The Exploration of Mars
Where to From Here?

Operational 2001-2009
- Odyssey
- Mars Express Collaboration
- MRO

2011
- Mars Science Lab

2013
- MAVEN Aeronomy Orbiter

2016
- ESA-NASA Trace Gas Mapper (+ telecomm.)

2018
- NASA and ESA Rovers (Astrobiology/ Sample Return Tech. and ExoMars)

2020 & Beyond
- The Era of Mars Sample Return

NASA-ESA Joint Mars Initiative (in final planning)
Ten instrument packages with the objective to explore and quantitatively assess a region of Mars as a potential habitat for life, past or present.

- MSL will carry an analytical laboratory of unprecedented capability,
  - SAM: Gas Chromatograph/Mass Spectrometer & TLS
    - In rocks, soil, and atmosphere, will be able to measure mineralogy, organics, and isotopes
  - Chemin: X-Ray Diffractometer for state-of-the-art mineral identification
  - ChemCam: New to planetary exploration instrumentation, is a laser induced breakdown spectroscope for meters-distant remote sensing of elemental/chemical composition.

- The other instruments
  - MastCam – stereo camera, 12 filters, 10 frames/s, 7.4 cm/pixel @ 1km
  - MAHLI – color hand lens, 15 um/pixel with white and UV light sources
  - MARDI – Mars Descent Imager
  - RAD (ESMD) – high-energy radiation (direct & secondary)
  - APXS (Canada) – alpha Particle X-ray Spectrometer, all elements above sodium
  - REMS (Spain) – pressure, humidity, UV radiation, wind speed, & temperature
  - DAN (Russia) – water distribution in the near subsurface

- With its sophisticated instruments, MSL is the first astrobiology mission since Viking, and will characterize the nature of current and ancient Martian environments.
Remote Sensing (Mast)
- **ChemCam**: Laser Induced Breakdown Spectrometer & Remote Micro Imager
- **Mastcam**: Color Medium and Narrow-Angle Imager

Contact Instruments (Robotic Arm)
- **MAHLI**: Hand-Lens Imager
- **APXS**: X-Ray Backscatter Spectrometer

Analytical Laboratory
- **SAM**: Gas Chromatograph/Mass Spectrometer/Tunable Laser Spectrometer
- **CheMin**: X-Ray Diffraction

Environmental Characterization
- **MARDI**: Descent Imager
- **REMS**: Meteorological Monitoring
- **RAD**: Surface Radiation Environment Monitor
- **DAN**: Neutron Backscatter Subsurface Hydrogen Detection

Delivered to ATLO
In Storage @ Instrument Provider
In-Work @ Instrument Provider
MSL Science Payload Status July 2009

- SAM
- MAHLI
- MARDI
- DEA
- REMS
- CheMin
- MAST Unit
- ChemCam
- RAD
- APXS
- DAN PNG
- DAN DE
Sample Processing System

Turret

MAHLI
DRT
DRILL
CHIMRA
2009
July 31: AA review of SAM
Aug 6: REMS Risk Technical Interchange Review
Aug 19: SAM Go-Forward Review
Aug 13: Mastcam Review and Delivery
Aug 22: CheMin Delivery
Sep 24: MSL V&V Plan Review
Oct: Call for Potential 5th Landing Site Candidate
Oct: REMS: Review and Delivery
Nov 17-19: MSL Readiness-to-Proceed Review
2010
Summer: SAM delivery (TBD Aug 19)
Sep : Landing Site Workshop
### MSL Landing Sites

- **Eberswalde Crater** (24°S, 327°E, -1.5 km) contains a clay-bearing delta formed when an ancient river deposited sediment, possibly into a lake.

- **Gale Crater** (4.5°S, 137°E, -4.5 km) contains a 5-km sequence of layers that vary from clay-rich materials near the bottom to sulfates at higher elevation.

- **Holden Crater** (26°S, 325°E, -1.9 km) has alluvial fans, flood deposits, possible lake beds, and clay-rich sediment.

- **Mawrth Vallis** (24°N, 341°E, -2.2 km) exposes layers within Mars’ surface with differing mineralogy, including at least two kinds of clays.

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Project has baselined the *option* of adding a new site by early summer 2010—Bar will be very high from science perspective; Site must be at least as safe as current sites.
Mars Science Laboratory

- MSL is the first astrobiology mission since Viking. Ten instrument packages with the objective to explore and quantitatively assess a potential habitat for life, past or present. Analytic and in-situ measurements will provide essential ground truth to anchor regional and global remote sensing mineralogy data
  - These in-situ data will:
    - Test hypotheses of early Martian environmental evolution, including climate history
    - Determine which environments might have best preserved environmental signals, and possibly biosignatures
    - Test interpretations of global mineralogy inferred from orbit

- Feed Forward Engineering:
  - New EDL system will enable future high-mass landings
  - Develop experience with sample collection, manipulation, and sample preparation
  - Targeted landing—critical capability for accessing high-priority science targets
  - Next generation of complex lab instruments to another planetary surface
# Mars Missions - Progress of Capabilities for Mars Exploration

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<td>Launch Mass</td>
<td>894</td>
<td>1,060</td>
<td>576</td>
<td>725</td>
<td>1,063</td>
<td>2,180</td>
<td>670</td>
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<td>Fuel</td>
<td>94</td>
<td>300</td>
<td>64</td>
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<td>1,149</td>
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<td>EDL System</td>
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<td>140</td>
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<td>N/A</td>
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<tr>
<td>Landed Mass</td>
<td>370</td>
<td>N/A</td>
<td>290</td>
<td>N/A</td>
<td>348 + rover</td>
<td>N/A</td>
<td>350</td>
<td>900</td>
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<tr>
<td>Mobile Mass</td>
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<td>N/A</td>
<td>N/A</td>
<td>185</td>
<td>N/A</td>
<td>N/A</td>
<td>900</td>
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<tr>
<td>Science Instruments</td>
<td>8 kg, 0.75 kg on rover</td>
<td>6 instr. (75 kg)</td>
<td>3 instr.</td>
<td>3 instr. (45 kg)</td>
<td>5 instr. (5.5 kg)</td>
<td>6 instr. (130 kg)</td>
<td>6 instr. (35 kg)</td>
<td>13 instr. (75.5 kg) (3 shell)</td>
</tr>
</tbody>
</table>
Powered Descent
Sky Crane

Touchdown Bridle/Umbilical Cut, Flyaway

MSL EDL
Flight Heat Shield with PICA
Integrated Spacecraft
ATLO EDL SkyCrane Testing
MSL’s value to Society

• MSL will quantitatively assess the habitability through time of a region, based on well-chosen site with stratigraphic sequences demonstrating clear evidence of hydrated minerals and morphologic attributes evincing former interaction with water

• MSL is a critical step towards answering, is there life outside Earth
  – We now believe that Mars preserves a record of habitable environments, some of which may be active today
  – Mars’ environmental record is both diverse and dynamic – it has changed in time and space and is preserved in the stratigraphic record
  – Our next step is to determine whether or not life ever started on Mars