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Mars Science Laboratory

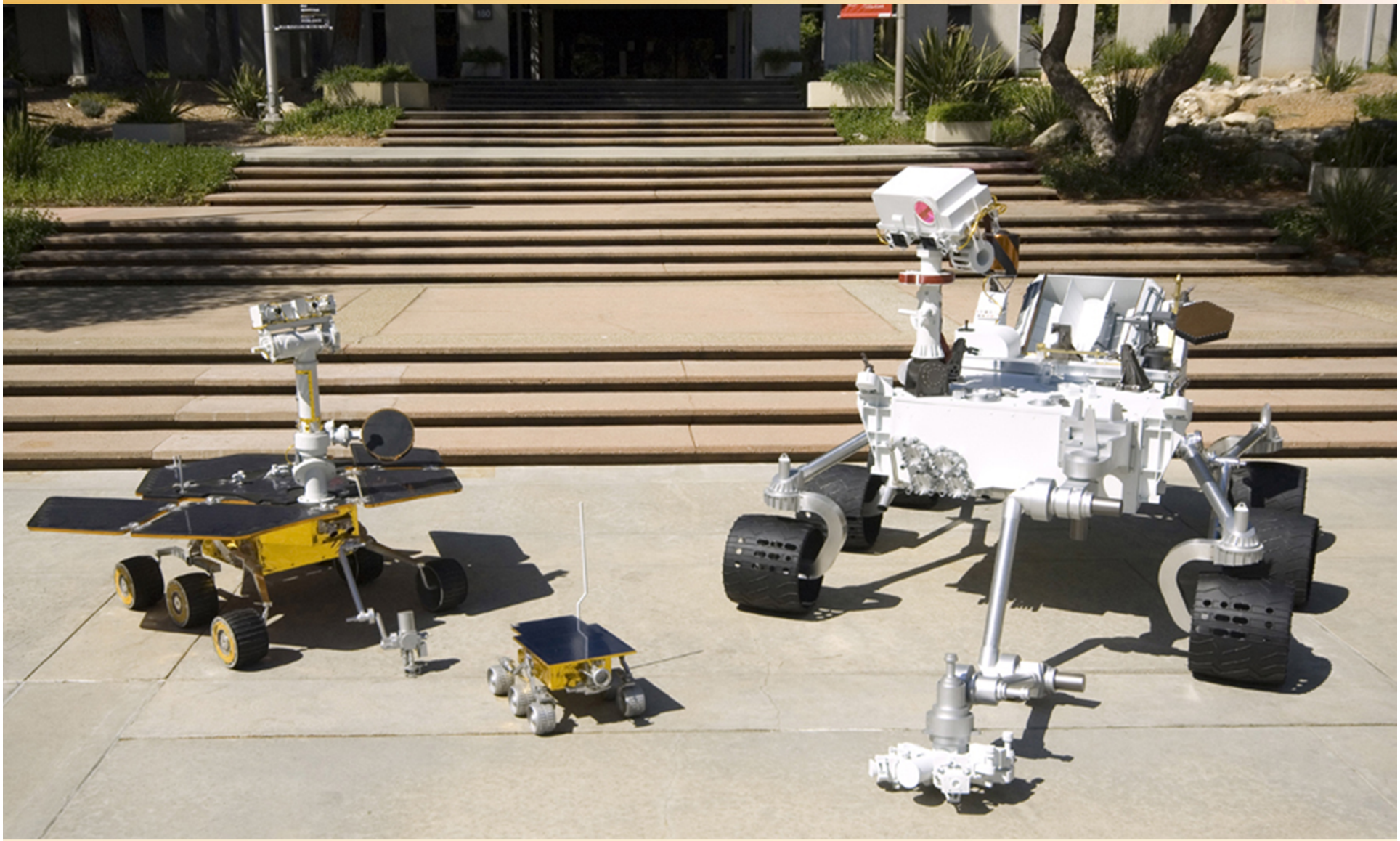
Kendra Short

Manager, Mechanical Systems Division

Jet Propulsion Laboratory

SIEMENS

Mars Rover Family Portrait



MARS SCIENCE STRATEGY: Follow the Water!

Common Thread

W A T E R

When? Where? Form? Amount?

Determine if Life Ever Arose on Mars

LIFE

Characterize the Climate

CLIMATE

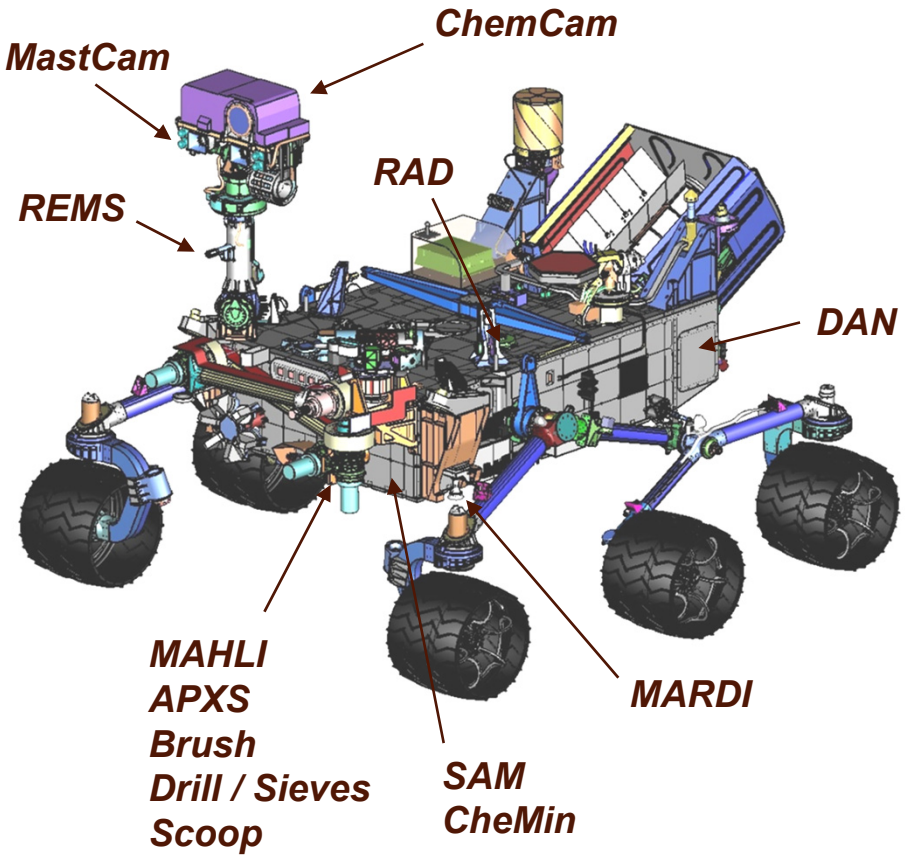
Characterize the Geology

GEOLOGY

Prepare for Human Exploration

HUMAN

MSL Payload



Wheel Base:	**2.2 m**
Height of Deck:	**1.1 m**
Height of Mast:	**2.2 m**

REMOTE SENSING

MastCam (M. Malin, MSSS) - Color imaging, atmospheric opacity

ChemCam (R. Wiens, LANL/CNES) – Chemical composition; remote micro-imaging

CONTACT INSTRUMENTS (ARM)

MAHLI (K. Edgett, MSSS) - Microscopic imaging

APXS (R. Gellert, U. Guelph, Canada) - Chemical composition

ANALYTICAL LABORATORY (ROVER BODY)

SAM (P. Mahaffy, GSFC/CNES) - Chemical and isotopic composition, including organics

CheMin (D. Blake, ARC) - Mineralogy

ENVIRONMENTAL CHARACTERIZATION

MARDI (M. Malin, MSSS) - Descent imagery

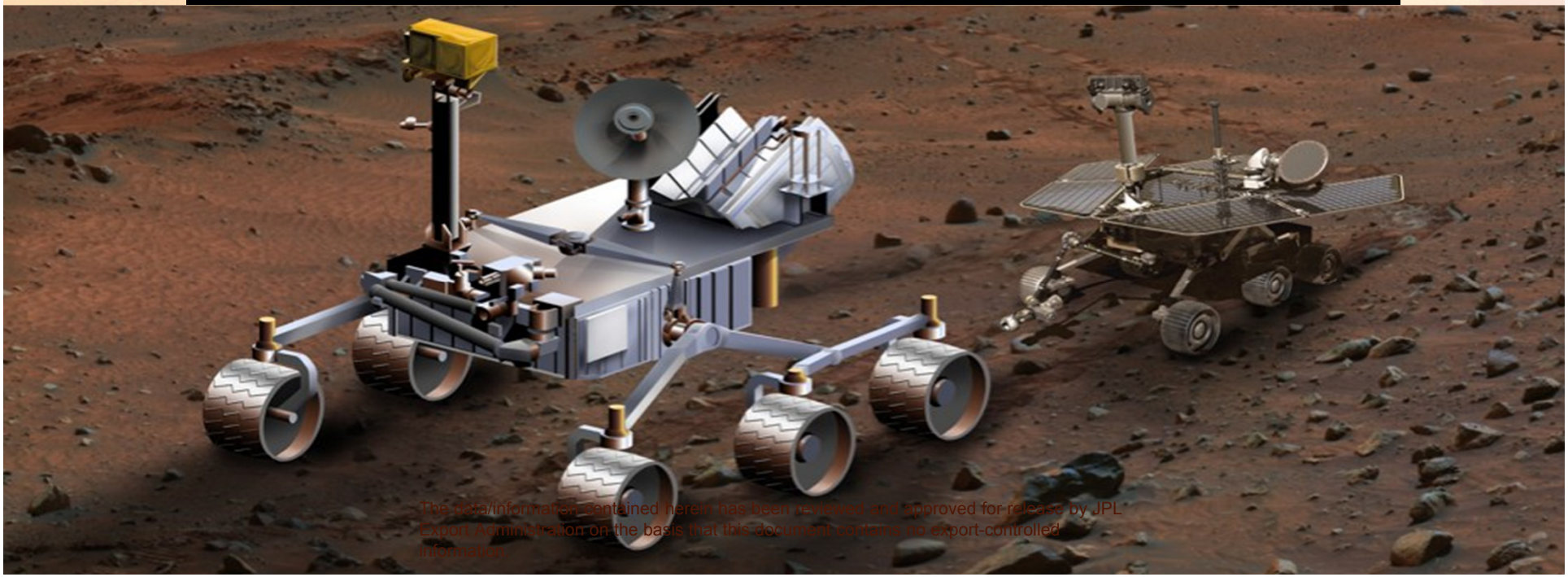
REMS (J. Gómez-Elvira, CAB, Spain) - Meteorology / UV

RAD (D. Hassler, SwRI) - High-energy radiation

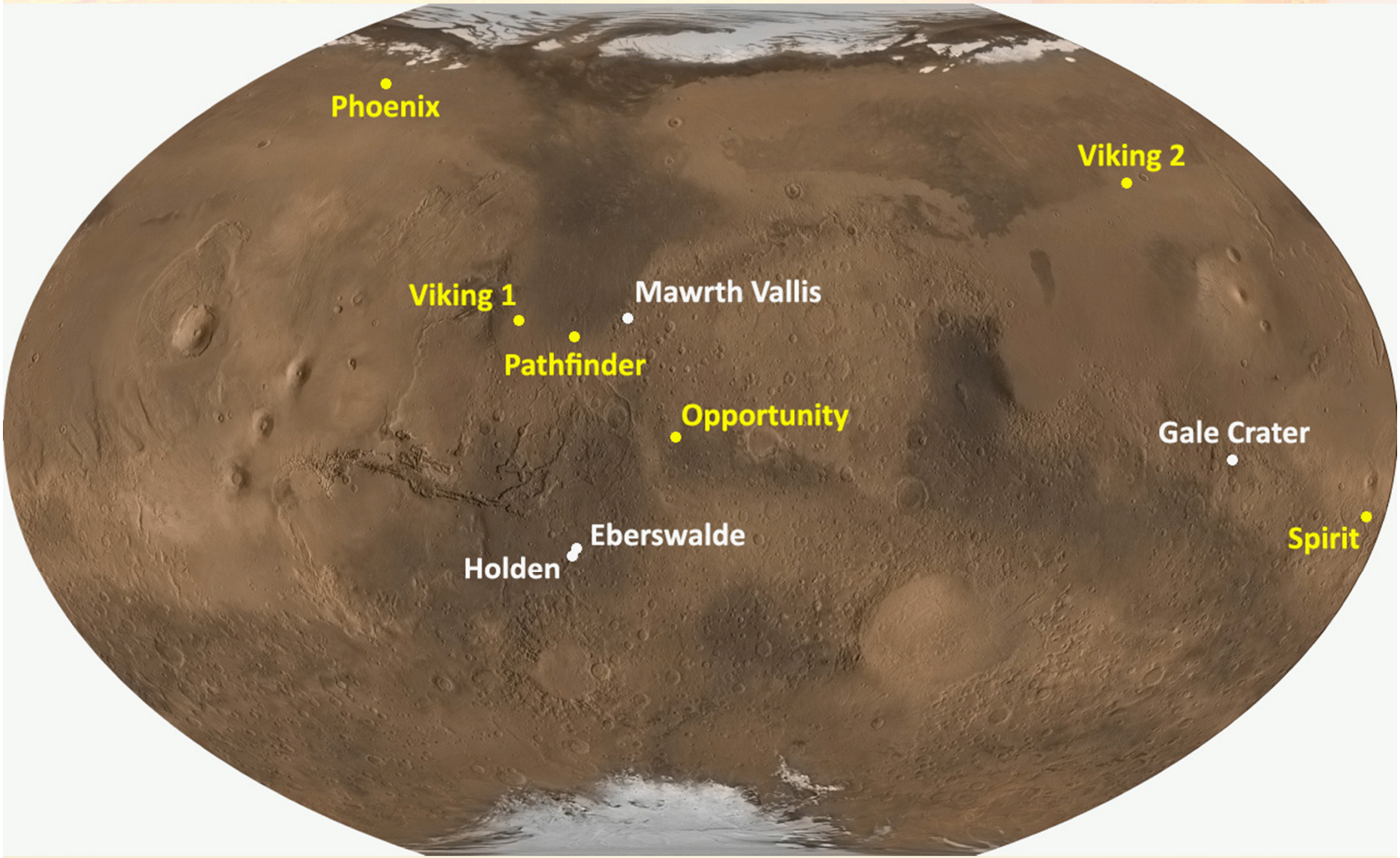
DAN (I. Mitrofanov, IKI, Russia) - Subsurface hydrogen

MSL - MER Mission Comparison

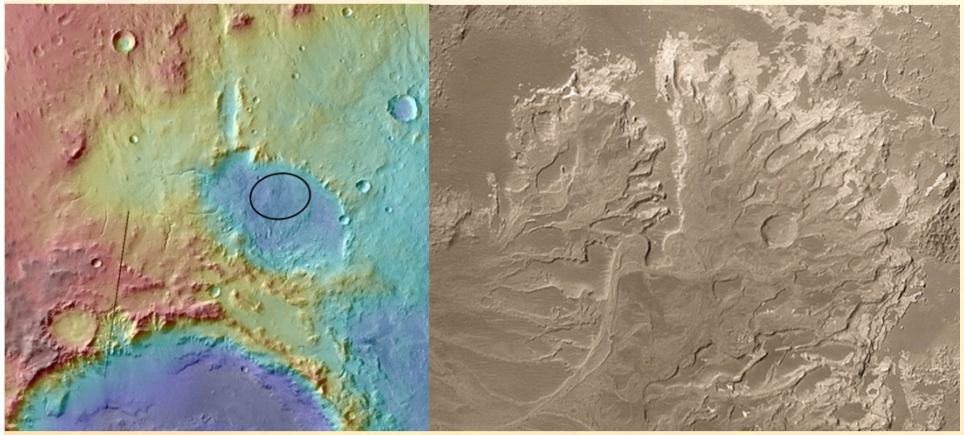
	MSL	MER
LV/Launch Mass	Atlas V/4000 kg	Delta II/1050 kg
Prime Mission	1 yr. cruise/2 yrs. surface	7 mo. cruise/3 mo. surface
Payload	10 instruments (80 kg)	5 instruments (~5 kg)
EDL System	Guided entry + skycrane	MPF Heritage/Airbags
Heatshield Diam.	4.5 m	2.65 m
Surface Power	RTG at 2500 W-hr/sol	Solar Panels at <900 W-hr/sol
Rover Mass	950 kg (allocation)	170 kg (actual)
Rover Range	>20 km	>600 m (few km actual)



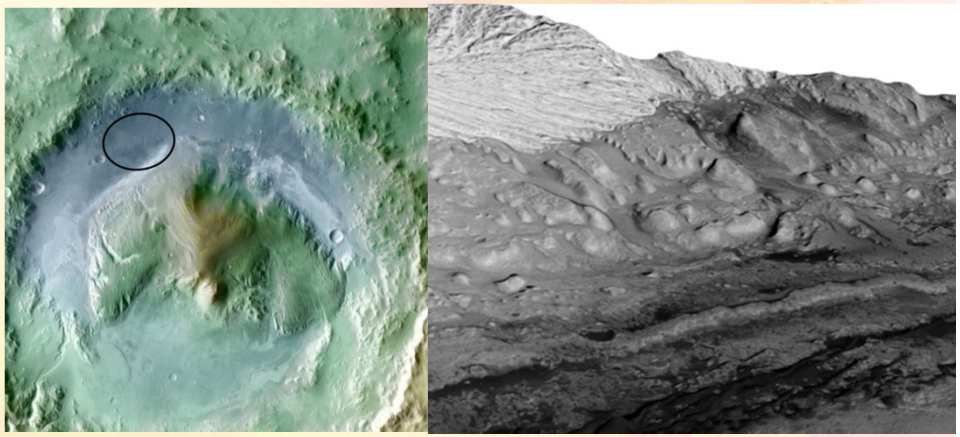
Previous and MSL Landing Sites



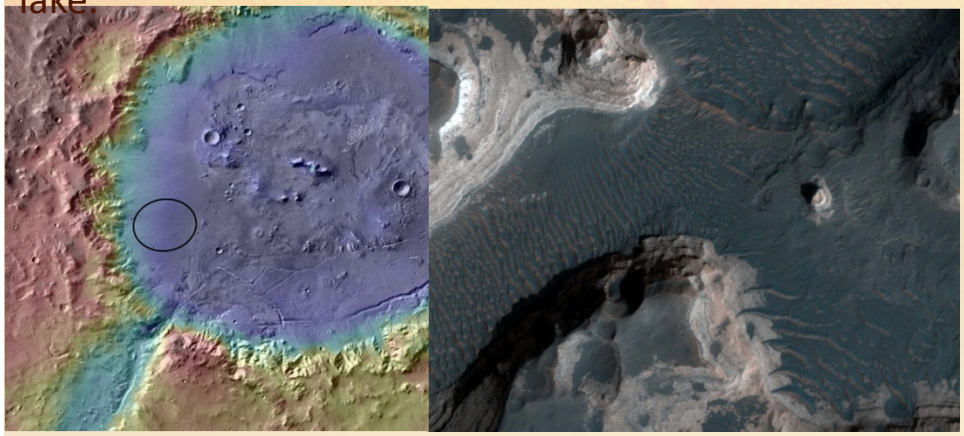
MSL Final Candidate Landing Sites



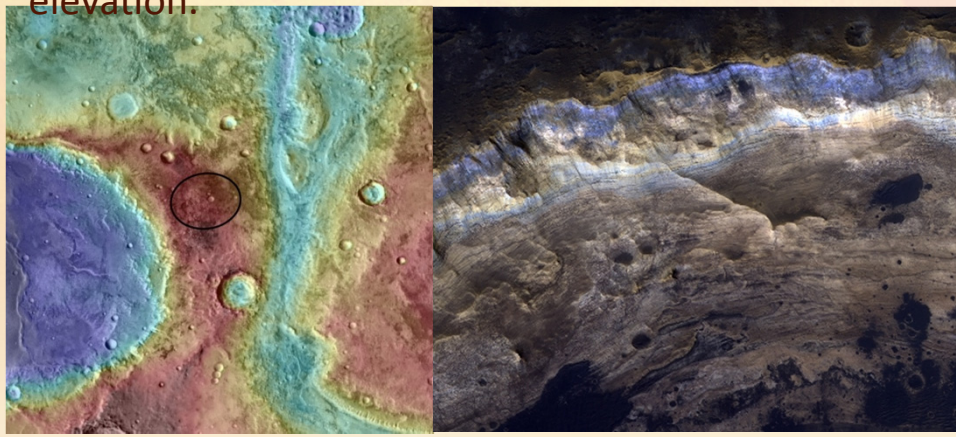
Eberswalde Crater (24° S, 327° E, -1.5 km) contains a clay-bearing delta formed when an ancient river deposited sediment, possibly into a lake.



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.

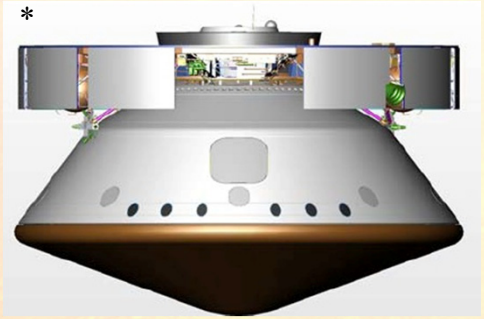


Holden Crater (26° S, 325° E, -1.9 km) has alluvial fans, flood deposits, possible lake beds, and clay-rich sediment.



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

MSL Mission Overview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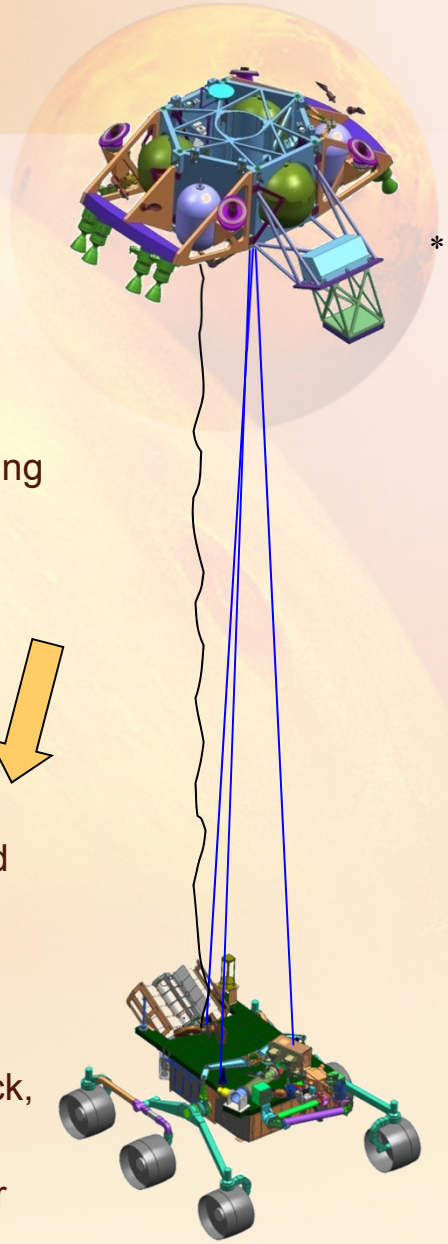
CRUISE/APPROACH

- 9-10 month cruise
- Spinning cruise stage
- Arrive N. hemisphere summer

ENTRY, DESCENT, LANDING

- Guided entry and controlled, powered “sky crane” descent
- 20 × 25-km landing ellipse
- Discovery responsive for landing sites ±30° latitude, <0 km elevation
- ~1000-kg landed mass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SURFACE MISSION

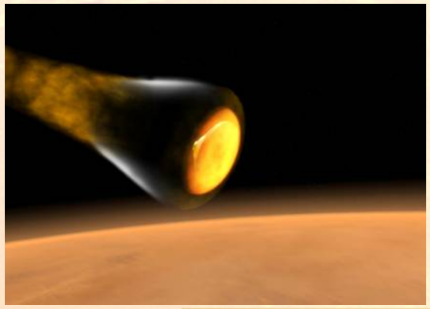
- Prime mission is one Mars year
- Latitude-independent and long-lived power source
- 20-km range
- 85 kg of science payload
- Acquire and analyze samples of rock, soil, and atmosphere
- Large rover, high clearance; greater mobility than MPF, MER

LAUNCH

- Nov. 2011
- Atlas V (541)

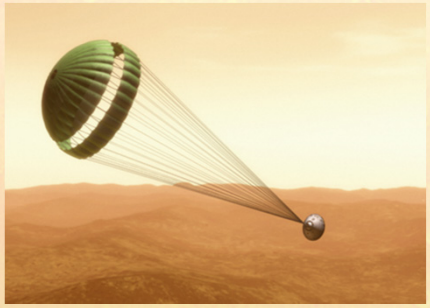
* Artist’s Renderings

Entry, Descent and Landing Timeline



Entry

Energy Dissipation Via: Aerodynamic Drag / Aerothermodynamic heating
Velocity Range: 12,000 mph → 1,000 mph
Peak Temperature : 1447° C

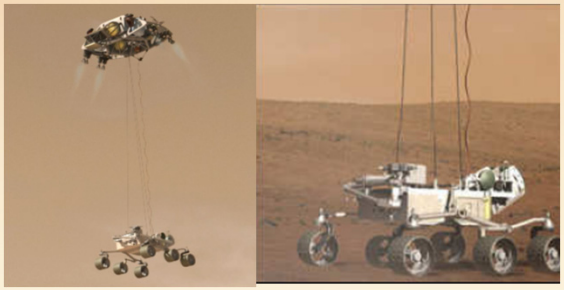


Parachute Descent

Energy Dissipation via: Aerodynamic Drag
Velocity Range: 1,000 mph → 200 mph

Powered Descent

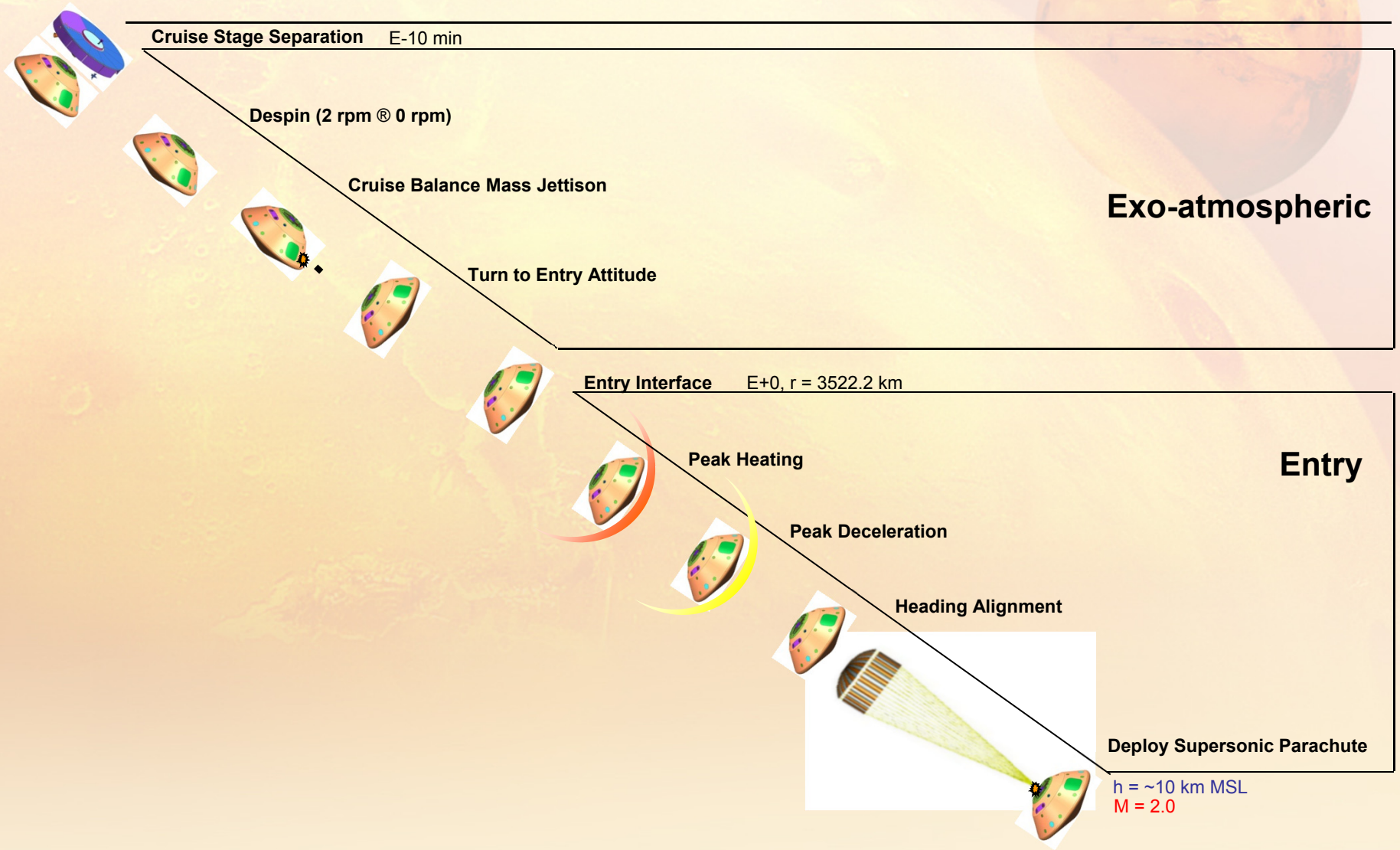
Energy Dissipation Via: Rocket Thrust
Velocity Range: 200 mph→4-40 mph



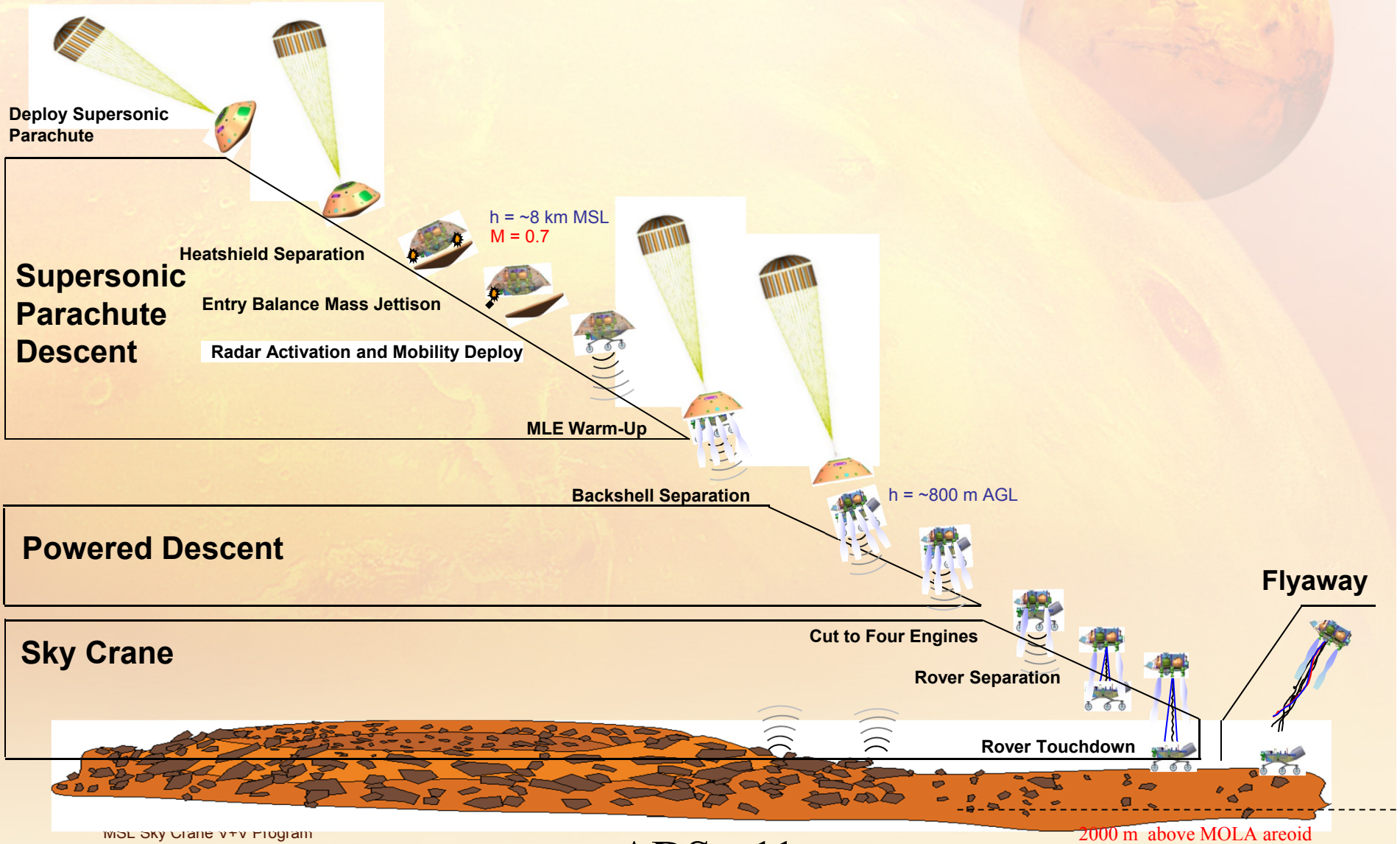
Landing

Energy Dissipation Via: Viscous Damping
Velocity Range: 4 – 40 mph → 0.0 mph

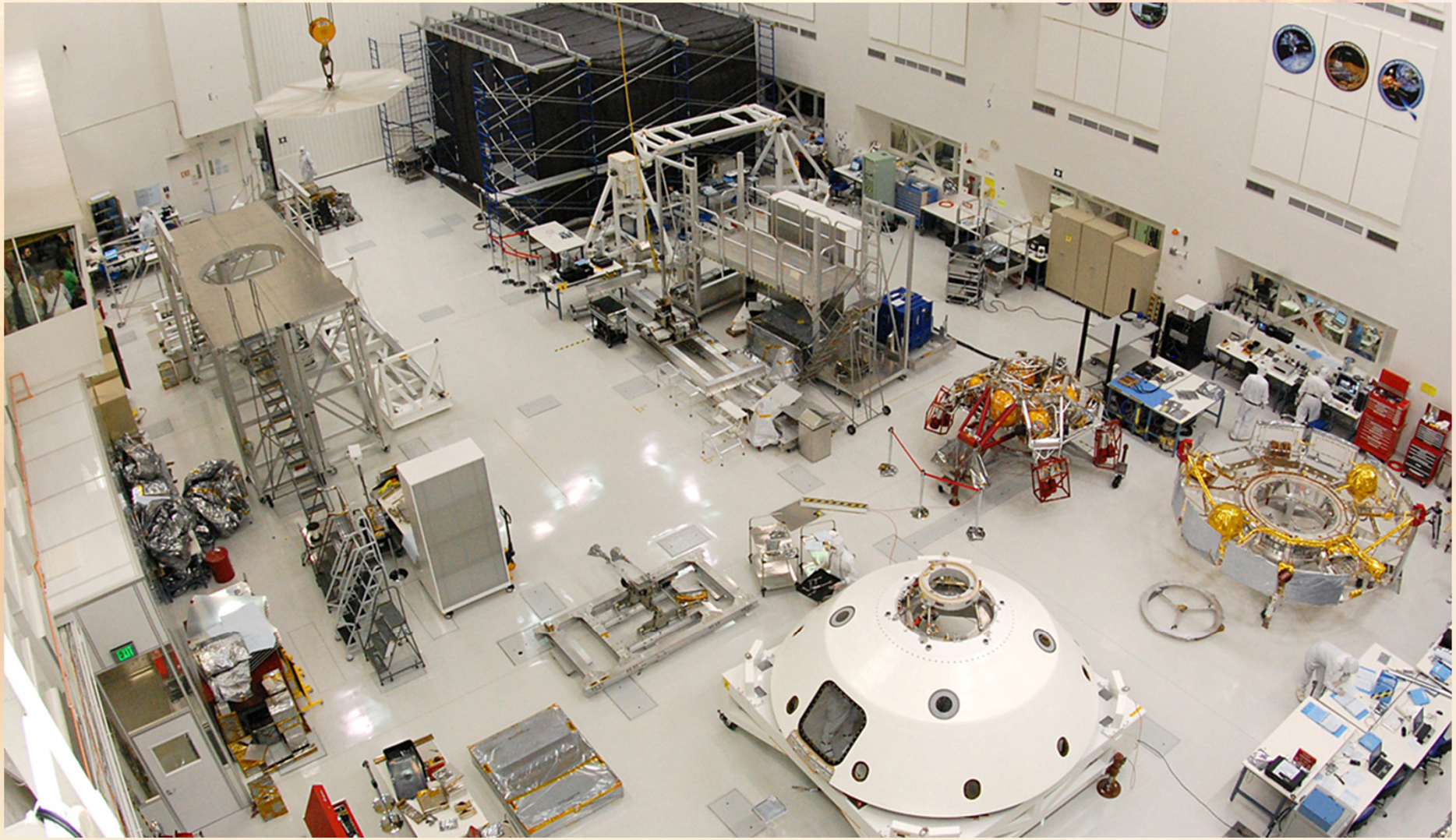
EDL Overview – Event Timeline



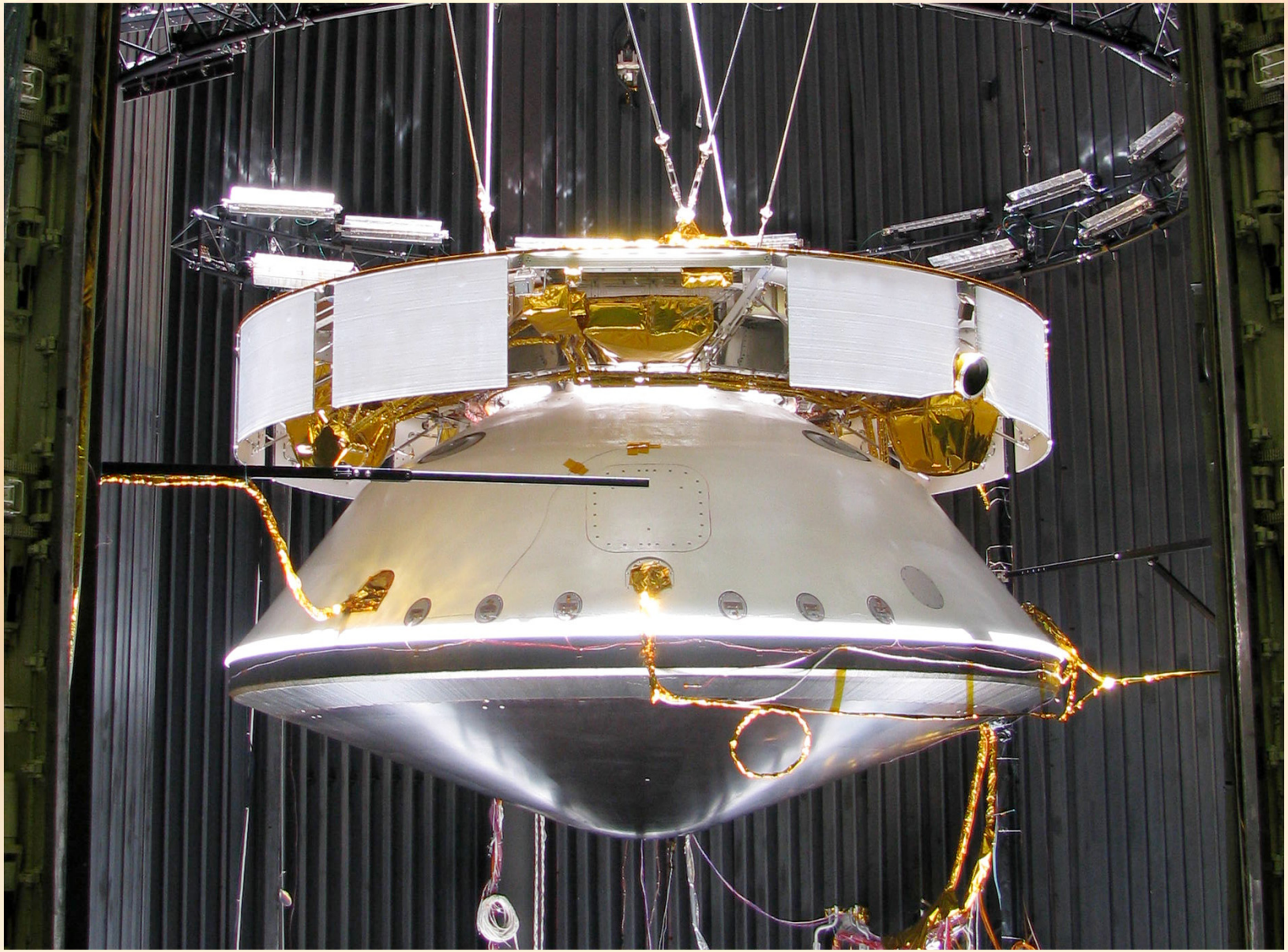
EDL Overview – Event Timeline (cont.)



Assembly High Bay



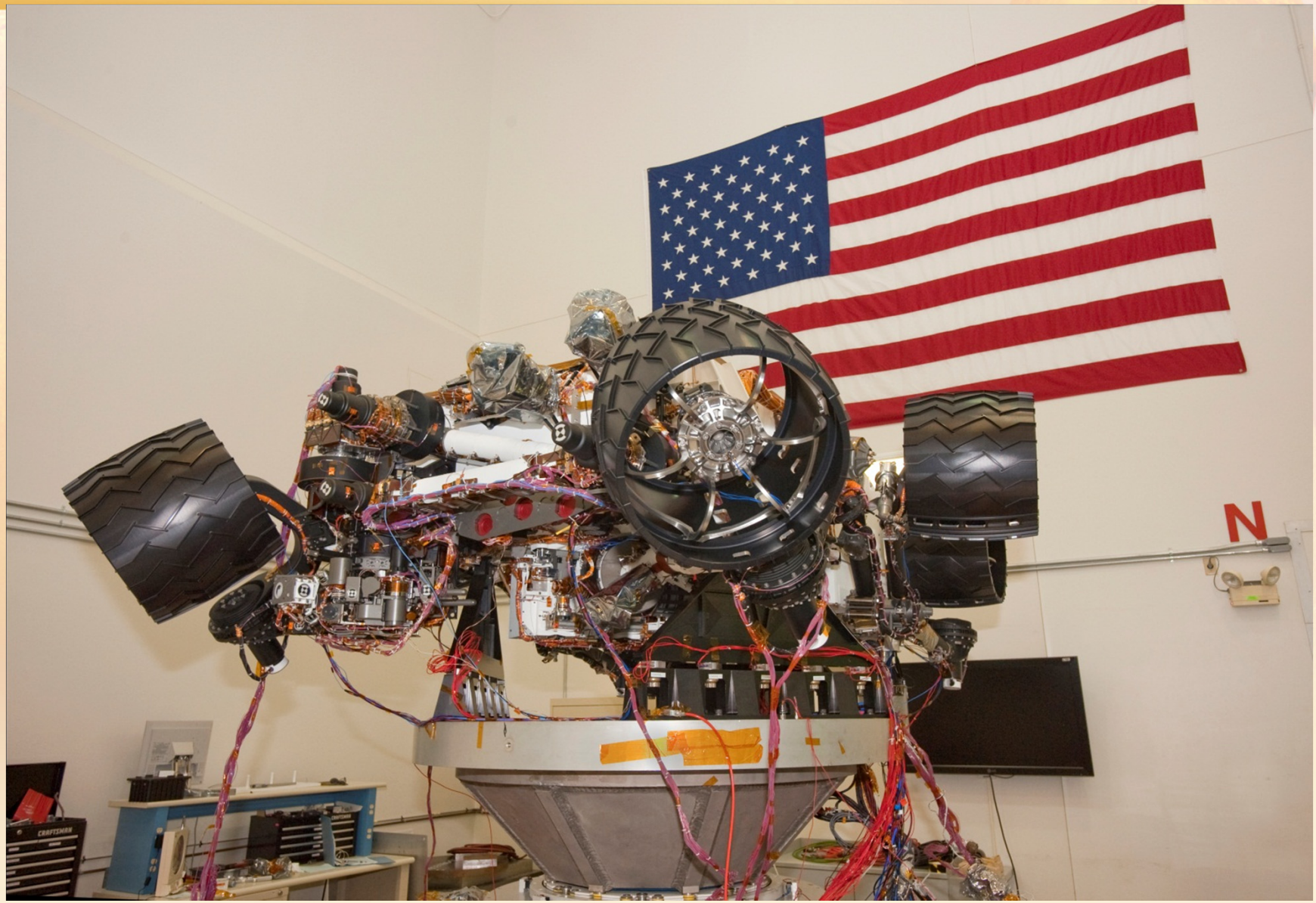
Cruise System Solar Thermal Vacuum Test



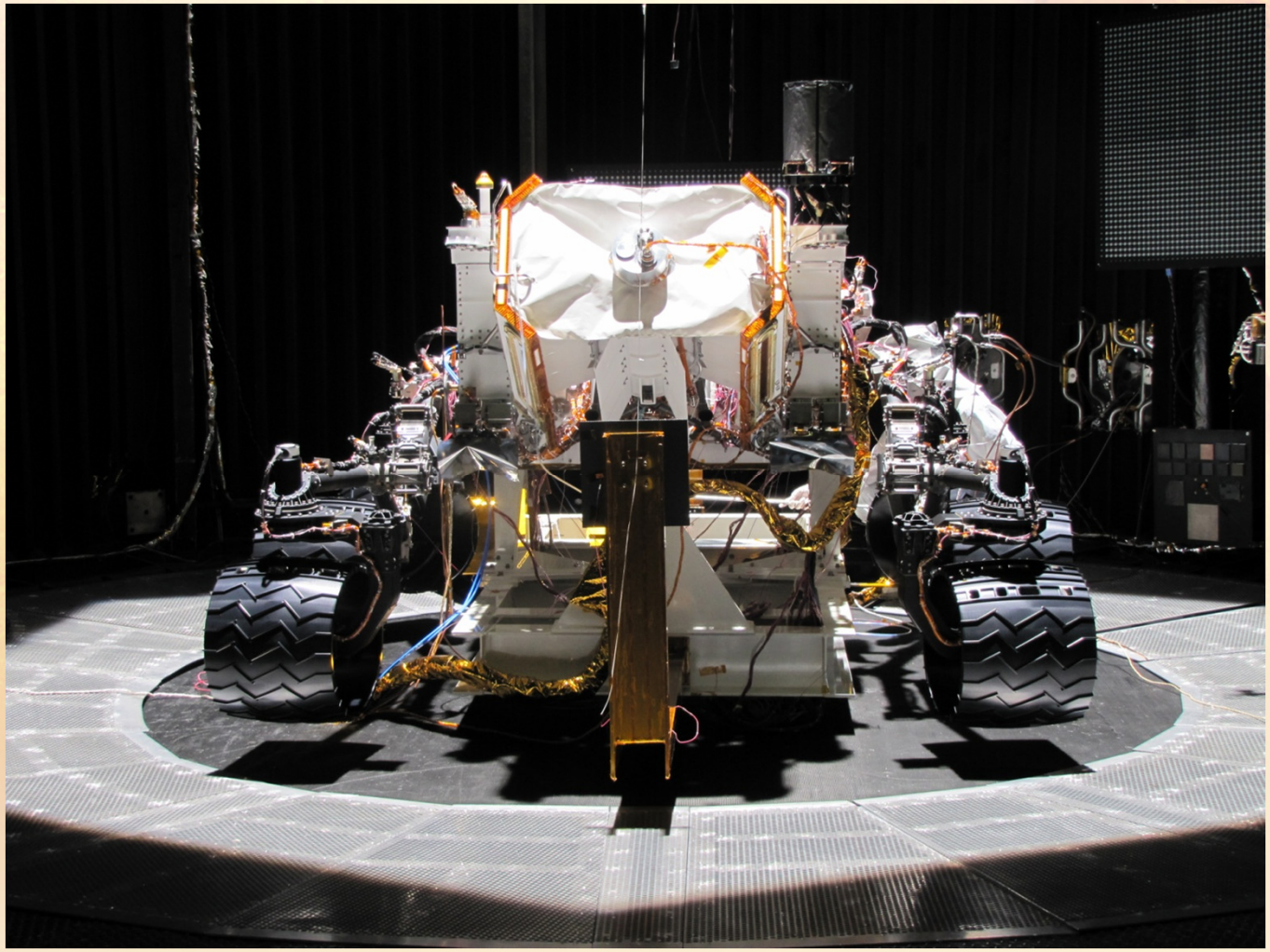
Rover Traverse

Arm Operations

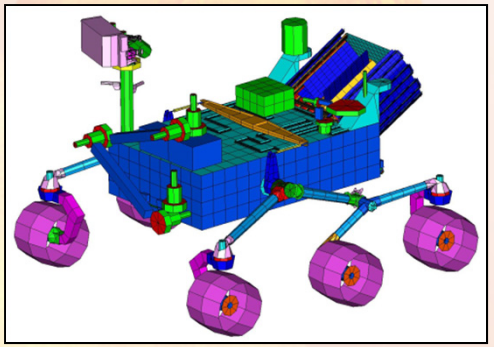
Rover Z-Axis Vibe



Rover Surface Test



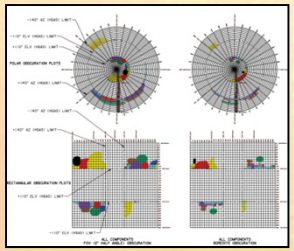
NX Design and Simulation- MSL Mapping



System Design and Configuration - parts and assembly models, drawings, WIP data management, top assembly configuration, viewing

Thermal Analysis & Performance – modeling, test predictions and correlation

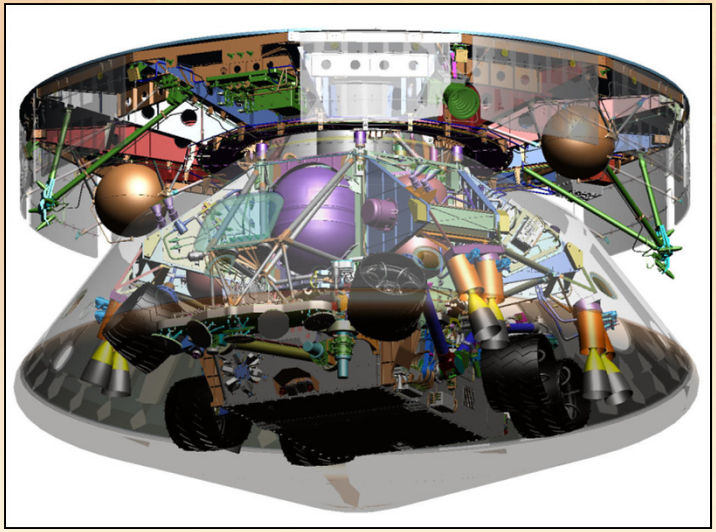
Cabling – design and routing of round wire and flex



System Loads & Dynamics - parts stress, FEM, testing

Separation Events – clearances, dynamics, validation tests

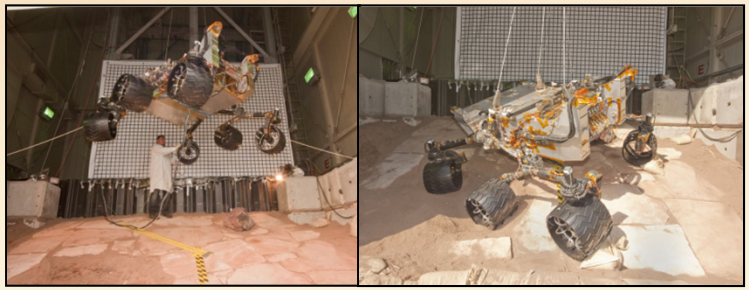
Motion – deployments, range of motion, swept volumes, interferences



Mass Properties – CG determination

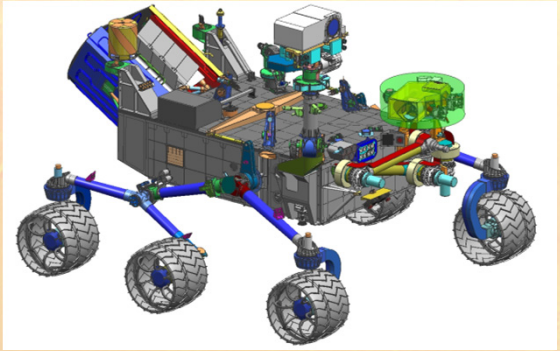
View Factors – Obscurations, FOVs

Released Products – data mgmt

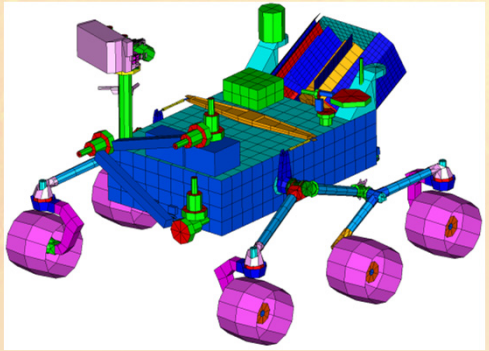


Rover Thermal Design, analysis and test

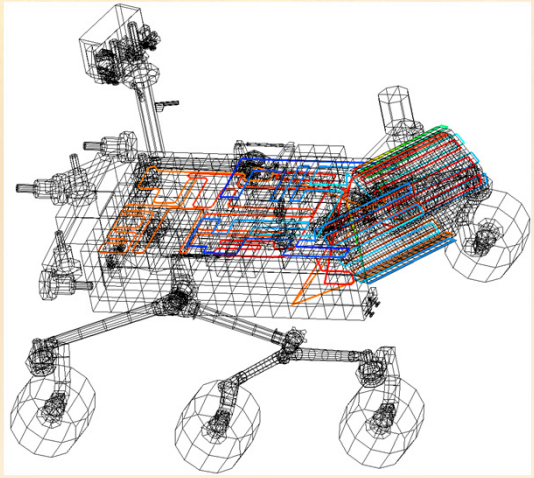
Based on UGNX solid model design geometry, a full system surface model was generated in TMG. Both a thermal mesh and a flow mesh were created for the rover with emphasis on the HRS.



MSL Solid Geometry

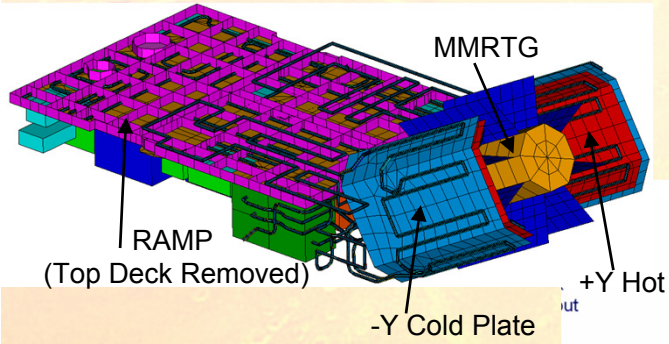


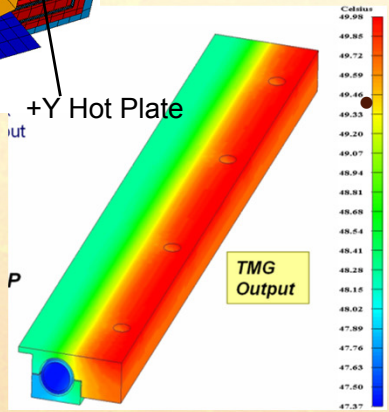
MSL Thermal Mesh



MSL Fluid Mesh

Rover Thermal Design & System Model



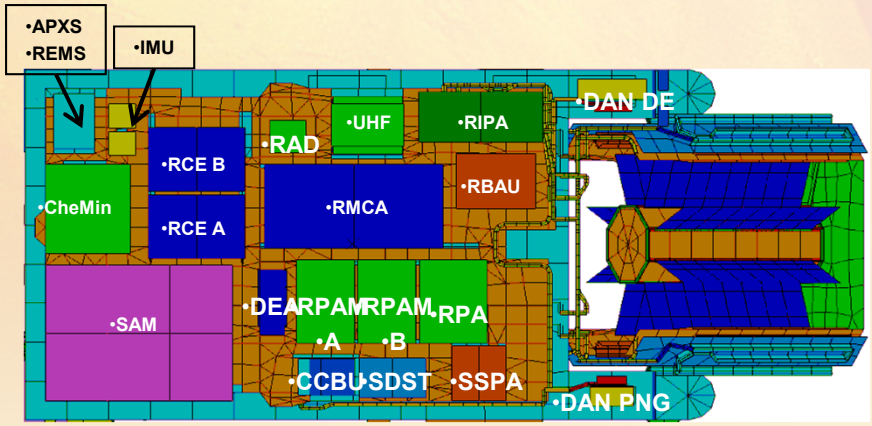


- *Active Thermal Design*
  - *Surface Heat Rejection System (SHRS)*
  - *Heaters controlled by FSW or mechanical thermostats and commandable heaters*

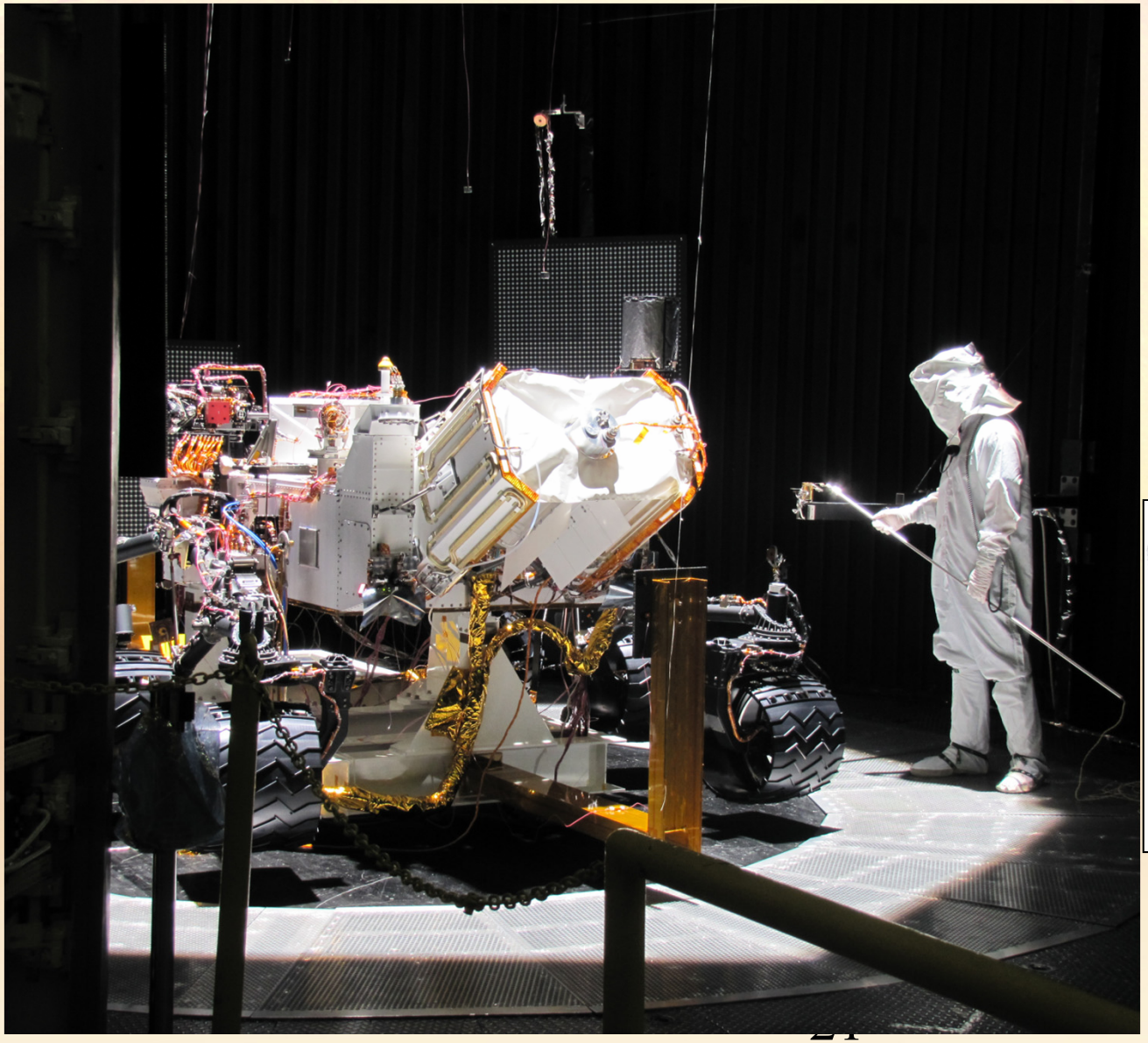
Passive Thermal Design

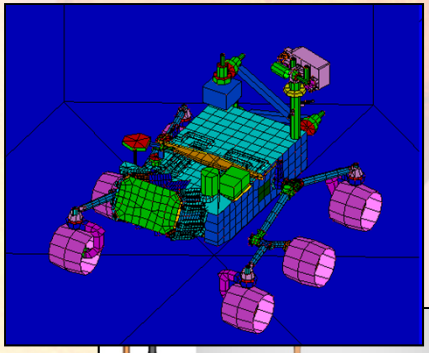
- *Paints (top deck, chassis walls, hot/cold plates are white)*
- *SLI blankets (bellypan and UHF antenna)*
- *Thermal straps (CheMIN)*

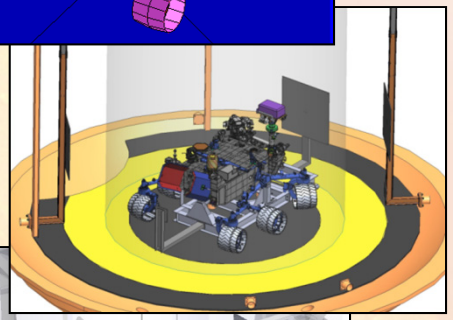
- *Detailed model of HRS and RAMP mounted Electronics interfaces*
- *All major external components coarsely represented for radiation blockage*
- *HRS valve logic modeled using Fortran subroutine with Flight valve data interfacing to TMG*

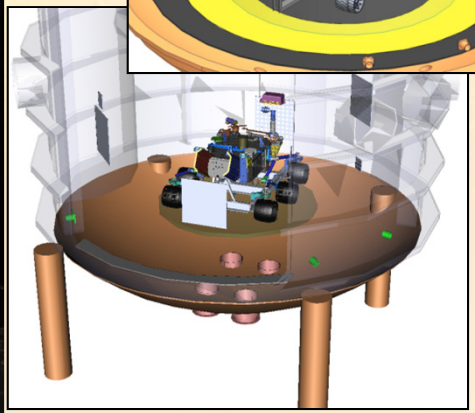


Rover Solar Thermal Test

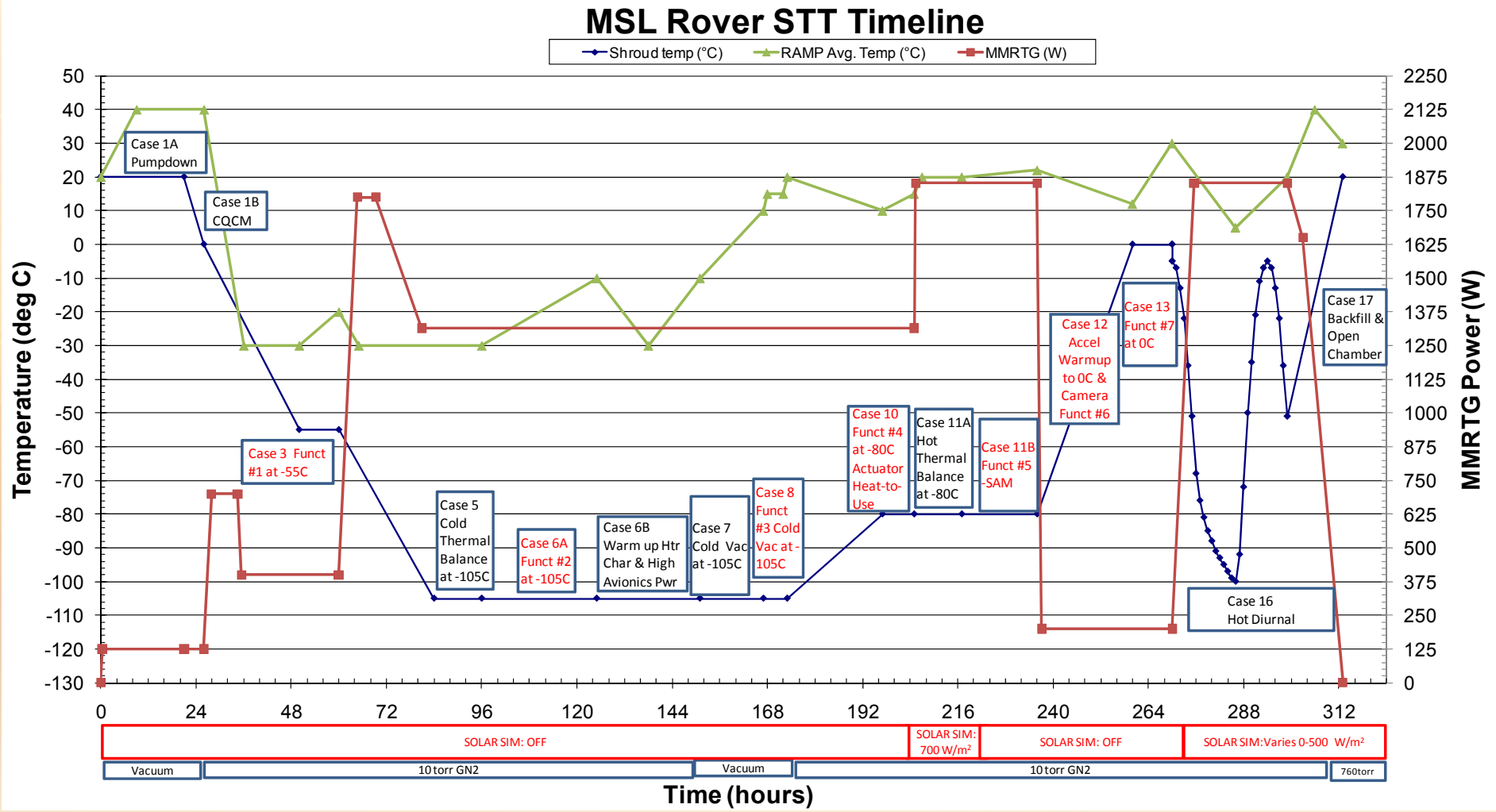




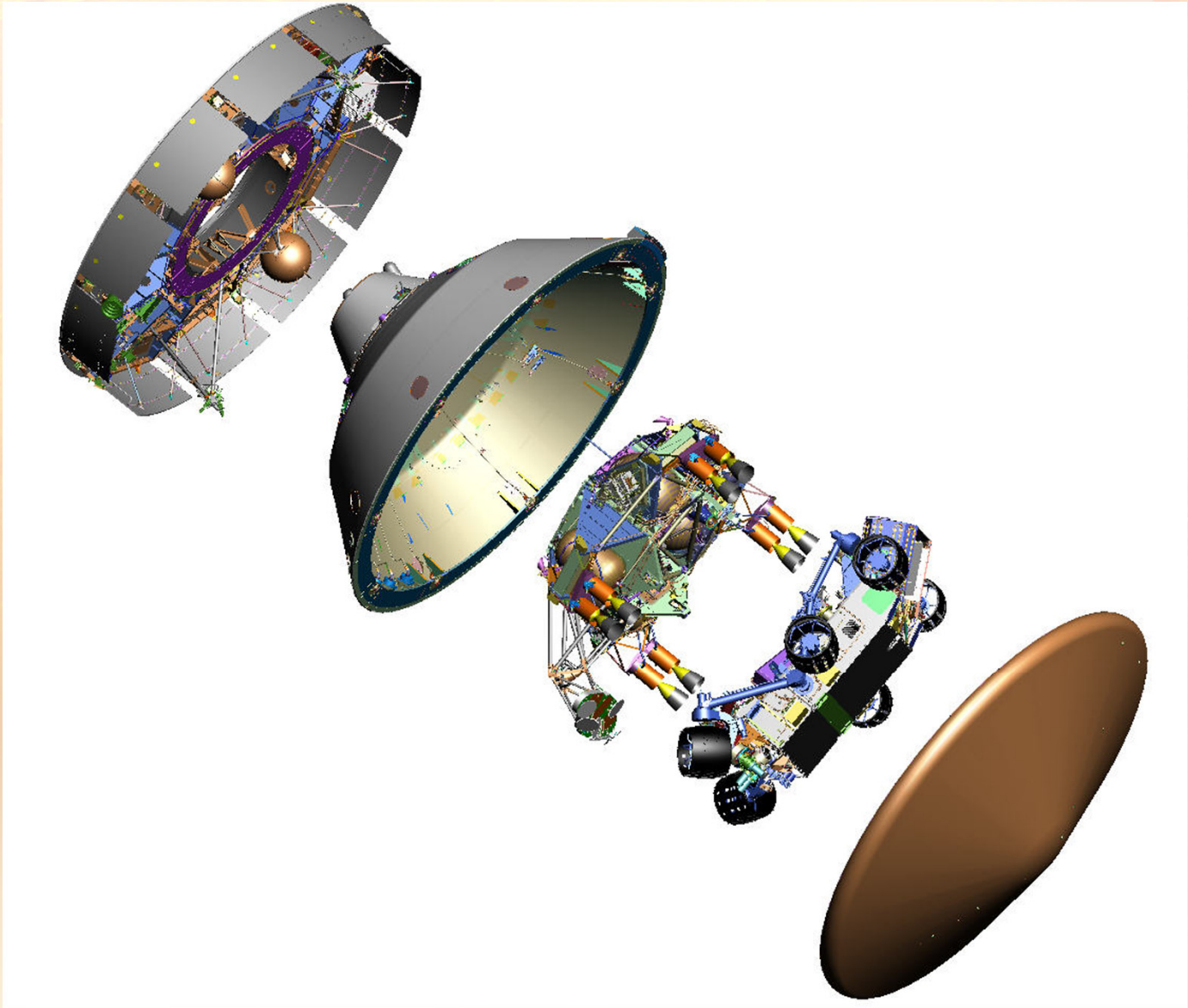




Test Profile

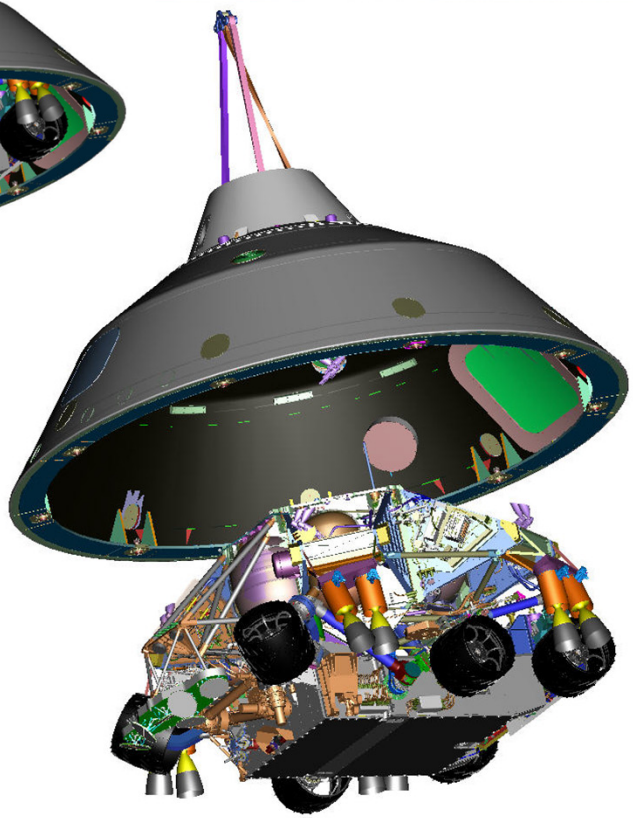


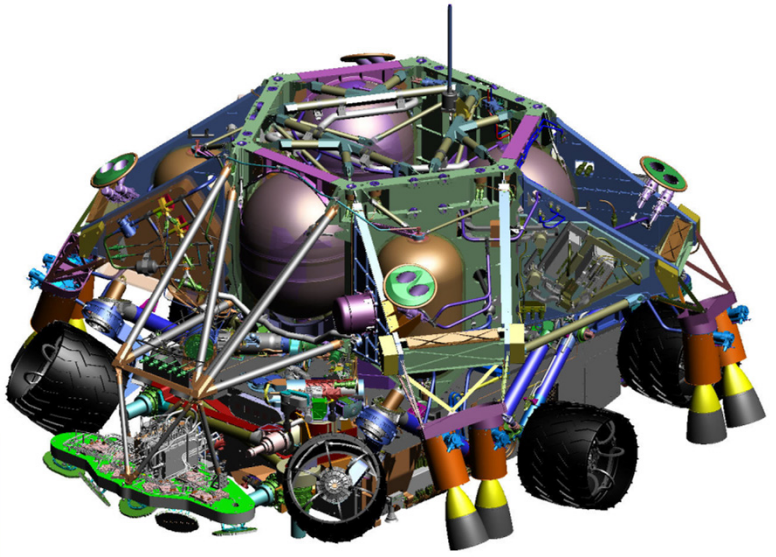
Separation Events



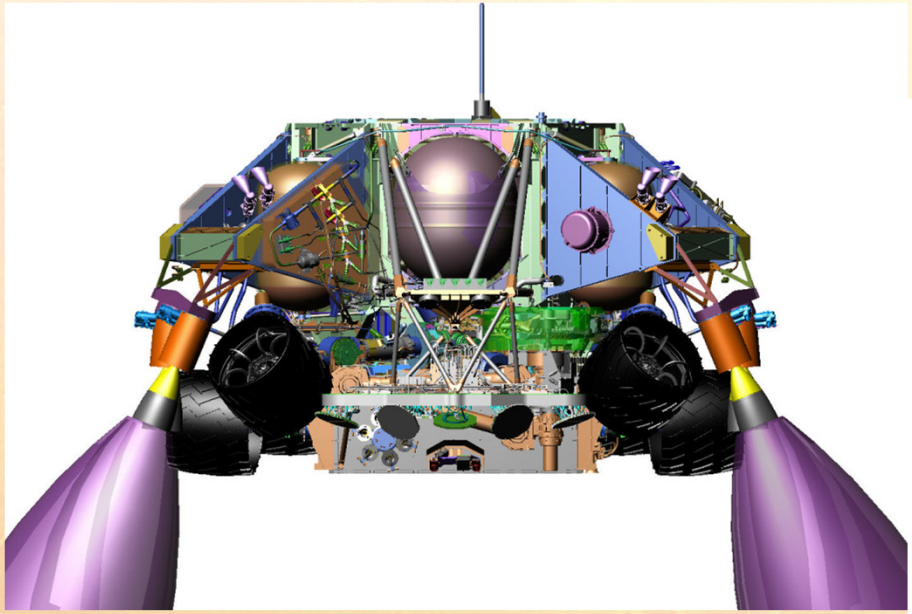
MSL has EIGHT major separation events and two post landing deployments

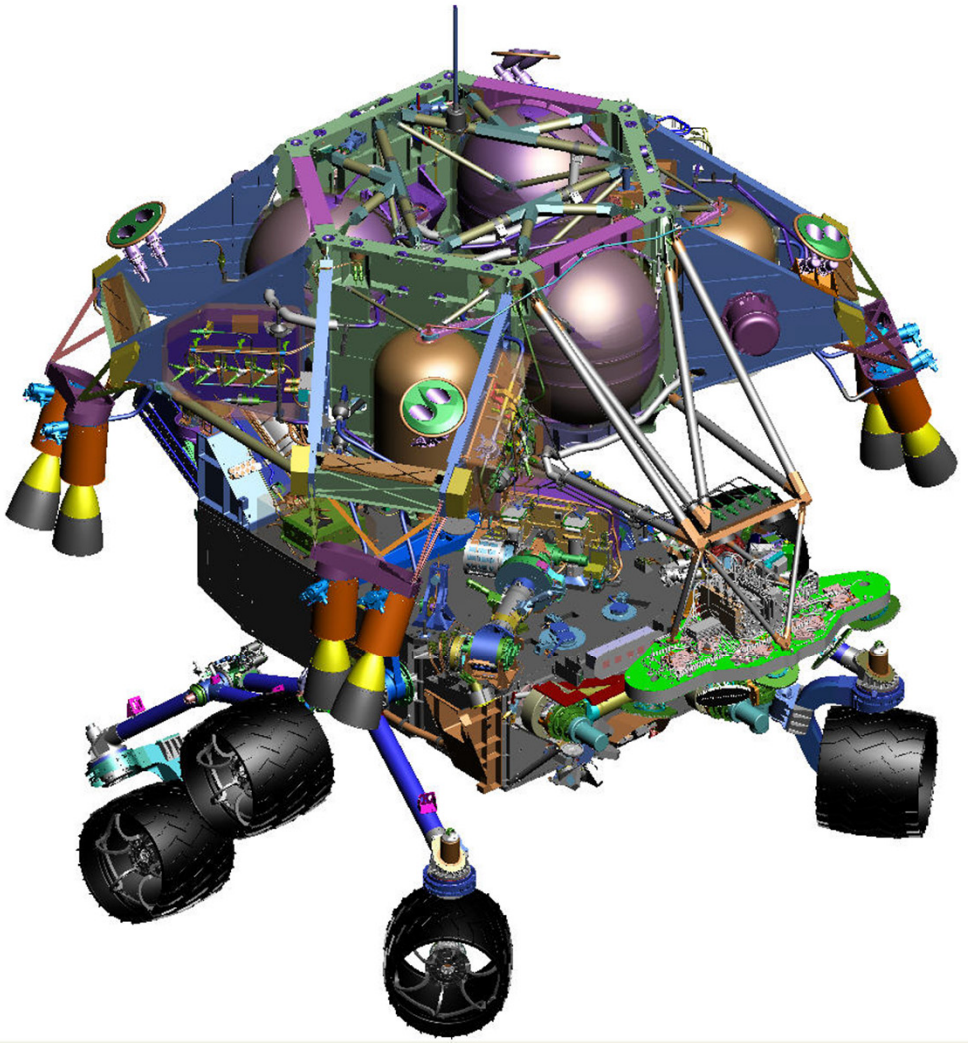
Powered Descent Vehicle Drop



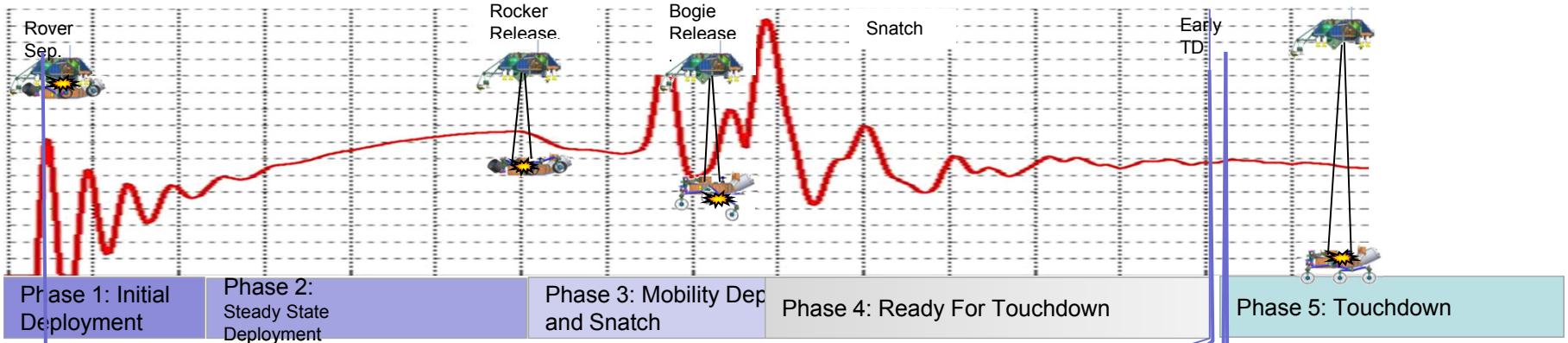


Skycrane Full Motion Drop





Rover Separation and Mobility Deploy Dynamics



Skycrane Initial Conditions

dVd/t
PDV Tilt angle
PDV X rate
PDV Y rate
PDV Z rate
Vel X
Vel Y
Vel Z

Margin Summary
BUD
Mobility

Ready for TD States: 3 sigma results

Vv
Vh
Chassis Pitch angle
Chassis Roll angle
Chassis Pitch rate
Chassis Roll rate
Chassis Yaw rate
Rocker angle
Bogie angle
Rocker rate
Bogie rate

Touchdown Initial Conditions

Vel h
Vel v

Chassis Pitch rate
Chassis Roll rate
Chassis Yaw rate
Rocker angle
Bogie angle

TD Performance Metrics

Mobility margins
Overturning stability

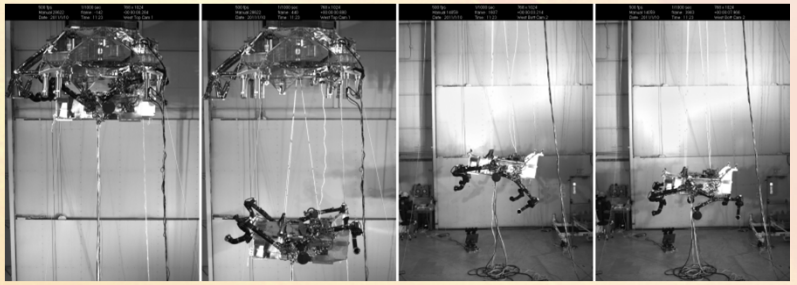
Traditional Dichotomy

A) Planar Rigid Slopes
B) Rock Strike

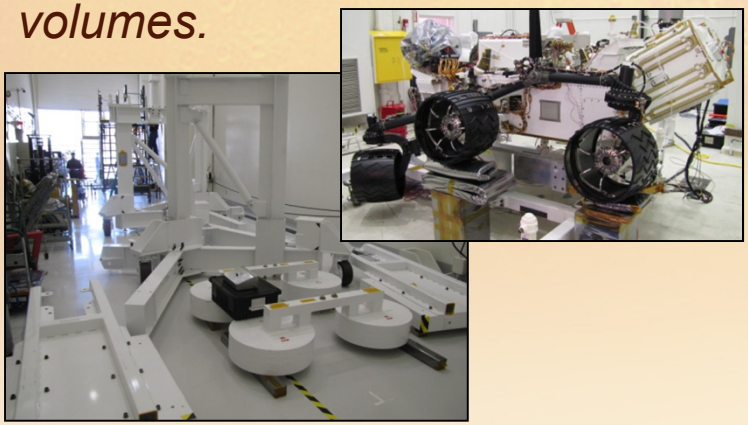
What's Next for JPL with NX?

- *Seamless integration of Design and Analysis Data in Design Reviews*

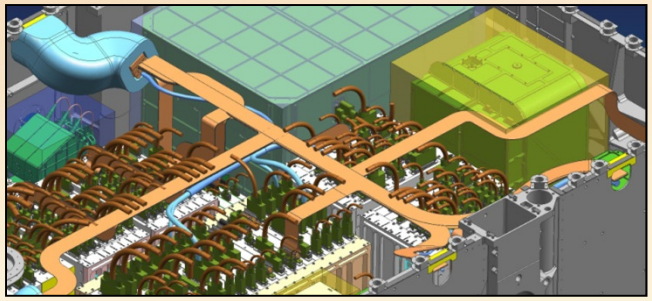
- *Increased integration of physics-based dynamics analysis, including quantification of margins and uncertainty.*



- *All Mechanical GSE in NX/TC Eng for interference checking with swept volumes.*



- *Full utilization of cable design and routing. "Virtual" cable mockups.*



Closing Comments

- *A strong partnership between the project engineers and the software developers isn't just good business practice, it's essential to engineering success.*

- *Successful evolution into a new CAE environment is a shared responsibility between application engineers and software suppliers.*
  - *It depends not just on new programs/capabilities, but achieving user confidence to migrate work practices. This is best achieved working hand in hand on real applications.*

- *The corporate environment must encourage utilization of the new environment to overcome the complexity-conundrum.*
  - *Complex problems will drive users to try new capabilities, but may pose more challenges to success.*
  - *Less challenging problems pose no necessity to do something new but offer greater chances of success.*

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Thank You!

Siemens PLM Connection 2011

Las Vegas, NV

May 2-5

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http://plmworld.org/