Greetings from MARS

“M” - Martian Arctic: Polygonal Terrain  
“A” - A Footpad on the Martian Surface  
“R” - Robot: SSI Self Portrait In Shadow  
“S” - Solar Array Deployed
Memorable Scenes from Phoenix

Spacecraft thruster expose water-ice in permafrost

Robotic Arm digs trench and discovers water ice. SSI camera documents H2O sublimation.

Top: Robotic Arm delivers soil/ice dug from trench to the Thermal Evolved Gas Analyzer (TEGA)

Bottom: TEGA CELL #0 after receiving ice-bearing sample

TEGA’s mass spectrometer confirms presence of water-ice on Mars.
Phoenix Meteorology is Changing

SSI camera images water-ice particles clouds and their movement

Phoenix images early morning water-frost. Lasts longer every morning as winter approaches

SSI camera images multiple dust devils

Dust Devil
Atmospheric pressure and temperature data have been recorded at the Phoenix landing site every 2 seconds since landing.

Morning wind is up to about 9 mph; enough to rattle the solar arrays but not to damage the spacecraft.
Virga, in the form of water -snow, has been detected in the atmosphere, getting nearer to the ground daily.
MECA’s Wet Chemistry Lab (WCL) discovers **perchlorates** in soil!

**Perchlorates**: Powerful, but stable oxidant. Very hygroscopic.

Q: What do perchlorates mean for the potential of life on Mars, past and present?

Q: Could perchlorates - if globally present - help control atmospheric H2O content?

MECA’s Optical Microscope: highest resolution (4 microns/pixel) optical images delivered from any planetary surface other than earth

Attempted delivery of organic blank to TEGA
The End is in Sight

Available power (measurement based)

Utilized power (modeled)

Survival heater power (measurement based)

Survival Heater Curves: a = All heaters on; b, c, d = heaters progressively disabled
Priorities Through End of Mission

• Only a few weeks of power remaining to execute anything other than meteorology, occasional image, communications and heaters

• Senior Review and NASA priorities
  – Collect D/H ratio of the ice
  – Daily meteorological observations and SSI imaging to document winter’s approach

• Near-Term project priorities
  – Fill and analyze all TEGA cells
    • Icy soil highest priority - D/H ratio
    • Organic Free Blank
  – Complete Optical Microscope substrates/AFM activities
  – Excavate surface to reveal more of underlying ice table
  – Coordinated science with MRO
  – Nighttime science
  – Thermal & Electrical Conductivity Probe in soil

• An attempt is being made to turn on MARDI’s microphone
NASA Selects Scout-13—MAVEN

- Fulfillment of a high-priority National Academy of Science Objective—Aeronomy
- Importance to Mars Exploration Program:
  - Addresses key science objectives for upper atmosphere, solar wind interaction, and escape to space, as defined by MEPAG (2006) and the NRC (2003)
  - Provide telecommunications infrastructure “refreshment”

- The Mission Team:
  - CU/LASP PI: Bruce Jakosky
    - GSFC Project Management
    - Lockheed Martin spacecraft and Ops
    - Instruments from UCB, LASP, GSFC, and CESR/France
## Mars Exploration Program Status

<table>
<thead>
<tr>
<th></th>
<th>TECH</th>
<th>COST</th>
<th>SCHD</th>
<th>PROG</th>
<th>COMMENTS</th>
</tr>
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<tbody>
<tr>
<td><strong>Odyssey</strong></td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>Nominal spacecraft/instrument extended mission operations. Started drift to 3PM orbit for science enhancement</td>
</tr>
<tr>
<td><strong>Mars Exploration Rovers</strong></td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>Rovers both in good health; Spirit survived the winter, Opportunity is roving the plains outside Victoria Crater</td>
</tr>
<tr>
<td><strong>ESA/Mars Express</strong></td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>Nominal extended operations.</td>
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<tr>
<td><strong>Mars Reconnaissance Orbiter</strong></td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>Operations nominal; prime mission complete in Nov 08</td>
</tr>
<tr>
<td><strong>Phoenix</strong></td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>Landed in the Martian Arctic May 25! Extended mission begun 10/1/08.</td>
</tr>
<tr>
<td><strong>Mars Science Laboratory</strong></td>
<td>G</td>
<td>R</td>
<td>Y-R</td>
<td>R</td>
<td>Cost growth solutions being implemented for FY08/09; still capable of 2009 LRD; critical meetings in October with NASA/A</td>
</tr>
<tr>
<td><strong>Scout-13</strong></td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>On-time selection in September '08; MAVEN selected</td>
</tr>
</tbody>
</table>

**Key:**
- **Green**: Progress according to plan. All commitments can be met.
- **Yellow**: Area of concern; Problem can be resolved within reporting organization; Needs attention.
- **Red**: Significant problem; Solution not identified. Needs action/help beyond reporting organization.
Mars Science Laboratory
Headlines

• Major flight structural elements have been delivered to the assembly floor—Cruise Stage, Descent Stage, and Rover Chassis.
  – Flight cabling and avionics being installed and tested

• Preparing to start launch/cruise environmental testing in November.

• Instrument development is proceeding well.
  – Flight Mars Descent Imager (MARDI) has been delivered
  – Mars Hand Lens Imager (MAHLI) and Dynamic Albedo of Neutrons (DAN) instruments will deliver in October.
  – The rest of the instruments, particularly the Chemistry Camera (ChemCam), Sample Analysis at Mars (SAM), and Chemistry and Mineralogy (CheMin), are due in November and December.

• The third community-based landing site workshop was completed in mid-September
  – 7 landing sites evaluated; 3 sites rated high for science value
  – All 7 sites are acceptable at this time for engineering/landing criteria.

• Cache—status is TBD
  – Decision is moot in 1-2 weeks

• Still on track for 2009 launch
  – SRB review of ATLO and V&V plans Sept 25-26; “reasonable” chance of meeting 2009 LRD with acceptable risk
  – NASA reviews in October will determine go-forward strategy
Family Tree
Flight Aeroshell
Flight Heatshield with First Row of Tiles
Flight SkyCrane (Decent Stage)

- Propellant Tanks (x3)
- Pressurant Tank (x2)
- PCA
- Service Valves
- TDS Truss (aka Proboscis)
- MLE
Flight Rover Chassis and MMRTG
Flight Rover Internal Assembly

- X-band System
- Power Analog Modules
- SAM Mass Model
- Compute Element
- Instrument Mass Model
- Motor Control Mass Model
- CE Mass Model
- Instrument Mass Model
- Batteries
- HRS Pump Assembly
- UHF System
Payload Hardware

CCMU FM: Crédit CNES - INSU - OMP - CESR

ChemCam Mast Unit

APXS

RAD

CheMin

MAHLI

SAM Chassis

SAM SuperQMS
Descent Stage Structure

Rover Chassis

Cruise Stage
## Flight System Delivery Status

<table>
<thead>
<tr>
<th>Area</th>
<th>Component</th>
<th>Launch/Cruise Delivery Status</th>
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</thead>
<tbody>
<tr>
<td><strong>CRUISE STAGE</strong></td>
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<td></td>
</tr>
<tr>
<td>AVS</td>
<td>CPAM-A</td>
<td>Delivered</td>
</tr>
<tr>
<td>AVS</td>
<td>CPAM-B</td>
<td>Delivered</td>
</tr>
<tr>
<td>AVS</td>
<td>CPA</td>
<td>10/04 ok starting tvac</td>
</tr>
<tr>
<td>AVS</td>
<td>CSA</td>
<td>09/29 ok completing rework at</td>
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<td>GNC</td>
<td>DSE-A</td>
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<tr>
<td>GNC</td>
<td>DSH-A (x4)</td>
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<tr>
<td>GNC</td>
<td>DSE-B</td>
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</tr>
<tr>
<td>GNC</td>
<td>DSH-B (x4)</td>
<td>Delivered</td>
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<tr>
<td>GNC</td>
<td>SSA</td>
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<tr>
<td>Prop</td>
<td>CS Structure w/Prop</td>
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<tr>
<td>THM</td>
<td>CIPA (Cruise IPA)</td>
<td>09/30 ok final weld/x-ray/retest</td>
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<td>THM</td>
<td>Thermal Circuits</td>
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<tr>
<td>TEL</td>
<td>CS Antennas</td>
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<tr>
<td><strong>AEROSHELL</strong></td>
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<tr>
<td>Mech</td>
<td>Backshell</td>
<td>09/27 ok</td>
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<tr>
<td>Mech</td>
<td>Heatshield</td>
<td>10/14 ok</td>
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<tr>
<td>MEDLI</td>
<td>MEDLI</td>
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<td><strong>DESCENT STAGE</strong></td>
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<td>AVS</td>
<td>DPAM-A</td>
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<td>AVS</td>
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<td>AVS</td>
<td>DPA</td>
<td>Delivered</td>
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<td>AVS</td>
<td>DMCA</td>
<td>10/09 with abbreviated env testing</td>
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<td>AVS</td>
<td>PWTB</td>
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<tr>
<td>AVS</td>
<td>PYTB</td>
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<td>GNC</td>
<td>DIMU-A</td>
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<td>GNC</td>
<td>TDS</td>
<td>Delivered (Flight Safe Digital)</td>
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<tr>
<td>MECH</td>
<td>BUD</td>
<td>09/26 ok prepping for delivery</td>
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<tr>
<td>MECH</td>
<td>Pyro Circuits</td>
<td>10/01 ok</td>
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<td>Prop</td>
<td>DS Structure w/Prop</td>
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<td>TEL</td>
<td>DS X-Band</td>
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<td>TEL</td>
<td>DS Antennas (non-PUHF)</td>
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<td>PUHF / PCC</td>
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<td>Thermal Circuits</td>
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<td>RCE-B</td>
<td>01/01/09</td>
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<td>AVS</td>
<td>RMCA</td>
<td>01/10/09</td>
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<td>NavCams-A [pair]</td>
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<td>GNC</td>
<td>NavCams-B [pair]</td>
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<td>HazCams, front-A [pair]</td>
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<td>HazCams, rear-A [pair]</td>
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</tr>
<tr>
<td>GNC</td>
<td>HazCams, rear-B [pair]</td>
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<td>RIMU-A (LN200)</td>
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</tr>
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<td>RIMU-B (LN200)</td>
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<td>MECH</td>
<td>RVR Chassis</td>
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<td>MECH</td>
<td>RVR Heat Exchanger</td>
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<td>MECH</td>
<td>Mobillity</td>
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<tr>
<td>MECH</td>
<td>Remote Sensing Mast</td>
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<tr>
<td>MECH</td>
<td>Cache</td>
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<tr>
<td>MECH</td>
<td>Robotic Arm Assembly</td>
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</tr>
<tr>
<td>MECH</td>
<td>PADS Drill</td>
<td>02/21/09</td>
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<tr>
<td>MECH</td>
<td>CHIMRA</td>
<td>02/28/09</td>
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<td>MECH</td>
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<td>MECH</td>
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<tr>
<td>PLD</td>
<td>Other</td>
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<tr>
<td>PLD</td>
<td>MARDI &amp; DEA</td>
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<td>RVR X-band</td>
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<td>TEL</td>
<td>High Gain Antenna System</td>
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<td>Rover Antennas (non-HGA)</td>
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<td>TEL</td>
<td>UHF-A (Electra)</td>
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### MSL Landing Sites – Final 7

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<tr>
<th>NAME</th>
<th>LOCATION</th>
<th>ELEVATION</th>
<th>TARGET</th>
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<tbody>
<tr>
<td>Nili Fossae Trough</td>
<td>21.00°N, 74.45°E</td>
<td>-608 m</td>
<td>Noachian Phyllosilicates</td>
</tr>
<tr>
<td>Holden Crater Fan</td>
<td>26.37°S, 325.10°E</td>
<td>-1940 m</td>
<td>Fluvial Layers, Phyllosilicates</td>
</tr>
<tr>
<td>Mawrth Vallis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site 1</td>
<td>24.65°N, 340.09°E</td>
<td>-3093 m</td>
<td>Noachian Layered Phyllosilicates</td>
</tr>
<tr>
<td>Site 2 Site 3</td>
<td>23.19°N, 342.41°E</td>
<td>-2187 m</td>
<td></td>
</tr>
<tr>
<td>Site 4</td>
<td>24.86°N, 339.42°E</td>
<td>-3359 m</td>
<td></td>
</tr>
<tr>
<td>Eberswalde Crater</td>
<td>23.86°S, 326.73°E</td>
<td>-1450 m</td>
<td>Delta</td>
</tr>
<tr>
<td>Miyamoto</td>
<td>3.34°S, 352.26°E</td>
<td>-1807 m</td>
<td>Phyllosilicates, Sulfates?</td>
</tr>
<tr>
<td>S Meridiani</td>
<td>3.05°S, 354.61°E</td>
<td>-1589 m</td>
<td>Sulfates, Phyllosilicates</td>
</tr>
<tr>
<td>Gale Crater</td>
<td>4.49°S, 137.42°E</td>
<td>-4451 m</td>
<td>Layered Sulfates, Phyllosilicates,</td>
</tr>
</tbody>
</table>

v. 7; 07/08/08

http://marsoweb.nas.nasa.gov/landingsites/index.html
MSL Cost/Schedule Status

• Cost Status
  – Expenditure to-date is $1.5B (incl. technology, MMRTG, and all Phases to-date).
  – MSL budget: $223M (FY09); $64M (FY10); $55M (FY11)

• Overguide status
  – Exceeded 15% overguide threshold of NASA Authorization Act, in FY08
  – Approximately $200M total requested by JPL to-date (not including pending request)
  – JPL’s pending request for additional funding for FY09 LRD is expected to be >$100M, spread across FY09 and FY10
    • Independent Cost Estimates support that range as well
  – This level of request will exceed the 30% threshold with next week’s request
    • Detailed Breach Report to Congress and potential “Stop Work” requirement
  – Slip to 2010 or 2011 will require an additional (estimated) $300+M, minus pending request
MSL Cost/Schedule Status (con’t)

• MSL additional funding needs will impact Planetary and SMD
  – Mars Program has literally exhausted all sources of funds
  – MSL descopes are no longer viable, short of outright cancellation
    • Important mission to the Agency and SMD; cancellation probably not a viable option
  – Additional funding will come from a JPL mission (slippage or cancellation) depending on the severity of the final cost requirements
    • Payback from Mars Next Decade funds—2016 mission, technology, etc.

• NASA paying close attention to progress and cost
  – Weekly and monthly reporting to HQ
  – HQ/MEP participation in weekly JPL reviews
  – Reviews with NASA Administrator in February and May 2008
  – Next review with SMD AA Oct 6th, and NASA/A in October 10th
Threshold has been adjusted to reflect 15% growth in direct development cost only. Nunn-McCurdy is actually measured against full-cost development cost—LCC is shown.

PNAR $1546M

NAR $1601M (Includes $36M increase in Phase E)

Confirmed $1633M (additional reserves inserted by Program)

LCC increase to $1673M

15% adjusted Nunn-McCurdy threshold* $1779M

70% ICE curve $1699M (FY09 Pres Budget LCC $1696M)

FY08 Op Plan 4 LCC at $1886M (development at $1225M–26.5% above the $969M MPAR baseline; breached 15% “Nunn-McCurdy threshold)

$253M

JPL and supplier delivery delays; dbl shift ATLO

SLA to PICA over-guide

Overguide + caching

JPL pending request estimated >$100M FY09-10 (w/o reserves) (breach of 30% MPAR “Nunn-McCurdy” threshold)

9/2008

10/08

1/2008

12/2007

8/2006

8/2006

2/2006

FY08 Op Plan 4 LCC at $1886M (development at $1225M–26.5% above the $969M MPAR baseline; breached 15% “Nunn-McCurdy threshold)

15% adjusted Nunn-McCurdy threshold* $1779M

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PNAR $1546M

JPL and supplier delivery delays; dbl shift ATLO

SLA to PICA over-guide

Overguide + caching

JPL pending request estimated >$100M FY09-10 (w/o reserves) (breach of 30% MPAR “Nunn-McCurdy” threshold)
Issues Summary

• Cost
  – Development costs are now 26.5% higher than baseline, soon to exceed 30%. Solutions are likely to impact other SMD missions (Mars and Planetary first).

• Schedule
  – Complex subsystems and components; e.g., Landing Radar, actuators, and Sample Acquisition/Sample Processing, are driving the critical path with longer development and delivery times.
  – Actuator delivery, and avionics maturity, are the major outstanding issues, along with the unknowns of system test.

• Technical
  – Schedule compression limits the amount of testing that can be completed prior to launch. System Assembly, Integration & Test and the System Test beds are now running 2 shifts to launch.

• Risk
  – All Entry, Descent, and Landing (EDL) tests as well as all system functional tests must be completed prior to launch. Some surface operations tests and calibrations may be deferred to post-launch.
The Next Decade
MEP Next Decade—Where to From Here?

Launch Year

Operational
- Odyssey
- Mars Express Coop
- MER
- Phoenix
- Mars Science Lab

2009
- MRO

2011
- MAVEN

2013
- ESA/ExoMars Cooperation

2016
- Lander Mission X

2018 & Beyond
- The Era of Mars Sample Return

Under Review
Drivers for Planning the Next Decade

• What are the driving requirements behind the Program’s baseline content?
  – MEP architecture *must* be viable with or without Mars Sample Return
  – MSR in 2018 is *not viable* with the FY09 budget, or maybe any budget that can be expected in the near term

• What are the drivers for developing Program content?
  – The mission portfolio must reflect methodical scientific progress and stakeholder expectations—alignment with NRC and MEPAG
  – It must include missions for science and infrastructure

• How does Mars Sample Return fit in the architecture?

• Technology development must enable all missions in the portfolio
Conclusions

- MSL is currently the dominant factor for Mars
  - A significant challenge in 2008/09/10 that will impact more than just the Mars Program
  - Ability to meet 2009, and financial impacts and solutions, will be clear in the next couple months
  - The upcoming decisions are not just schedule/technical —financial impacts worsening

- Re-establishment of a viable Program is underway
  - The next decade of Mars has started with the selection of MAVEN!
  - Next Decade missions must support established scientific priorities—NRC and MEPAG
  - Budget level is TBD, but a stable and predictable budget is required to operate a strategically-driven program (loosely coupled, in NPD 7120.5D parlance)
  - Architectural decisions will be vetted through advisory structures and transition teams

- The wild card is the upcoming election cycle
  - Delayed FY09 budget through Congress
  - New TBD Presidential priorities—FY09 budget
Back Up
## Community Architecture Priorities

### MATT-provided Options for Planning Purposes

<table>
<thead>
<tr>
<th>Option</th>
<th>2016</th>
<th>2018</th>
<th>2020#2</th>
<th>2022#2</th>
<th>2024</th>
<th>2026</th>
<th>Comments</th>
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<tbody>
<tr>
<td>2018a#1</td>
<td>MSR-O</td>
<td>MSR-L</td>
<td>MSO</td>
<td>NET</td>
<td>Scout</td>
<td>MPR</td>
<td>Funded if major discovery?</td>
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<tr>
<td>2018b#1</td>
<td>MSO</td>
<td>MSR-L</td>
<td>MSR-O</td>
<td>NET</td>
<td>Scout</td>
<td>MPR</td>
<td>Restarts climate record early; trace gases</td>
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<td>MSR-O</td>
<td>MSO</td>
<td>NET</td>
<td>Scout</td>
<td>Gap in climate record; telecom?</td>
</tr>
<tr>
<td>2020a</td>
<td>MPR</td>
<td>MSO</td>
<td>MSR-L</td>
<td>MSR-O</td>
<td>NET</td>
<td>Scout</td>
<td>MPR helps optimize MSR</td>
</tr>
<tr>
<td>2020b</td>
<td>MPR</td>
<td>Scout</td>
<td>MSR-L</td>
<td>MSR-O</td>
<td>MSO</td>
<td>NET</td>
<td>Gap in climate record, early Scout</td>
</tr>
<tr>
<td>2022a</td>
<td>MPR</td>
<td>MSO</td>
<td>NET</td>
<td>MSR-L</td>
<td>MSR-O</td>
<td>Scout</td>
<td>Early NET; MPR helps MSR</td>
</tr>
<tr>
<td>2022b</td>
<td>MSO</td>
<td>MPR</td>
<td>NET</td>
<td>MSR-L</td>
<td>MSR-O</td>
<td>Scout</td>
<td>Early NET, but 8 years between major landers (MSL to MPR)</td>
</tr>
<tr>
<td>2024a</td>
<td>MPR</td>
<td>MSO</td>
<td>NET</td>
<td>Scout</td>
<td>MSR-L</td>
<td>MSR-O</td>
<td>Early NET; 8 years between major landers; late sample return</td>
</tr>
</tbody>
</table>

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**MSO = Mars Science Orbiter**

**MPR = Mars Prospector Rover (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**

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**FOOTNOTES:**

#1 Requires early peak funding well above the guidelines

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

Mars Exploration Program FY09 President’s Budget Submit

FY08 Program Budget
FY09 Program Budget
MSR 20/22

MSL
ExoMars
Scout 2013
Mars 2016
Prog Mgt, Technology
R&A
Mission Ops

FY09 President’s Budget
Planetary Science Div. planning budget from FY09 POP Process