Status of Mars Science Laboratory

Presentation to Mars Panel
Planetary Science Decadal Survey

September 9-11, 2009

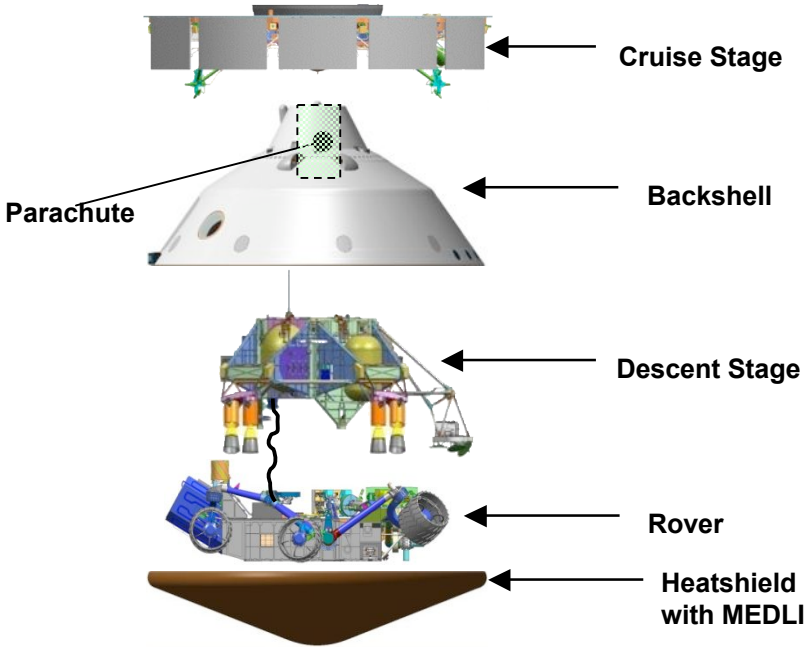
Fuk Li
Mars Exploration Program

MSL Status: Overview

- Science capability of MSL remains intact
  - Discuss science payload status
- MSL technical challenges/capability feed-forward
- Status of system development
- Go-forward development, integration and test activities will meet 2011 launch window

MSL Overview

Launch and Cruise Configuration



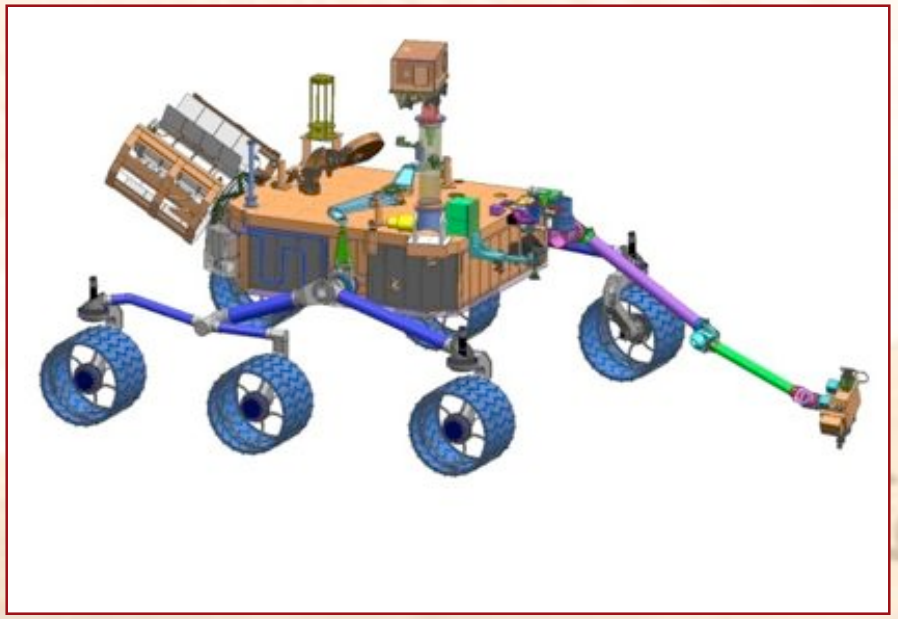
MSL Is 3
Sub-spacecraft in One

Rover Family Portrait

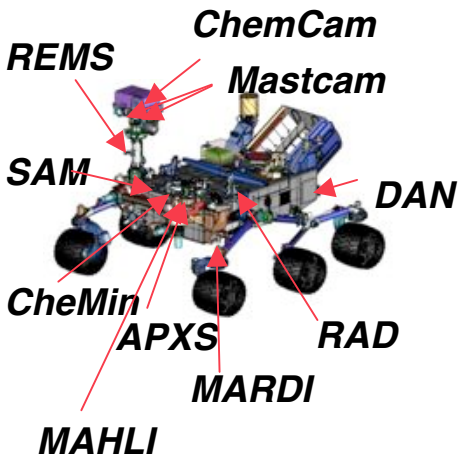
	Pathfinder	MER	MSL
Entry mass (kg)	580	830	3400
Landed mass (kg)	290	540	930
Rover mass (kg)	10	175	930
Instrument Mass (kg)	1	5	80

Mars Science Laboratory Key Attributes

- 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 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

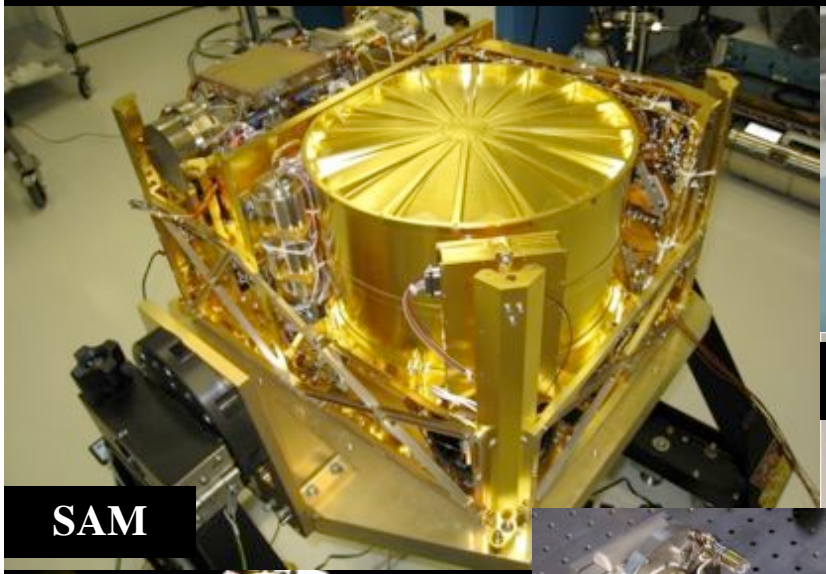


MSL - Science Payload Capabilities

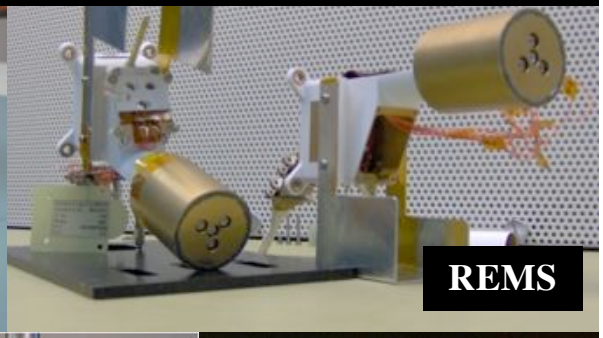


	Functional Capabilities	Comments
Remote Sensing (Mast)		
• **ChemCam**: Laser Induced Breakdown Spectrometer & Remote Micro Imager	Elemental chemistry of a 0.5 mm spot from 1 to 9 m distance, 80 µrad imaging @ 20 mrad FOV	No similar capability in previous missions.
• **Mastcam**: Color Medium and Narrow-Angle Imager	Stereo-capable Bayer-color +12 filter panoramic, 5° and 15°FOV cameras, video capabilty	MER Pancam: fixed focus, no video, no internal storage, fewer-pixel-CCDs, no Bayer-color.
Contact Instruments (Robotic Arm)		
• **MAHLI:** Hand-Lens Imager	Bayer-color,15 µm/pix, 1600x1200, LED lighting, autofocus	MER MI: monochrome, 30 µm/pix, 1024x1024, no autofocus
• **APXS:** X-Ray Backscatter Spectrometer	Rock/soil elemental chemistry of a 1.5 cm spot in15 min to 3 hrs.	MER: Takes ~3x longer to take a measurement. Spot size 3.8 cm.
Analytical Laboratory		
• **SAM**: Gas Chromatograph/Mass Spectrometer/Tunable Laser Spectrometer	Molecular & isotopic composition, 2-535 Dalton mass range for atmosphere and evolved gas. Continuous oven heating to 1000°C.	Viking,12-200 Dalton range, oven heating in steps to 500°C. Sensitive to a narrower range of organics. No internal calibrants.
• **CheMin**: X-Ray Diffraction	Identification of multiple minerals at > 3 wt% abundance	MER Moessbauer: could only identify iron-bearing minerals
Environmental Characterization		
• **DAN**: Neutron Backscatter Subsurface Hydrogen Detection	Active and passive neutron spectroscopy in-situ: H in upper 1 m	ODY GRS: Passive neutron spectroscopy, 2° x 2° lat/long
• **MARDI**: Descent Imager	Hundreds of images, Bayer-color	MER DIMES: 3 images
• **REMS**: Meteorological Monitoring	Wind, temperature, pressure, humidity, UV, ground temp	PHX MET: rough wind estimate, temperature, pressure, lidar
• **RAD**: Surface Radiation Environment	Radiation measured at the surface	ODY measured rad. from orbit

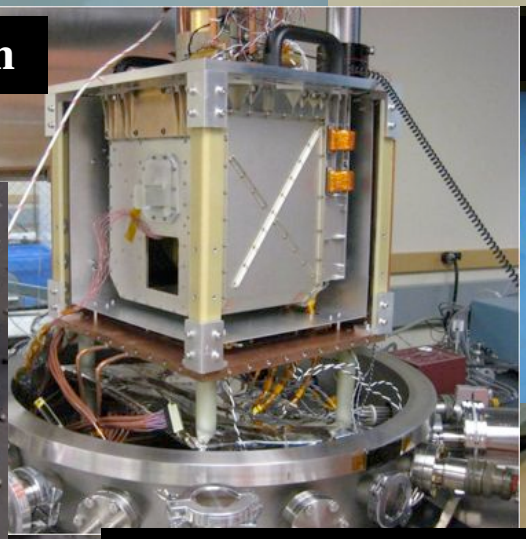
MSL Science Payload Status August 2009


SAM

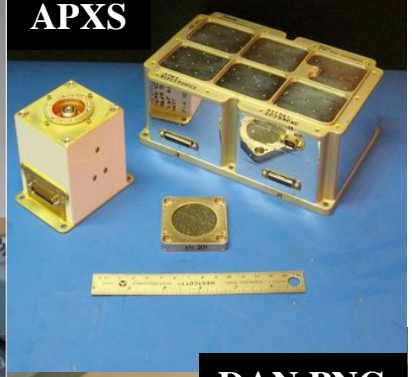

RAD

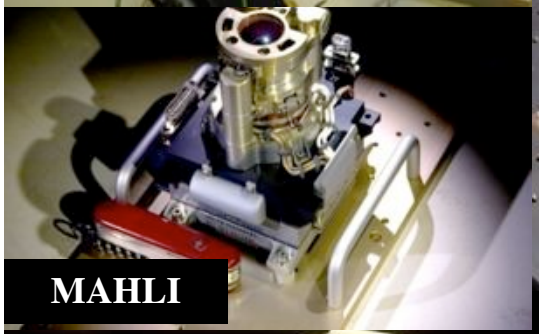

REMS

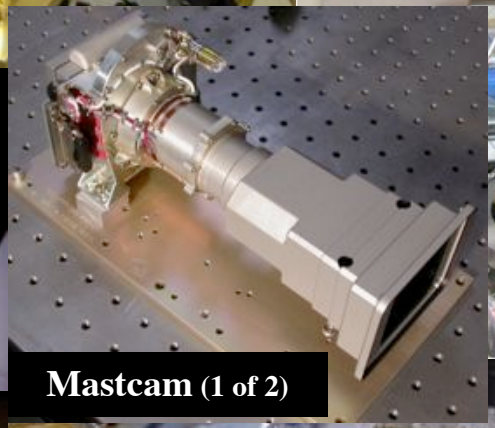
CheMin



APXS

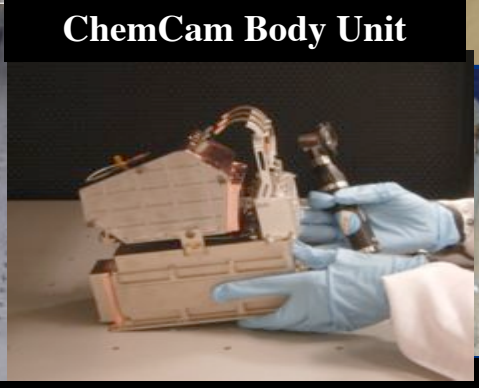


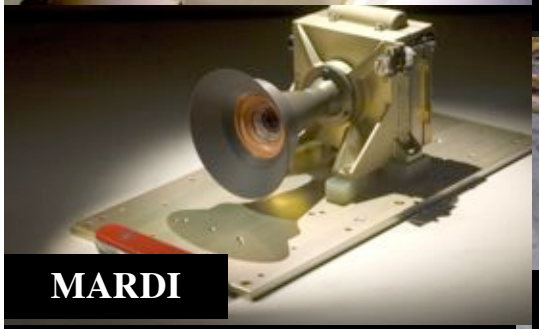

MAHLI

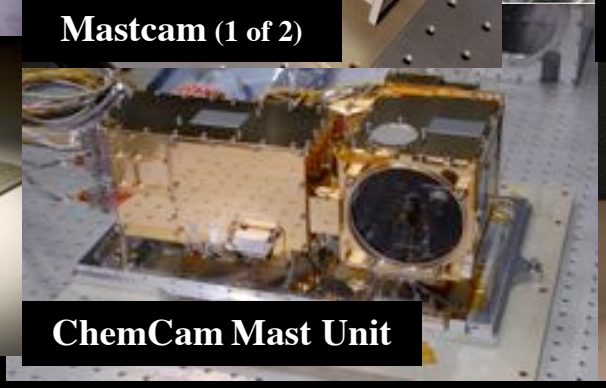

Mastcam (1 of 2)

DAN PNG

ChemCam Body Unit

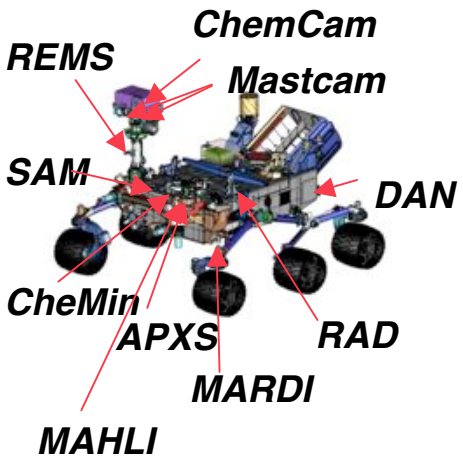



MARDI


ChemCam Mast Unit

DAN DE

MSL Science Instrument Status



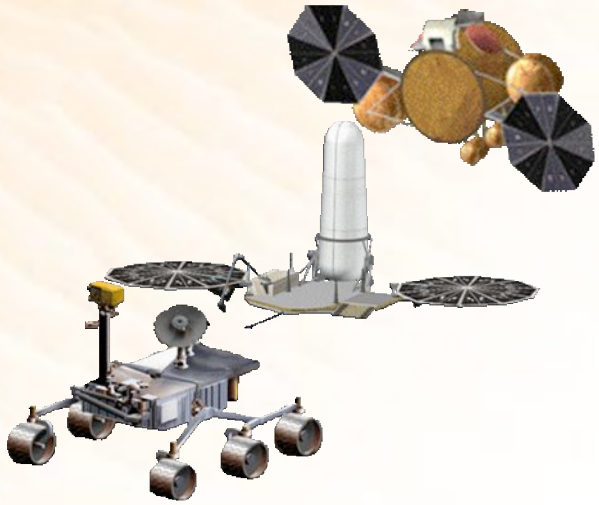
	Status
Remote Sensing (Mast)	
• **ChemCam**: Laser Induced Breakdown Spectrometer & Remote Micro Imager	Being retrofitted with internal CCD cooler to compensate for heat-to-use actuators restrictions
• **Mastcam**: Color Medium and Narrow-Angle Imager	In final calibration at PI facility. Instrument Delivery Review Complete
Contact Instruments (Robotic Arm)	
• **MAHLI:** Hand-Lens Imager	Delivered, In ATLO storage
• **APXS:** X-Ray Backscatter Spectrometer	Delivered, In ATLO Storage
Analytical Laboratory	
• **SAM**: Gas Chromatograph/Mass Spectrometer/Tunable Laser Spectrometer	Baseline instrument in rework after Env. Test Issues. Parallel path WRP replacement as a backup to installed pumps
• **CheMin**: X-Ray Diffraction	Completed, Cooler interface heat leak repairs being tested prior to final delivery
Environmental Characterization	
• **DAN**: Neutron Backscatter Subsurface Hydrogen Detection	Delivered, In ATLO Storage. Flt#2 with fresh Source delivers to KSC
• **MARDI**: Descent Imager	Delivered, on Rover for EDL Tests
• **REMS**: Meteorological Monitoring	In final Ass'y and Test
• **RAD**: Surface Radiation Environment Monitor	Completed, In dry-purge storage at SwRI prior to final storage

MSL Technical Challenges: Level 1 requirements

Key Level I	Requirement	Threshold
Landing Altitude	+1.0 km MOLA	0.0 km MOLA
Latitude	+/- 45 deg	+/- 30 deg
Landing Accuracy	10 km radial	20 km
EDL Comm	Throughout	Same
Lifetime	1 Mars year	0.5 Mars year
Traverse	20 km	10 km
Sample Capability	74 samples	28 samples
Instruments	10 instruments	AO driven

MSL Technical Capability Feed-forward

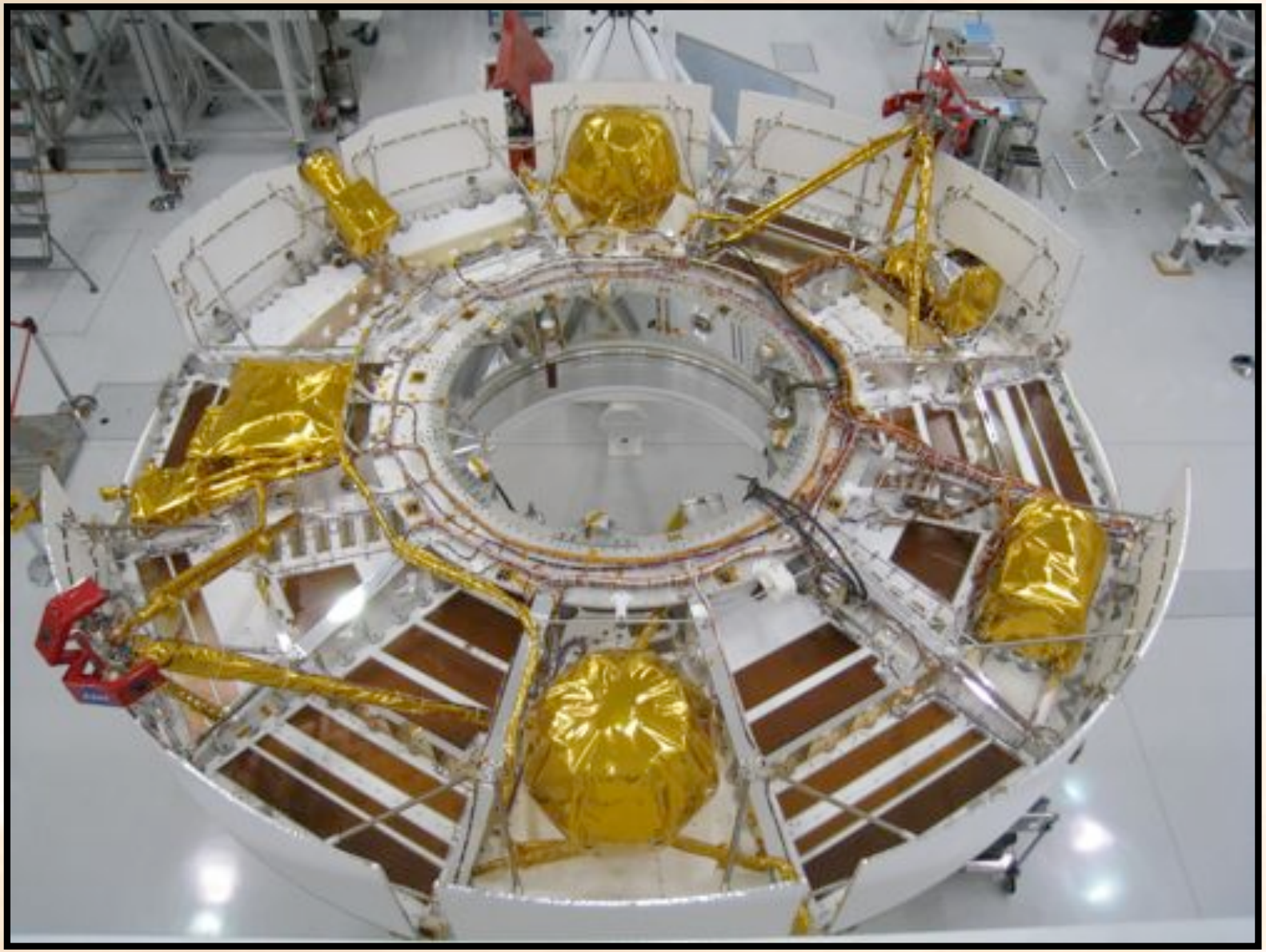
- New EDL system will enable future high-mass landings
- “Work Horse” for lander missions in next decade
- Precision landing via guided entry
- critical capability for accessing high-priority science targets
- Long Distance Traverse Capability
    - Enables larger scale exploration
- Flexible & Robust Sample Acquisition & Processing
    - Capability feed-forward to future sample acquisition systems, including preparing samples for return



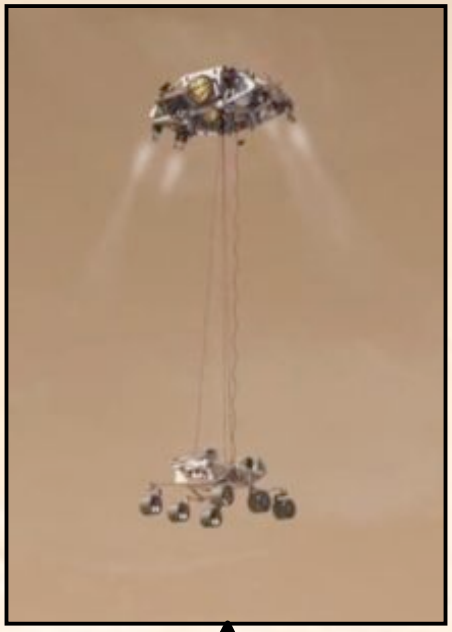
MSL Development Status/To-go plan

- Cruise stage/Descent Stage systems plus skeletal rover system went through portions of the overall system integration/test prior to decision to slip launch to 2011
- After launch slip, project re-planned go-forward activities with the following overall focus:
  - FY09 - Risk Reduction/Design Completion
    - Retire high risk development issues
  - FY10
    - Complete hardware builds and prepare/initiate system test programs
  - FY11: completes system tests and launch campaign
  - FY12 : Cruise and landing in August'12
  - FY13/14: Surface operation

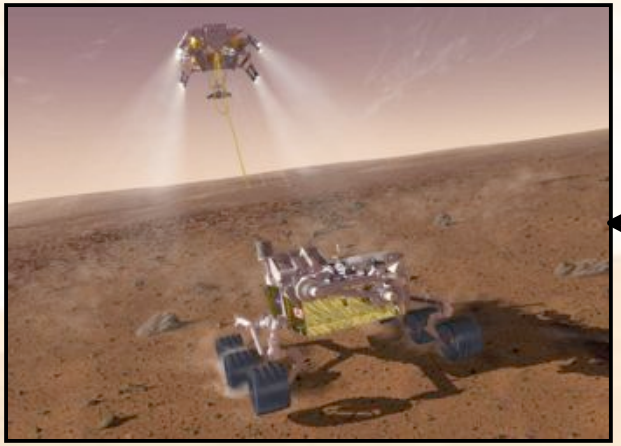
Cruise Stage



Entry, Descent and Landing (EDL)

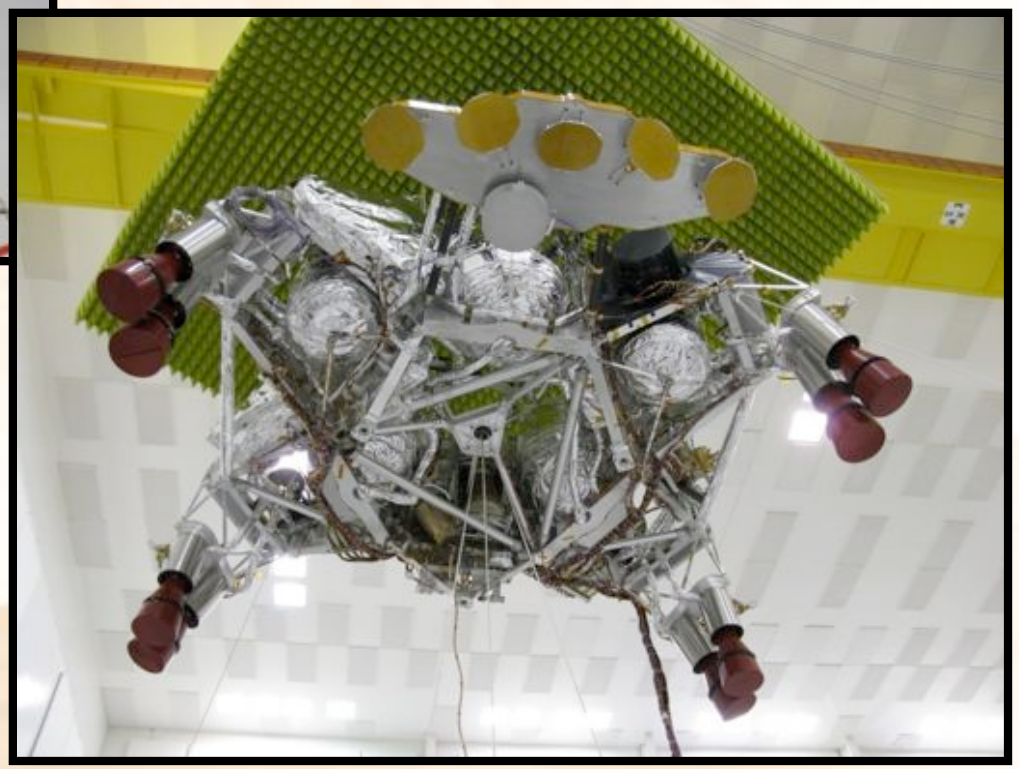


Powered Descent
Sky Crane



Touchdown
Bridle/Umbilical Cut,
Flyaway

MSL Descent Stage



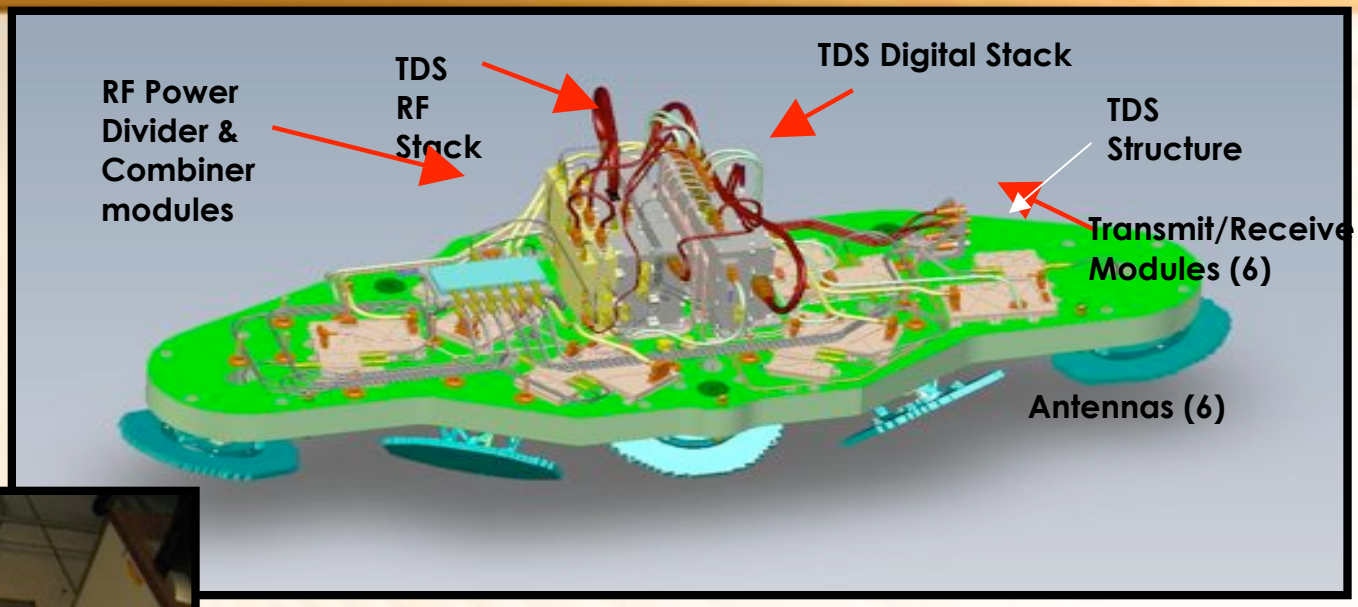
MSL Back Shell / Heatshield

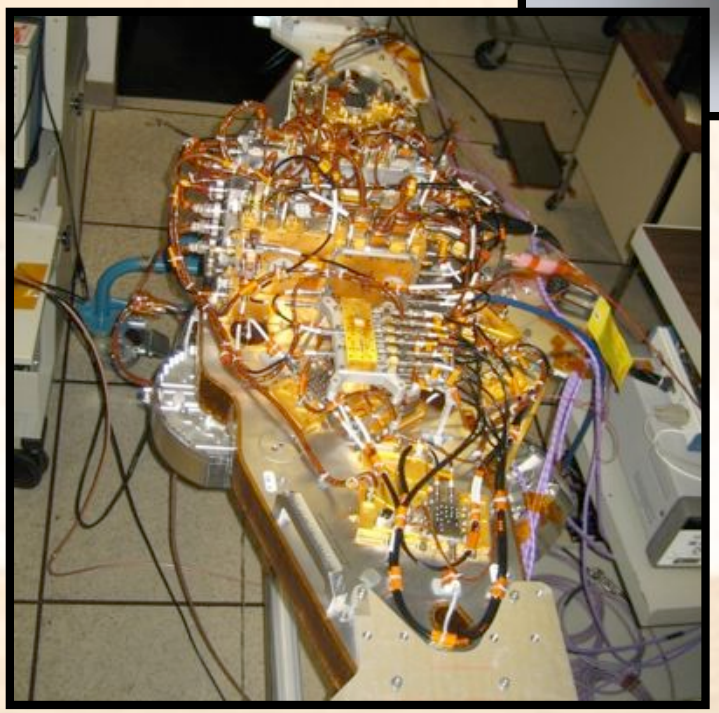
MSL Heat Shield

MSL Back Shell

Flight Backshell being moved into oven

MSL Touchdown Sensor - Radar

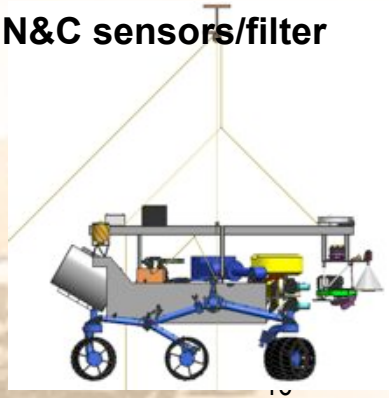




Radar Field Test Plan

Helicopter: May ’10
- > Powered descent flight envelope
- > Integrated GN&C sensors/filter
- > Sidelobes
- > High attitude rate

China Lake: Jul ’10
- > Skycrane profile
- > Low altitude/speed performance
- > Rover interaction
- > Integrated GN&C sensors/filter



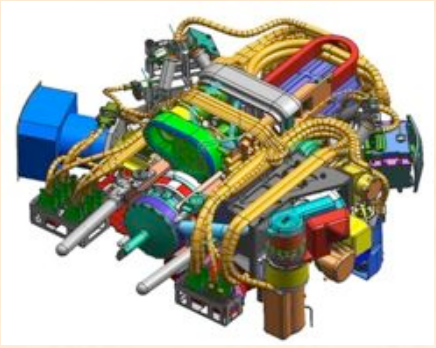
F/A-18: Oct ’10
Objectives
- > Acquisition/on-chute flight envelope
- > High altitude/speed performance
- > Provoke range/velocity ambiguities, if any

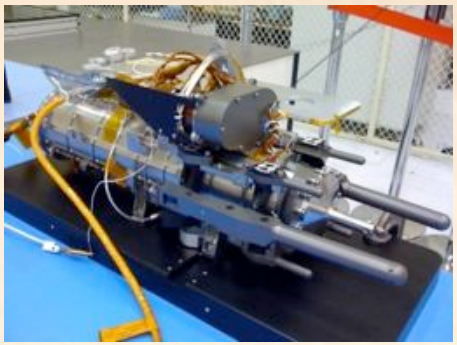
Previous Cycle of Integration / Test

ATLO EDL SkyCrane Testing

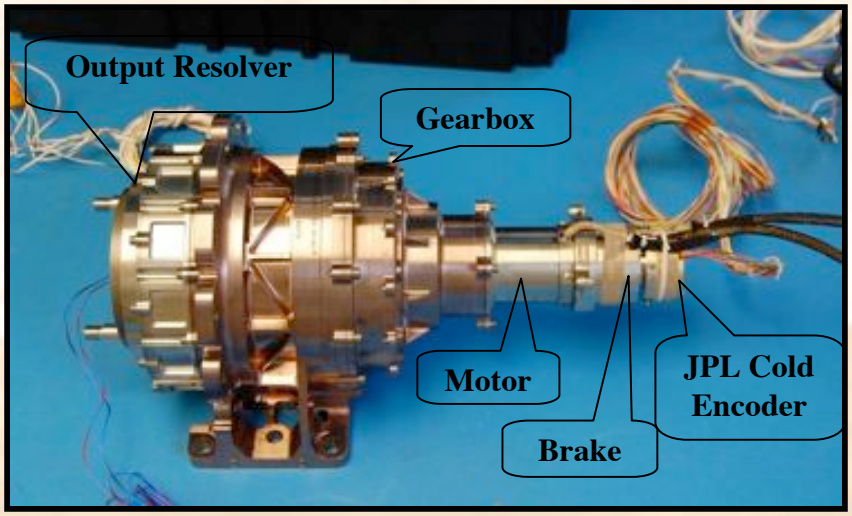
MSL Rover Status

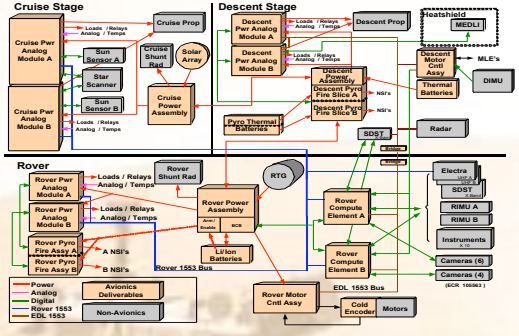
SA/SPaH System



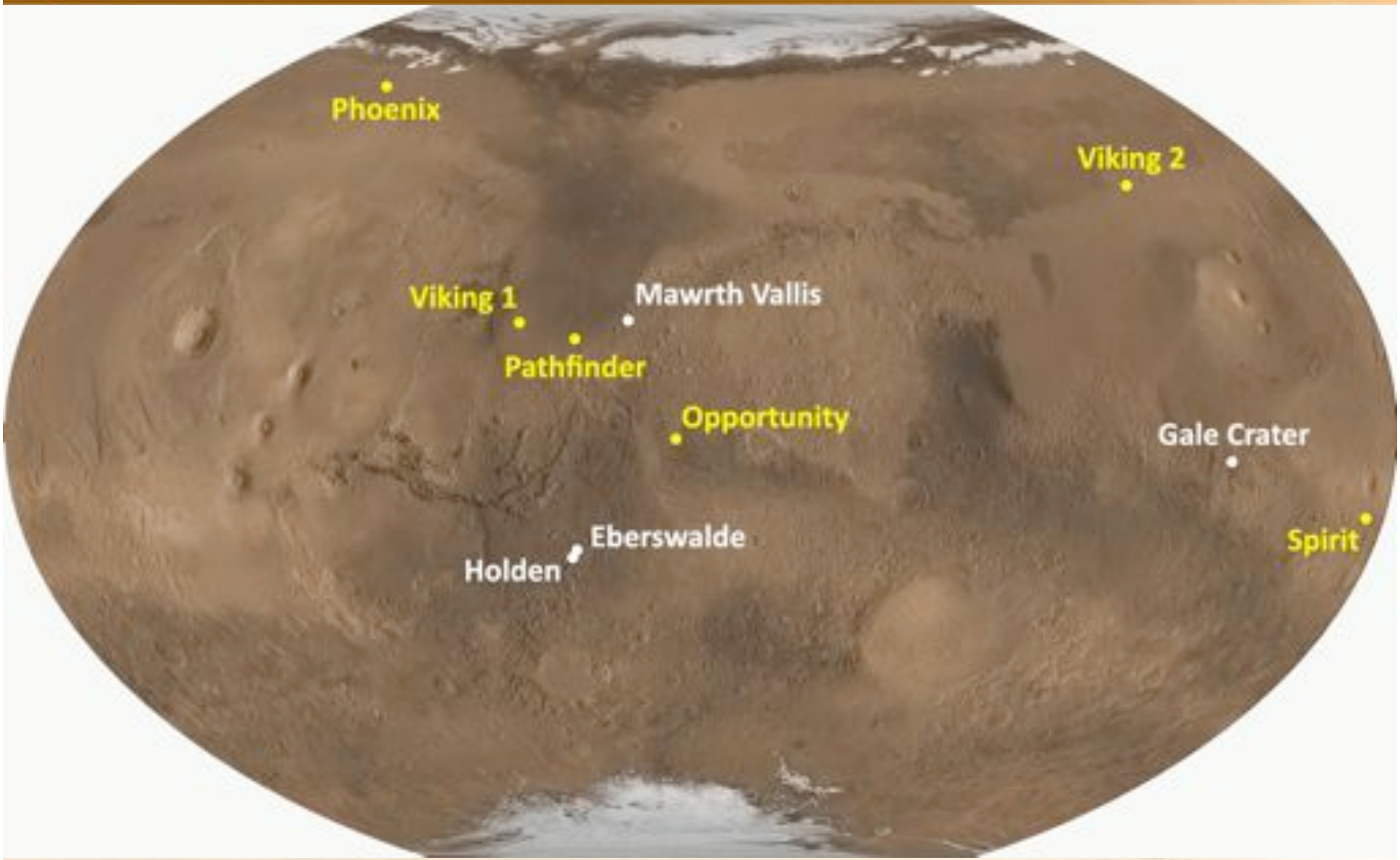


Actuator

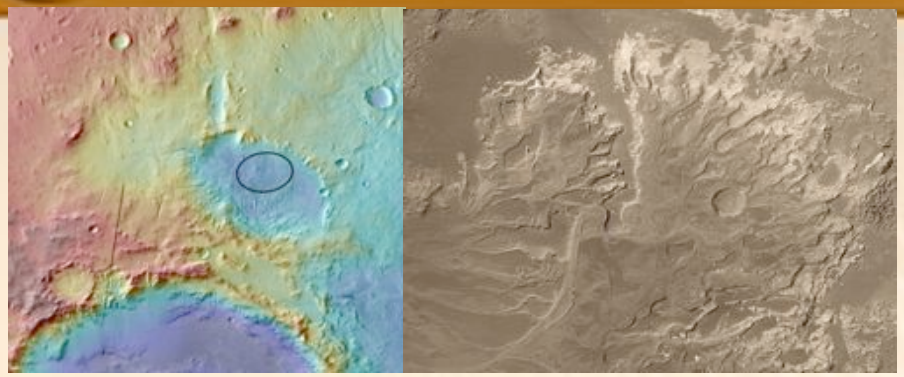




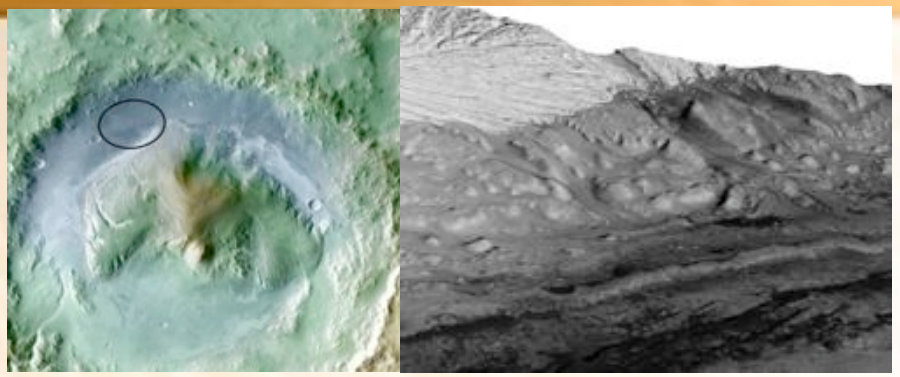
Previous and MSL Landing Sites



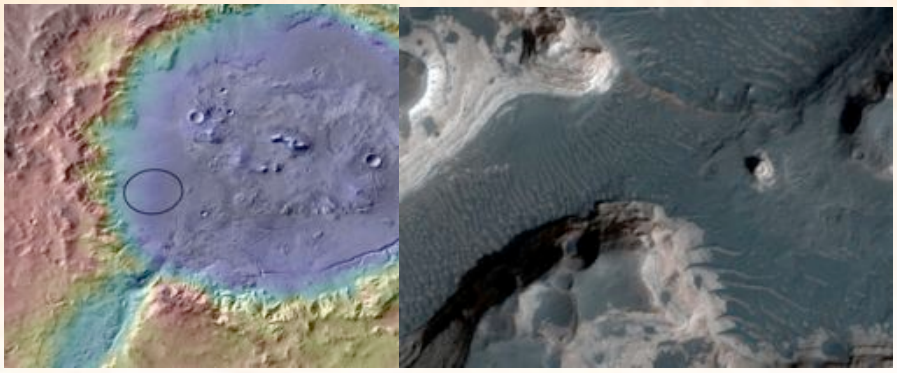
MSL Landing Sites



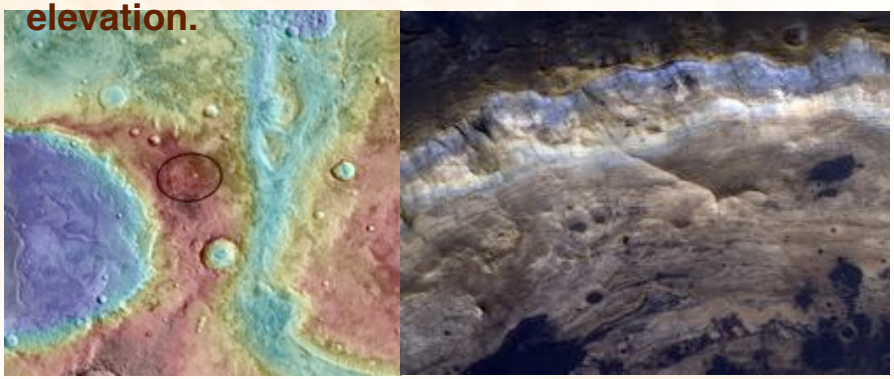
Eberswalde Crater (24°S, 327°E, -1.5 km) contains a clay-bearing delta formed when an ancient river deposited sediment, possibly into a lake.



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.

Project has baselined the *option* of adding a new site by early summer 2010

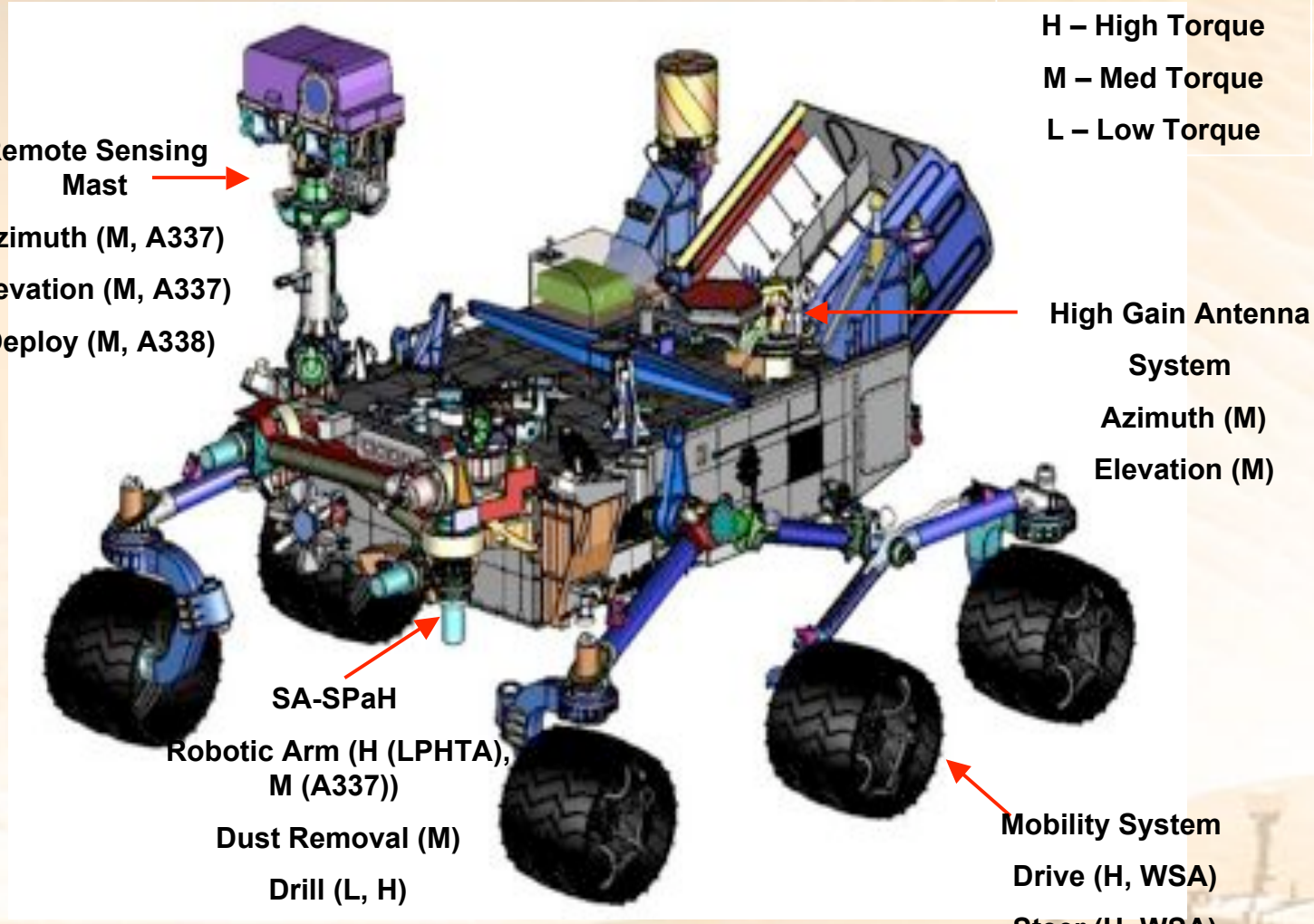
– Bar will be very high from science perspective; Site must be at least as safe as current sites

MSL Status Summary

- Science capability of MSL remains intact
- Discussed MSL technical challenges/capability feed-forward
- Discussed status of system development
- Go-forward development, integration and test activities will meet 2011 launch window

Backup

Status of Actuators: Location of Actuators



H – High Torque

M – Med Torque

L – Low Torque

Remote Sensing Mast

Azimuth (M, A337)

Elevation (M, A337)

Deploy (M, A338)

High Gain Antenna System

Azimuth (M)

Elevation (M)

SA-SPaH

Robotic Arm (H (LPHTA), M (A337))

Dust Removal (M)

Drill (L, H)

CHIMRA (L, H)

Inlet Covers (L)

Mobility System

Drive (H, WSA)

Steer (H, WSA)

MER-MSL Actuator Comparison

	MER	MSL
Total Actuators	153	101
BB & EM	60	51
Flight 1	39	31
Flight 2	39	n/a
Spare	15	19
Motors		
Current Range	<1 amp	1-10 amps
Variants	2	5
Commutation Type	Brush	Brushless DC
Lifetime (output)	2.5 million revs	45 million revs
Gearbox		
Variants	18	16
Mass	0.5 – 1 kg	0.5 – 6 kg
Temp Capability	-70C	-70C
Lifetime (output)	500	15000
Torque Capability	< 200 n m	< 800 n m