MATT-2

Seeking Habitable Environments

Science Perspectives for Candidate Mars Mission Architectures 2016-2026

Mars Architecture Tiger Team (MATT)

P. R. Christensen, Chair

June 16, 2008

Final Report

Purpose of the MATT-2 Study

Propose a Mars exploration architecture(s) that would optimize the science return within fiscal and programmatic constraints.

The report should include a discussion answering four questions:

1. Is the proposed MSR the highest priority for the Mars science community, assuming the cost constraint listed below?
   - $550M/yr (2009 $)
2. Given that the 2016 opportunity would be too early for the launch of either of two elements of the proposed MSR, what should be the 2016 mission?
3. Could the proposed MSR be split between more than two flight elements to reduce peak costs in any fiscal year?
4. What would be the architecture if there is no sample return in the foreseeable future?

Other suggestions and items for consideration are listed in the back-up slides

Starting Point: MSS-SAG Summary

(MSS-SAG Report, Murchie et al., 2008)

- **The MEP is on the cusp of major revelations about Mars' past and present habitability, and whether life ever existed on Mars**
- **A well-planned program got us here**
- **The next steps are exploring past and present habitable environments**
- **Continued measurements with existing assets would prepare for future landed missions to investigate past habitable environments**
- **An MSR would be the most important of the landed missions, but understanding the diversity of past wet environments would take several more landed missions**
- **Prior to an MSR, the proposed MSO mission focusing on trace gas and climatologic investigations would provide highly complementary (and perhaps paradigm-altering) results on present habitability**

Goals for the Next Decade

- **The MEP has "followed the water" and discovered a diverse suite of water-related features and environments.**
  - There are unanswered questions about each of these environments that MER showed can be addressed with *in situ* measurements
  - There are also unanswered questions about present habitability, especially whether trace gases are a signature of present habitable environments
  - There remain major questions about the state of the interior and the history of tectonic, volcanic, aqueous processes that are highly relevant to habitable environments
- **The focus on future missions should be "seeking habitable environments" of the past and present, including the "how, when and why" of environmental change. Key measurements would be:**
  - Rock and mineral textures, grain- to outcrop-scale mineralogy, and elemental abundances & gradients in different classes of aqueous deposits
  - Abundances and spatial/temporal variations of trace gases and isotopes in the present atmosphere
  - Nature and history of the interior and of processes shaping the surface
- **The most comprehensive measurements of water-formed deposits would be made on returned samples**

Expected Outcomes

The candidate MEP mission architectures developed by MATT for 2013-2026 would strive to achieve the following objectives:

- ❑ Return carefully selected and well-documented samples from a potentially habitable environment to Earth for detailed analysis
- ❑ Explore a diversity of surface environments using rovers with sample acquisition, analysis, and caching capabilities
- ❑ Determine the composition and structure of the current atmosphere
- ❑ Investigate the deep interior using a network of landed geophysical experiments
- ❑ Investigate the physics, chemistry, and dynamics of the upper atmosphere, the effects of solar wind and radiation, and the escape of volatiles to space
- ❑ Respond to new discoveries through focused missions

MATT Activities

- **MATT* focused on the theme "Seeking Habitable Environments" for the 2016-2026 time period**
  - This theme provides near-term focus for the general effort to understand "Mars as a System" for a planet where life may have developed
- **MATT proceeded as follows:**
  - **Distilled mission science goals for 2016-2026.** These goals:
    - Are consistent with the "Seeking Habitable Environments" theme
    - Are responsive to the NRC/Decadal Survey Priorities
    - Address MEPAG Goals, Objectives and Investigations
  - **Identified mission "building blocks" that address the mission science goals for the decade**
    - Would include: MSR, MPR, MSO, NET, Scout
      - Mission "blocks" identified at a high level--see following slides
  - **Developed a set of guidelines to determine mission sequences**
    - Mission sequences considered in order of when MSR Lander might launch
      - MSR launches are considered high priority science, but are budget driven

**MATT membership is given in the back-up slide*

Mission Science Goals for 2016-2026

Candidate Mission Science Goals for MEP in 2016-2026:

- **Advance understanding of Mars planetary evolution, climate history and habitability through the return of carefully selected samples to Earth from well characterized sites**
  - Samples to be chosen must address a variety of Mars science disciplines
  - Would require contemporary instrumentation for sample collection and/or precursor characterization and caching (i.e., more than a "grab sample")
  - If sample return were to be delayed for budgetary reasons, explore new site based on recent discoveries
- **Advance understanding of Mars planetary evolution, climate history and habitability through in situ investigation of the planet's surface and interior**
  - Network science to characterize the Mars interior and surface processes
  - Explore more of the diverse nature of Mars surface composition, morphology and history by going to new sites, possibly back to high latitudes
- **Advance understanding of atmospheric composition, climatology and seasonal surface processes**
  - Characterize atmospheric composition, circulation and exchange with the surface in the present and in the past
  - Extend climatological records through multiple Mars years with long-lived missions

Note: Mapping of these candidate mission goals to the MEPAG Goals, Objectives and Investigations is qualitatively shown in back-up slides

MATT-2 MEP Building Blocks for 2016-2026

MATT identified the following potential mission building blocks to address the key scientific objectives for 2016-2026:

- **Mars Sample Return Lander (MSR-L) and Orbiter (MSR-O)**
  - Two flight elements: Lander/Rover/Ascent Vehicle & Orbiter/Capture/Return Vehicle
  - High-priority in NRC reports and Decadal Survey; must address multiple science goals with samples meeting the minimum requirements set out in the ND-SAG report
- **Network (NET):**
  - 4 or more landed stations arrayed in a geophysical network to characterize interior structure, composition, and process, as well as surface environments
  - Network meteorological measurements would be leveraged by concurrent remote sensing from orbit
  - High-priority in NRC reports and Decadal Survey
- **Mars Science Orbiter (MSO)**
  - Atmospheric composition, state, and surface climatology remote sensing plus telecom
- **Mars Prospector Rover (MPR)**
  - At least MER-class rover would be deployed to new water-related geologic targets
  - Precision landing (<6-km diameter error ellipse) would enable access to new sites
  - Would conduct independent science but with scientific and technical feed-forward to MSR
  - As a precursor, this should demonstrate feed-forward capabilities for MSR and may open the possibility for payload trade-offs (e.g., caching and cache delivery) with MSR Lander
- **Mars Scout Missions (Scout)**
  - Competed missions to pursue innovative thrusts to major missions goals

MATT Guiding Principles (1 of 2)

MATT developed these strategic principles to guide mission architecture development:

- Conduct a Mars Sample Return Mission (MSR) at the earliest opportunity, while recognizing that the timing of MSR is budget driven.
  - Returned samples to meet minimum requirements set out in the ND-SAG report
- If MSR is deferred, MEP needs to proceed with a balanced scientific program while taking specific steps toward a MSR mission
  - Immediately start and sustain a technology program to focus on specific sample return issues including, but not limited to, precision landing and sample handling
  - Address non-MSR high priority science objectives, particularly as endorsed by NRC strategies and the Decadal Survey (e.g., network)
- Conduct major surface landings no more than 4 launch opportunities apart (3 is preferred) in order to:
  - Respond to discoveries from previous surface missions and new discoveries from orbit
  - Use developed technologies and experienced personnel to reduce risk and cost to future missions, especially MSR

MATT Guiding Principles (2 of 2)

MATT developed these strategic principles to guide candidate architecture development (cont.):

- Require that rovers preceding MSR would:
  - Demonstrate sample acquisition and caching technologies that meet the minimum requirements set out in the ND-SAG report
  - Investigate new sites to explore the diversity of Mars revealed from orbit and to provide multiple options for MSR
    - This would require precision landing to access the most promising sites and to feed-forward to MSR
- Provide long-lived orbiters to observe the atmosphere and seasonal surface change, and to provide telecom and critical event support
  - Would provide flexibility to MSR flight configurations and would be especially synergistic with network science and telecom needs
- Scout missions are included in the candidate architecture to provide:
  - Rapid, innovative response to new discoveries
  - Opportunity to sustain program balance and diversity
  - Low-cost Scout missions were inserted as opportunities permitted and budget profiles demanded

MATT Architecture Assessment

Specific Assumptions:

- **2013 Scout would be chosen from the current competition**
  - Scout would provide telecom for a Lander/Rover launched in 2016
- **Mission sequences considered in order of when MSR Lander would launch (after FY16, as directed)**
- **MSR would be at least a 2-element mission (lander/rover/ascent + orbiter/capture/return)**
- **Generally would launch MSR-O after MSR-L to give extended sample time on surface**
- **2009 MSL launch => a major landed mission no later than 2018**
  - *If not MSR in 2018, substitute "Prospector" rover in 2016 or 2018*
- **Precede landed network (NET) with long-lived orbiter**
  - Synergistic both for atmospheric science and for telecom
  - MSR-O would not provide this capability
- **"Ballpark" Budget guidelines**
  - 450M/yr (2009 $ inflated for future years) if MSR is delayed
  - 550M/yr (2009 $ inflated for future years) for earlier MSR
  - Limit large, early ramp-up in funding level and large year-to-year deltas in peak costs
  - Early budget constraints preclude an MSR Lander launch in 2016

Proposed Mission Scenarios

Option	2016	2018	2020[#2]	2022[#2]	2024	2026	Comments
2018a[#1]	MSR-O	MSR-L	MSO	NET	Scout	MPR	Funded if major discovery?
2018b[#1]	MSO	MSR-L	MSR-O	NET	Scout	MPR	Restarts climate record; trace gases
2018c[#1]	MPR	MSR-L	MSR-O	MSO	NET	Scout	Gap in climate record; telecom?
2020a	MPR	MSO	MSR-L	MSR-O	NET	Scout	MPR would help optimize MSR
2020b	MPR	Scout	MSR-L	MSR-O	MSO	NET	Gap in climate record, early Scout
2022a	MPR	MSO	NET	MSR-L	MSR-O	Scout	Early NET; MPR would help MSR
2022b	MSO	MPR	NET	MSR-L	MSR-O	Scout	Early NET, but 8 years between major landers (MSL to MPR)
2024a	MPR	MSO	NET	Scout	MSR-L	MSR-O	Early NET; 8 years between major landers; very late sample return

MSO = Mars Science Orbiter

MPR = Mars Science Prospector (MER or MSL class Rover with precision landing and sampling/caching capability)

MSR = Mars Sample Return Orbiter (MSR-O) and Lander/Rover/MAV (MSR-L)

NET = Mars Network Landers ("Netlander") mission

FOOTNOTES:

#1 Would require early peak funding well above the guidelines (see back-up slides for rough costs); 2018b would be most affordable of these options

#2 Celestial mechanics are most demanding in the 2020 and 2022 launch opportunities, but ATLAS V-551 capabilities presently appear to be adequate

Preferred Scenario for given MSR-L Launch Opportunity (green)

MATT Response to the Questions

Propose a Mars exploration architecture(s) that would optimize the science return within fiscal and programmatic constraints.

Scenarios 2020a and 2022a

1. Is the proposed MSR the highest priority for the Mars science community, assuming the cost constraint listed below?

   MSR is the highest priority for this decade and should be conducted at the earliest opportunity; however, it would require additional (peak) funding above the cost guidelines, no matter when it occurs; international partnering could help

2. Given that the 2016 opportunity would be too early for the launch of either of two elements of the proposed MSR, what should be the 2016 mission?

   MPR in 2016 followed by MSO in 2018 if MSR-L would be launched after 2018

3. Could the proposed MSR be split between more than two flight elements to reduce peak costs in any fiscal year?

   Development and demonstration of precision landing and sample selection/caching would reduce risk and demonstrate progress towards sample return, but the MSR cost savings would be modest even when MPR is a critical path element in MSR

4. What would be the architecture if there is no sample return in the foreseeable future?

   Proceed with 2022a

MATT Notes

- **Note #1: Major discoveries by ongoing or near-term missions (PHX, MSL, ExoMars) could change the architecture assessment**
  - For example, a PHX discovery might motivate a high-latitude lander with vertical access
  - Response would depend on nature of discovery--no attempt was made here to map out a "response tree" to the many possible discoveries that could be made
  - *The current operating missions are fully capable of making major new discoveries and their observation programs should be extended and data analysis supported*

- **Note #2: Many candidate missions considered here would be well-suited to international participation and partnering**
  - Prime examples for major subsystems or flight elements are MSR and Network
  - Opportunities for payload participation would exist for MPR and MSO

MATT Summary

- **High-priority science objectives could be addressed in 2016-2026 with a series of missions including, but not limited to, Mars Sample Return (MSR)**
  - *Early sample return is preferred as the findings would likely profoundly affect future Mars exploration*
- **A MSR-L launch in 2018 – desired scientifically – would significantly exceed funding guidelines as early as FY15-17**
  - If early funding provided [unlikely], MSO would go in 2016 to provide mission support and to restart the climatology record measurements prior to MSR *[Option 2018b]*
- ***If a MSR-L launch is deferred until after 2018, MATT finds two near-term mission architectures to be scientifically compelling, while providing real progress towards an MSR. Furthermore, these two scenarios would have the same initial mission set for 2016 and 2018:***

  Now: Start technology program focused on developments that would enable MPR and feed-forward to MSR

  2016: Launch Mars Prospector Rover (MPR) to a new site

  2018: Launch Mars Science Orbiter (MSO) for long-lived observations and telecom support for science

  Option 2020a: Launch MSR-L in 2020 followed by NET in 2024

  Option 2022a: Launch MSR-L in 2022 preceded by NET in 2020

  -Earlier MSR option preferred

Back-Up

MATT-2

Guidelines for the MATT-2 Study

- **Assumptions**:
  1. Telecommunications infrastructure, site selection, and critical event coverage, early in the next decade, should not be a concern of MATT for this study. In other words, look at the science that is desired and assume the rest would follow.
  2. Assume the MEP budget is sustained at some rate (~$550M/yr beginning in 2010) and trades can be made in peak spending years.
  3. The 2016 mission could cost ~$1B
  4. Last element of MSR would be launched in 2022

- **Possible Considerations**:
  1. Proper caching of samples should be done on any future landed opportunity
  2. Possible role of virtual caching (i.e., sampling sites would be characterized but samples would not be cached)
  3. Two MER class rovers instead of one rover for sample caching.
  4. ESA may have a 2016 orbiter, for testing rendezvous and capture, and for delivery of small landers to the surface
  5. Could/should two rovers be built simultaneously, and then each rover launched independently (either in the same of separate opportunities)?
  6. Inform and solicit comments from the community, perhaps through an accompanying MEPAG announcement
  7. Possible Scout in 2018

MATT Study-2

❑ How the Team proceeded

- Held a number of telecons; iterated on draft powerpoint summary
- Built on earlier work:
  - MEPAG Goals, Objectives,Investigations documentation
  - NRC Reports and Decadal Survey
  - Mars Next Decade (ND) and Mars Strategic Science (MSS) SAGs
  - MATT-1 Discussions
- Involved the JPL Mars Office Advanced Studies Team regarding mission costs and feasibility

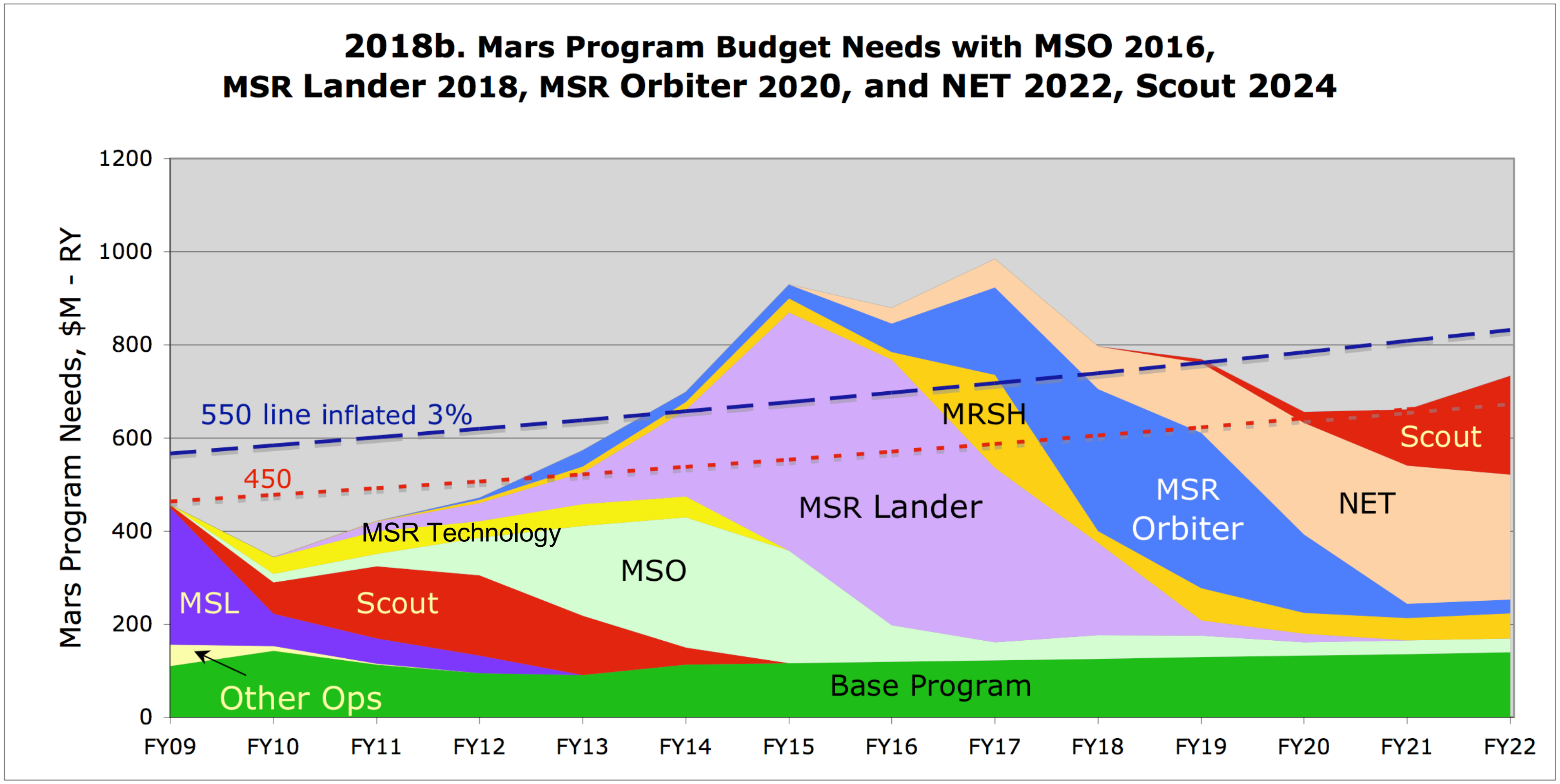
❑ Participants

Phil Christensen *(ASU, Chair)*
Lars Borg *(ND-SAG Co-Chair)*
Wendy Calvin *(MSO SAG Chair)*
Mike Carr
Dave DesMarais *(ND-SAG Co-Chair)*
Francois Forget
Noel Hinners
Scott Murchie *(MSS SAG Chair)*
Jack Mustard *(MEPAG Chair)*
Lisa Pratt
Chip Shearer *(CAPTEM)*
Mike Smith *(MSO SDT Chair)*
Steve Squyres
Christophe Sotin

JPL Mars Office
Dave Beaty
Jan Chodas
Frank Jordan
Richard Mattingly
Rich Zurek

NASA HQ
Lisa May
Michael Meyer *(MEP Lead Scientist)*

Option 2018b

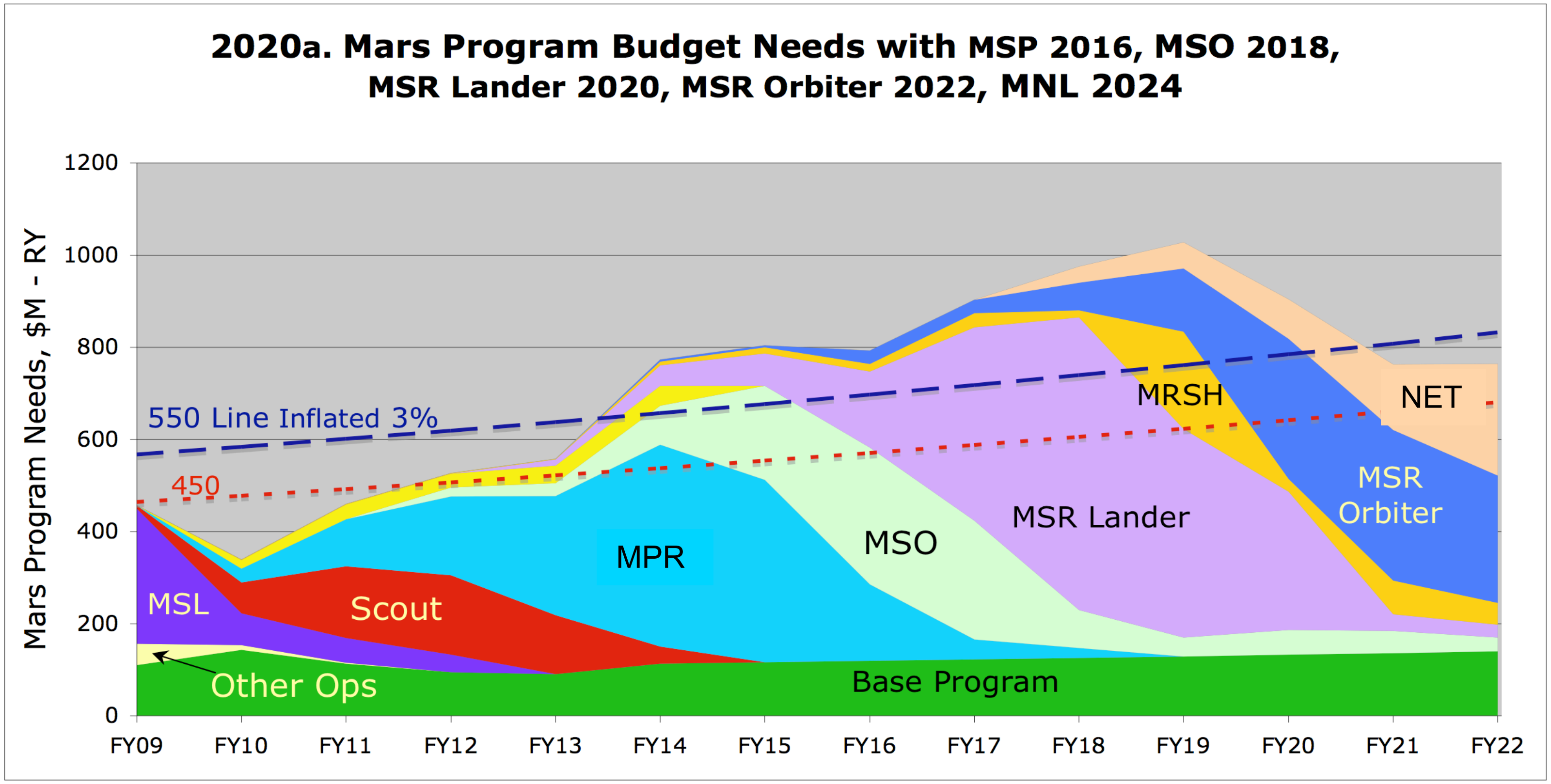


Real Year Costs FY09-22 ($B)

Scout	MPR	MSO	MSR-L	MRSH	MSR-O	NET
0.6	n.a.	1.1	2.2*	0.5+	1.2*	1.1+

*Includes additional 20% reserve factor + => significant costs beyond FY22

Option 2020a



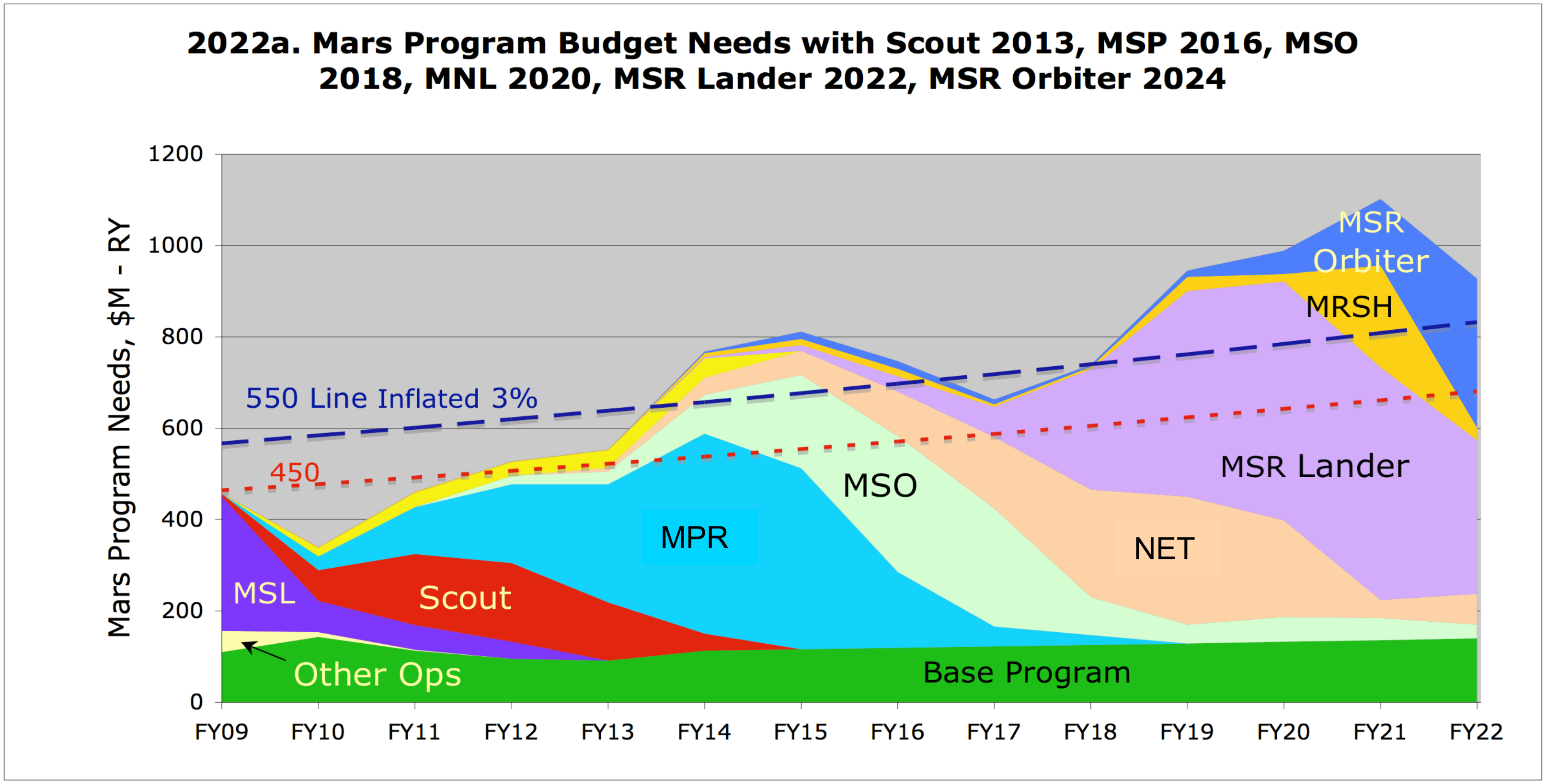
Real Year Costs FY09-22 ($B)

Scout	MPR	MSO	MSR-L	MRSH	MSR-O	NET
0.6	1.6*	1.1	2.3*	0.4+	1.2*	0.6+

*Includes additional 15% reserve factor for MPR, 20% for MSR-L & MSR-O

+ => significant costs beyond FY22

Option 2022a



Real Year Costs FY09-22 ($B)

Scout	MPR	MSO	NET	MSR-L	MRSH	MSR-O
0.6	1.6*	1.1	1.2	2.4*	0.4+	0.6*+

*Includes additional 15% reserve factor for MPR, 20% for MSR-L & MSR-O

\+ => significant costs beyond FY22

Option: Network

- **Concept: ≥ 4 Landed Stations Arrayed in a Seismic Network**
- **Goals**:
  - Characterize interior structure, composition and processes
  - Elucidate evolution of the interior over time and role in Mars climate history
  - Advance the comparative study of planetary formation and evolution
  - Characterize local meteorology and provide baseline for orbital climate measurements
    - Long-lived surface measurements
    - Substantially enhanced by concurrent orbital remote sensing of the atmosphere
  - Highest priority after sample return in NRC reports / Decadal Survey
- **Approach:**
  - Conduct interior measurements, particularly of seismic signals
  - Other goals: Heat flow, magnetics
  - Would not require precision landing
  - Would significantly be enhanced by Orbiter relay for telecom
  - Would significantly be enhanced by long-term (≥ 2 Mars years) observing period
  - Could easily be part of an international collaboration
  - ROM Cost: ~$1.2B (not including telecom)
- **Issues:**
  - Unknown signal character complicates payload design
    - A precursor demonstration might be needed to motivate (ExoMars?)
  - Could require new EDL design for implementation (i.e., other than MER/MSL technologies)

Option: Mars Science Orbiter

- **Concept: Science Orbiter Providing Long-lived Atmospheric Remote Sensing and Telecom for Landed Assets**
- **Goals**:
  - Extend atmospheric and seasonal surface climate baseline through the next decade
    - Provide improved and new (e.g., winds) profiling capabilities
  - Provide extensive global, diurnal and seasonal survey of key trace gases, including carbon-bearing compounds with implications for interior bio/geochemical processes
    - Methane and higher order hydrocarbons
    - Photochemical products, isotopes (CO, NO, etc.)
  - Particularly synergistic with Network for both relay and atmospheric science
  - Scientifically synergistic (lower atmosphere) with 2013 Scout (upper atmosphere)
- **Potential Approach**:
  - Use low-cost sounders & wide angle imagers with new microwave/sub-mm profilers
  - Provide high-resolution, high-sensitivity spectrometers for trace gas detection
  - Long-life (≥ 4 Mars Yrs) extends climate records and relay capability for next decade
  - Payload could accommodate international contributions
  - ROM Cost: ~$1.1B (includes long-life components and possibly site imaging)
- **Issues**:
  - Methane detection has been controversial; intervening landed rovers (MSL, ExoMars) might augment or dilute need for these particular measurements
  - Could be paradigm shifting in that trace gas measurements could take program in a different direction or to different places than currently envisioned, but would diverge from the current path of geologic/geochemical landed missions leading to MSR

MATT-2 Option: Mid-range Rover/Prospector

- **Concept: MER-Class Rover Deployed to New Class of Sites**
- **Goals**:
  - Respond to recent discoveries showing a variety of aqueous mineral deposits and geomorphic structures reflecting water activity on Mars
  - Find optimal sites for further scientific investigation, including sample return
    - Provide additional characterized site from which to return samples
- **Approach**:
  - MER-class payloads, with modest augmentation as capability allows
  - Would take advantage of latest EDL development and preserves it for MSR
    - Key is access to new sites not reachable with current MER/MSL landing error ellipses
  - Would update "Sky Crane" technology to enable precision landing (< 6 km diameter ellipse)
    - Capability would be needed to get to the most compelling sites
    - Capability also would be useful for MSR collection/rendezvous to return samples
  - Would provide opportunity ("Prospector Option") to demonstrate and/or prepare sample selection, encapsulation and general handling needed for MSR
  - ROM Cost: ~$1.6B
- **Issues**:
  - Would require (modest?) improvement of EDL system
  - Prospector concept would require development of sample handling capabilities
  - Would require new EDL design for implementation (I.e., cannot use MER/MSL technologies)
  - Would build on recent discoveries, but delay broadening scope of Mars science exploration

MATT-2 Qualitative Comparison of Candidates

Goal	Objective	Priority	#	Investigation	MSL	MSO (atmospheric)	Network	Prospector Rover	MSR (assuming non-polar site)
I. LIFE	A: Habitability	HIGH	1	CURRENT DISTRIBUTION OF WATER					Significant
			2	GEOLOGIC H2O HISTORY	Significant			Major	Major
			3	C,H,O,N,P, AND S - PHASES	Major	Major		Significant	Major
		LOW	4	POTENTIAL ENERGY SOURCES	Significant			Significant	Significant
	B: Carbon	HIGH	1	ORGANIC CARBON	Major	Significant			Major
			2	INORGANIC CARBON	Major			Significant	Significant
			3	LINKS BETWEEN C AND H, O, N, P, S					Significant
		LOW	4	REDUCED COMPOUNDS ON NEAR SURFACE	Significant	Significant			Significant
	C: Life	HIGH	1	COMPLEX ORGANICS	Significant				Major
			2	CHEMICAL AND/OR ISOTOPIC SIGNATURES	Major	Major			Major
			3	MINEROLOGICAL SIGNATURES				Major	Significant
		LOW	4	CHEMICAL VARIATIONS REQUIRING LIFE	Significant				Significant
II. CLIMATE	A. Present	HIGH	1	WATER, CO2, AND DUST PROCESSES	Significant	Major; not addressed by MSR	Not addressed by MSR	Significant; not addressed by MSR	
			2	SEARCH FOR MICROCLIMATES		Significant; not addressed by MSR	Significant; not addressed by MSR	Not addressed by MSR	
		LOW	3	PHOTOCHEMICAL SPECIES	Significant	Major; not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
	B. Ancient	HIGH	1	ISOTOPIC, NOBLE & TRACE GAS COMP.	Major	Significant			Significant
			2	RATES OF ESCAPE OF KEY SPECIES		Significant; not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
			3	ISOTOPIC, NOBLE, AND TRACE GAS EVOLUTION	Significant	Major			Significant
			4	PHYS AND CHEM RECORDS	Significant			Major	Significant
		LOW	5	STRATIGRAPHIC RECORD--PLD		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
	C. Safe s/c ops	HIGH	1	THERMAL & DYNAMICAL BEHAVIOR OF PBL	Significant	Significant; not addressed by MSR	Not addressed by MSR	Significant; not addressed by MSR	
			2	ATM. BEHAVIOR 0-80 KM		Major; not addressed by MSR	Significant; not addressed by MSR	Significant; not addressed by MSR	
			3	ATM. MD 80-200 KM		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
		LOW	4	ATM. MD >200 KM		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	

LEGEND	
Major contribution	(green)
Significant contribution	(teal)
2013-2016 investigations not addressed by MSR lander	(gray stipple)

Strong contribution to high-priority Goal II objectives not addressed by MSR; extends local MSL results spatially

MATT-2 Qualitative Comparison of Candidates

Goal	Objective	Priority	#	Investigation	MSL	MSO (atmospheric)	Network	Prospector Rover	MSR (assuming non-polar site)
III. GEOLOGY/GEOPHYSICS	A. Crust	HIGH	1	PRESENT STATE AND CYCLING OF WATER					Significant
			2	SEDIMENTARY PROCESSES AND EVOLUTION	Significant			Major	Major
			3	CALIBRATE CRATERING					Major
			4	IGNEOUS PROCESSES AND EVOLUTION	Major		Significant	Significant	Major
			5	SURFACE-ATM INTERACTIONS	Significant		Significant	Significant	Major
			6	LARGE-SCALE CRUSTAL VERT STRUCTURE	Significant		Significant	Significant	Significant
			7	TECTONIC HISTORY OF CRUST		Not addressed	Major	Not addressed	
			8	HYDROTHERMAL PROCESSES	Major		Significant		Major
			9	REGOLITH FORMATION AND MODIFICATION	Significant		Significant	Significant	Significant
			10	CRUSTAL MAGNETIZATION			Significant	Significant	Significant
		LOW	11	EFFECTS OF IMPACTS	Significant		Significant	Significant	Significant
	B. Interior	HIGH	1	STRUCTURE AND DYNAMICS OF INTERIOR			Major		Significant
			2	ORIGIN AND HISTORY OF MAGNETIC FIELD			Major		Significant
			3	CHEMICAL AND THERMAL EVOLUTION	Significant		Significant	Significant	Significant
		LOW	4	PHOBOS/DEIMOS		Not addressed	Not addressed	Not addressed	
IV. PREPARATATION	A: Science Measurements	HIGH	1	DUST - ENGINEERING EFFECTS	Significant			Significant	Major
			2	ATMOSPHERE (EDL/TAO)		Not addressed	Not addressed	Not addressed	
			3	BIOHAZARDS	Significant				Major
			4	ISRU WATER					Significant
			5	DUST TOXICITY					Major
			6	ATMOSPHERIC ELECTRICITY		Not addressed	Significant	Not addressed	
			7	FORWARD PLANETARY PROTECTION					Significant
			8	RADIATION	Significant	Not addressed	Significant	Not addressed	
			9	SURFACE TRAFFICABILITY		Not addressed	Not addressed	Not addressed	
			10	DUST STORM METEOROLOGY		Not addressed	Significant	Not addressed	
	B: Eng/TI Demos		1	AEROCAPTURE		Not addressed	Not addressed	Not addressed	
			2	ISRU DEMOS		Not addressed	Not addressed	Not addressed	
			3	PINPOINT LANDING		Not addressed	Not addressed	Significant	
			4	TELECOM INFRASTRUCTURE		Major	Not addressed	Not addressed	
			5	MATERIALS DEGRADATION		Not addressed	Not addressed	Not addressed	
		LOW	6	APPROACH NAVIGATION		Not addressed	Not addressed	Not addressed	

LEGEND	
Major contribution	(green)
Significant contribution	(cyan)
2013-2016 investigations not addressed by MSR lander	(grey)

Characterizes interior structure and composition in ways not possible with MSR, MSL; atmospheric objectives leveraged by orbital remote sensing

MATT-2 Qualitative Comparison of Candidates

Goal	Objective	Priority	#	Investigation	MSL	MSO (atmospheric)	Network	Prospector Rover	MSR (assuming non-polar site)
III. GEOLOGY/GEOPHYSICS	A. Crust	HIGH	1	PRESENT STATE AND CYCLING OF WATER					Significant
			2	SEDIMENTARY PROCESSES AND EVOLUTION	Significant			Major	Major
			3	CALIBRATE CRATERING					Major
			4	IGNEOUS PROCESSES AND EVOLUTION	Major		Significant	Significant	Major
			5	SURFACE-ATM INTERACTIONS	Significant			Significant	Major
			6	LARGE-SCALE CRUSTAL VERT STRUCTURE	Significant		Significant	Significant	Significant
			7	TECTONIC HISTORY OF CRUST		Not addressed	Major / Not addressed	Not addressed	
			8	HYDROTHERMAL PROCESSES	Major		Significant		Major
			9	REGOLITH FORMATION AND MODIFICATION	Significant		Significant	Significant	Significant
			10	CRUSTAL MAGNETIZATION			Significant		Significant
		LOW	11	EFFECTS OF IMPACTS	Significant		Significant	Significant	Significant
	B. Interior	HIGH	1	STRUCTURE AND DYNAMICS OF INTERIOR			Major		Significant
			2	ORIGIN AND HISTORY OF MAGNETIC FIELD			Major		Significant
			3	CHEMICAL AND THERMAL EVOLUTION	Significant		Significant	Significant	Significant
		LOW	4	PHOBOS/DEIMOS		Not addressed	Not addressed	Not addressed	
IV. PREPARATATION	A: Science Measurements	HIGH	1	DUST - ENGINEERING EFFECTS	Significant			Significant	Major
			2	ATMOSPHERE (EDL/TAO)		Not addressed	Not addressed	Not addressed	
			3	BIOHAZARDS	Significant				Major
			4	ISRU WATER					Significant
			5	DUST TOXICITY					Major
			6	ATMOSPHERIC ELECTRICITY		Not addressed	Significant / Not addressed	Not addressed	
			7	FORWARD PLANETARY PROTECTION					Significant
			8	RADIATION	Significant	Not addressed	Significant / Not addressed	Not addressed	
			9	SURFACE TRAFFICABILITY		Not addressed	Not addressed	Not addressed	
			10	DUST STORM METEOROLOGY		Not addressed	Significant / Not addressed	Not addressed	
	B: Eng/TI Demos		1	AEROCAPTURE		Not addressed	Not addressed	Not addressed	
			2	ISRU DEMOS		Not addressed	Not addressed	Not addressed	
			3	PINPOINT LANDING		Not addressed	Not addressed	Significant / Not addressed	
			4	TELECOM INFRASTRUCTURE		Major	Not addressed	Not addressed	
			5	MATERIALS DEGRADATION		Not addressed	Not addressed	Not addressed	
		LOW	6	APPROACH NAVIGATION		Not addressed	Not addressed	Not addressed	

LEGEND	
Major contribution	(green)
Significant contribution	(teal)
2013-2016 investigations not addressed by MSR lander	(grey)

Potential to extend analytical capabilities to classes of surface deposits not measured by MSL or MER