ✓ Identified potentially habitable environments from orbital data; placed in regional context
  - \+ *Curiosity* will investigate the habitability of one of these environments in detail.
  - – May follow with *Curiosity* Mid-Range Rover to new site
  - – Cooperative with ESA on ExoMars could provide related science

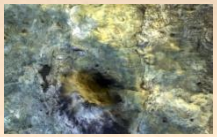
- **Mars Network -- *Little Progress***
  - – Still in planning stage

Mars Exploration Program
Science Goals & Drivers for the Next Decade

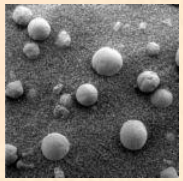
Methane



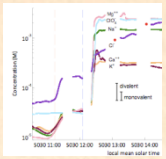
Martian Surface Diversity



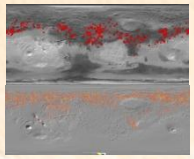
Water, Water, Water



Perchlorate



Salt Deposit



Prepare for Human Exploration

Seek Signs of Life

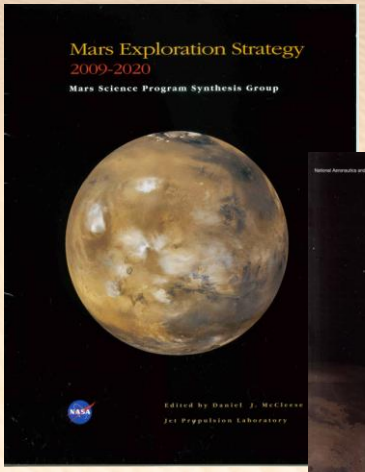
- Understand Trace Gas Origin: Detection, Characterization, Localization
- Habitability in Diverse Martian Environments
- Martian Interior Structure/Composition
- Analyses of Returned Martian Sample

Program Planning—Where to from Here?

2000: Program established; first complete architecture published in ~2003

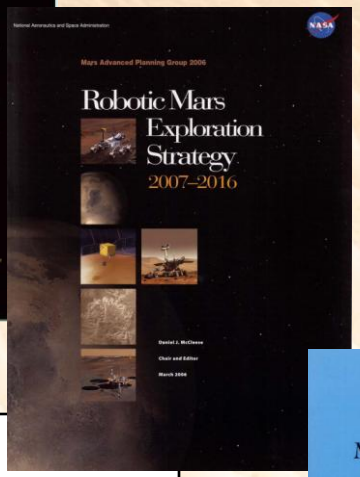
2005-06: major budget cuts required a new course for the next decade; vetted through the NRC/Space Studies Board

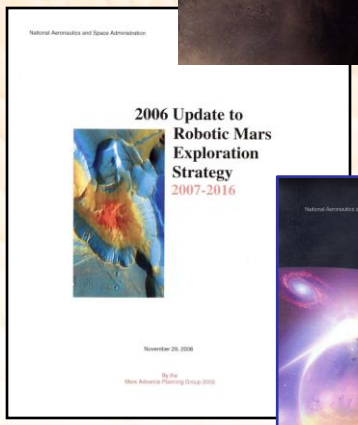
2007: NRC report endorsed sample return as a high-priority astrobiology and geochemical mission

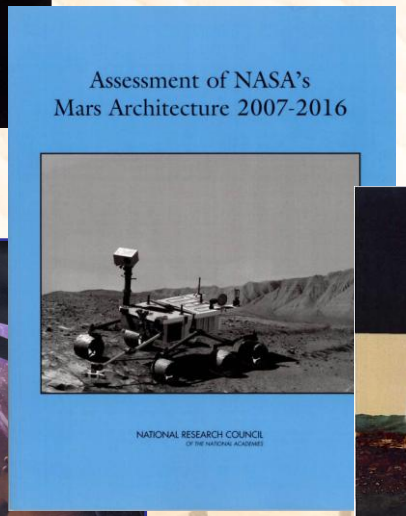


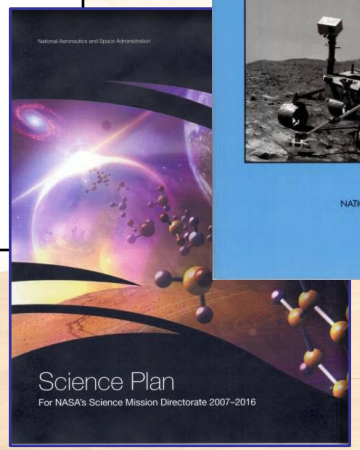
2002-2003

2005-2006

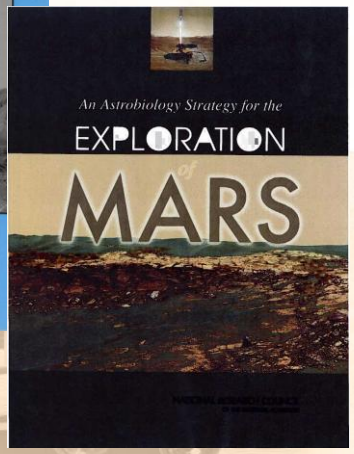








2006



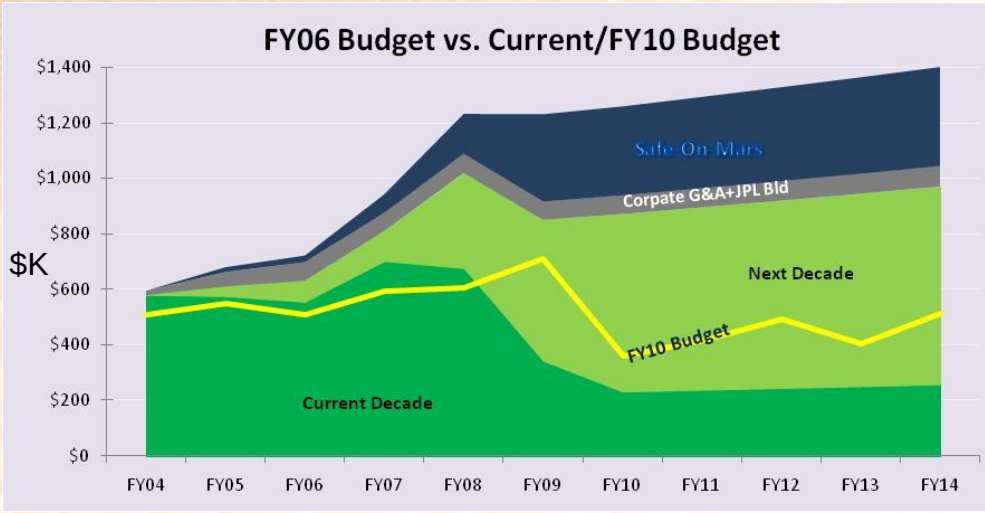
2007

2009: Another round of budget cuts and another reassessment

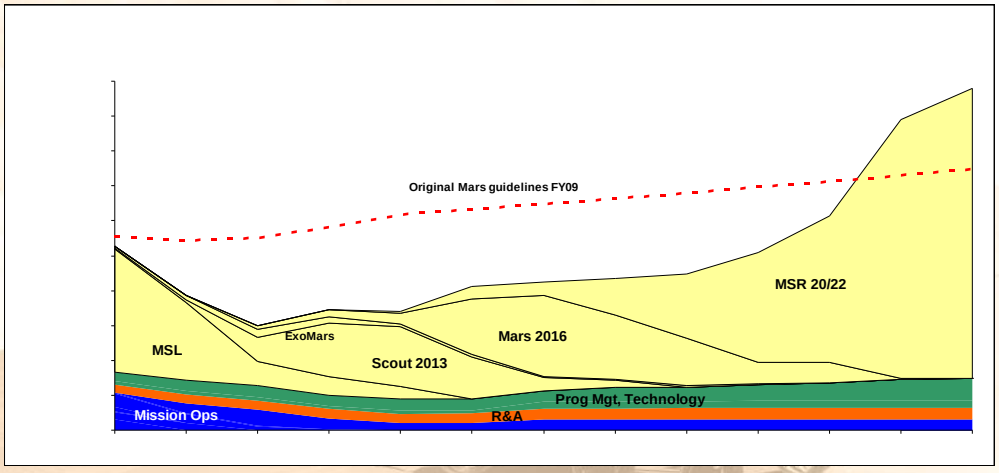
- Mars Architecture Tiger Teams (MATT-1,2&3)
- Mars Architecture Review Team (MART I&II)
- MSO Science Definition Team (2008, 2009)
- MEPAG Science Analysis Groups:
  - Next Decade SAG
  - Mars Strategic Science SAG
  - Mars Mid-Range Rover SAG
  - Mars Network Science SAG

Finding the Means to Address Challenging Goals

- ***Current Impediments to Exploring Mars and the Solar System***
  - Launch vehicle cost growth
  - Reduction of Mars Program (and Planetary Division) by >50% since 2005
  - Are flagships really affordable?



- ***Solution?***
  - NASA and ESA have similar science goals—can international partnering achieve the resources needed to do the highest priority science?



Study Principles Established for an ESA/NASA Collaboration

NASA Principles

1. Partnership must address NASA/MEP/NRC, as well as ESA, science goals
2. NASA-ESA establish a strategic partnership for Mars exploration in 2016/18/20 and beyond, with immediate focus on ExoMars and 2016-18

3. Plans must be budgetarily and technically realistic
3a. Develop two plans: what we can afford to do, and the "best" partnership

4. 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
6. Missions should be segmented with clean interfaces (ITAR requirements must be complied with as well)
7. US does EDL in at least one opportunity of 2016-18 (NASA core competency)
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
11. Missions must show identifiable progress toward Mars Sample Return

ESA Principles

4. ESA science priority for ExoMars—Exobiology
1. ESA-NASA establish a strategic partnership for Mars exploration in 2016/18/20 and beyond, with immediate focus on ExoMars and 2016-18
2. Shared science and science efforts on all missions, including sharing science data
5. ESA technology tenants for ExoMars-EDL, rover, drilling, sample preparation and distribution
7. Missions should be segmented with clean interfaces

6. Lead agency to be defined for each mission. For ExoMars (2016), ESA would like to be the lead agency

9. Shared opportunities require shared credit for outreach, public relations and national/organizational prestige
3. Missions must show identifiable progress toward Mars Sample Return

8. Need a communications data relay orbiter for 2016 opportunity which could be used as a science opportunity as a secondary objective

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

Joint ESA-NASA Studies: Structure & Results

- 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: McCuistion, 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

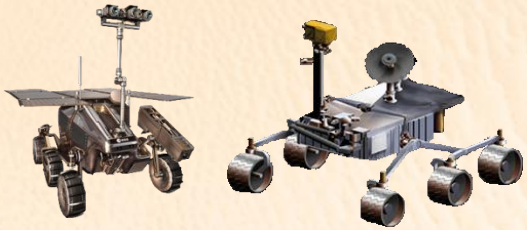
Joint ESA-NASA Mars Exploration Initiative Being Established

- 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

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

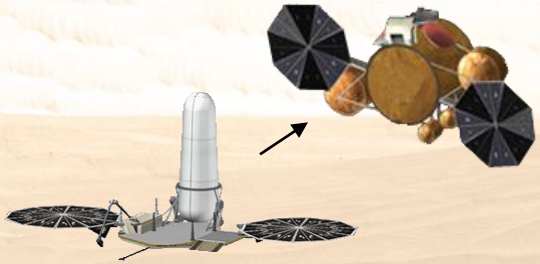


Rovers

- 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

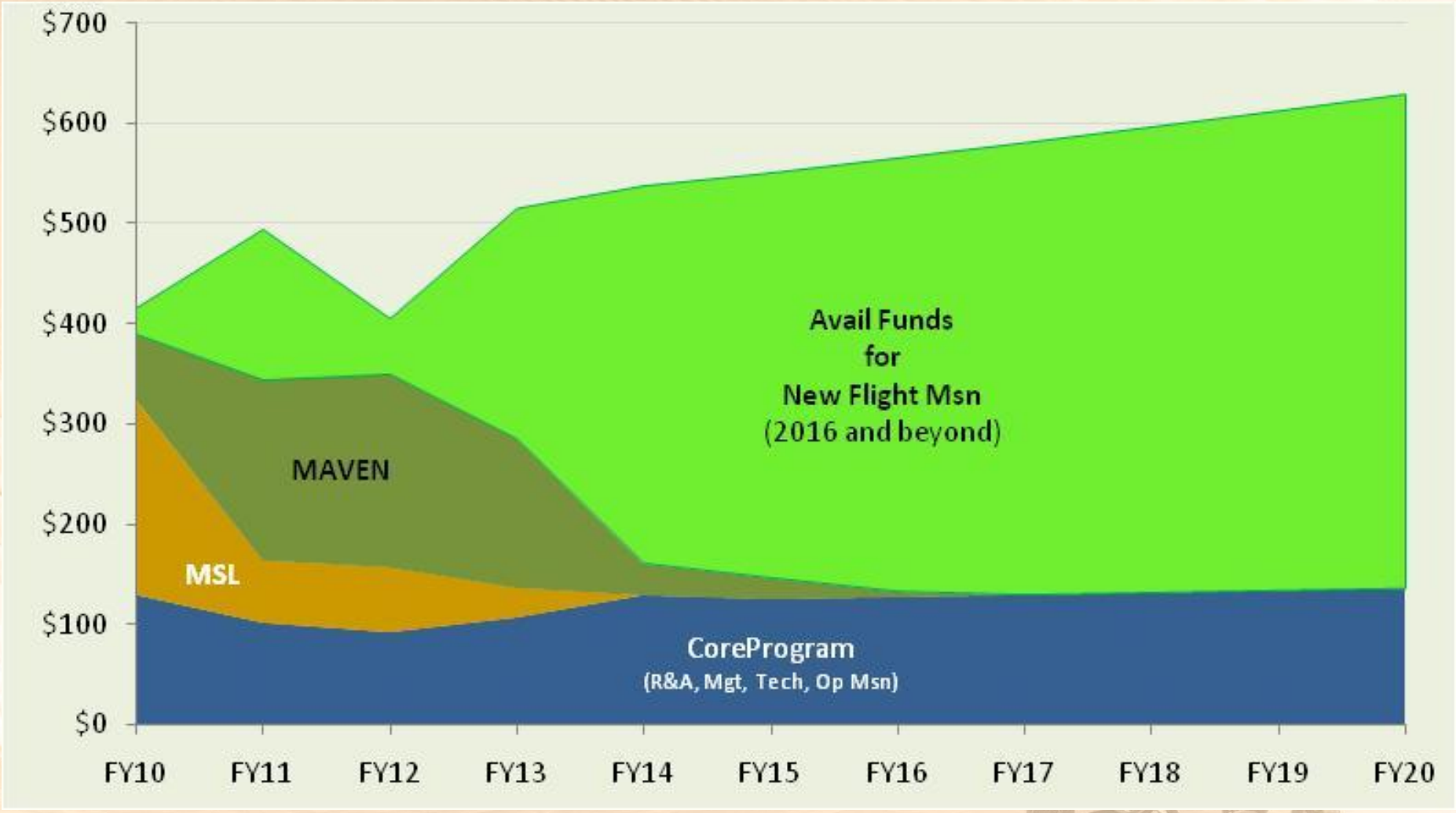


Mars Sample Return

- 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

Funds Available for Future Mars Missions

President's FY10 Budget



The Next Decade of Exploring Mars: Seeking the Signs of Life

- Mars Exploration Program is responsive to:
  - Priorities for Solar System Exploration
  - Discoveries made by missions within the Program
  - Shifting budget landscape
  - Opportunities to collaborate
- Mars science is evolving:
  - From finding pervasive evidence of water
  - To seeking the signs of life
- A joint ESA-NASA Initiative is vital to accomplishing an astrobiologically-intensive investigation of Mars, as recommended by the National Academies, MEPAG, and Mars Exploration Program Architecture Review Team (MART)