Mars Science Laboratory Entry, Descent and Landing

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Overview

- To date, NASA has placed three rovers on the surface of Mars
  - Mars Pathfinder (Sojourner), 1997 – technology demonstration for delivering a free-ranging robotic rover to the surface of Mars
  - Mars Exploration Rovers (Spirit and Opportunity), 2004 – Use the technology and lessons learned from Pathfinder to deliver rovers to look for evidence that liquid water once existed on Mars
- In 2009, NASA will launch the Mars Science Laboratory spacecraft to Mars
  - Assess the biological potential of the regions accessed by the rover.
  - Characterize the geology and geochemistry of these regions at all appropriate spatial scales (i.e., ranging from micrometers to kilometers).
  - Investigate planetary processes that influence habitability, including the role of water.
  - Characterize the broad spectrum of surface radiation, including galactic cosmic radiation, solar proton events, and secondary neutrons.
- In order to support these objectives the MSL system is several times larger than the MER system
  - MER: ~180 kg rover (~830 kg entry mass)
  - MSL: ~900 kg rover (~3000 kg entry mass)
  - For size perspective, the MSL rover is roughly the same size as a Mini Cooper
- **The EDL for MSL is more complex and has higher performance than any previous Mars mission.**

Size Comparison: MSL vs. Sojourner

MSL Technical Capabilities

Technical Capabilities

One Mars Year surface operational lifetime (669 sols/687 days)

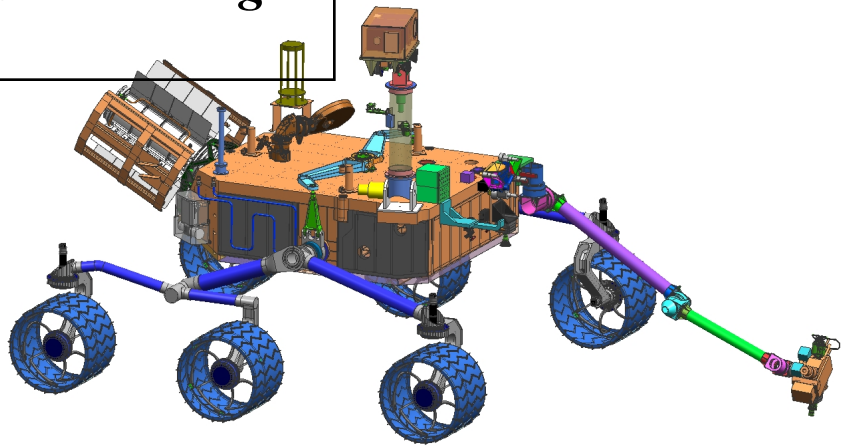
Discovery Responsive over wide range of latitudes and altitudes

Precision Landing via Guided Entry

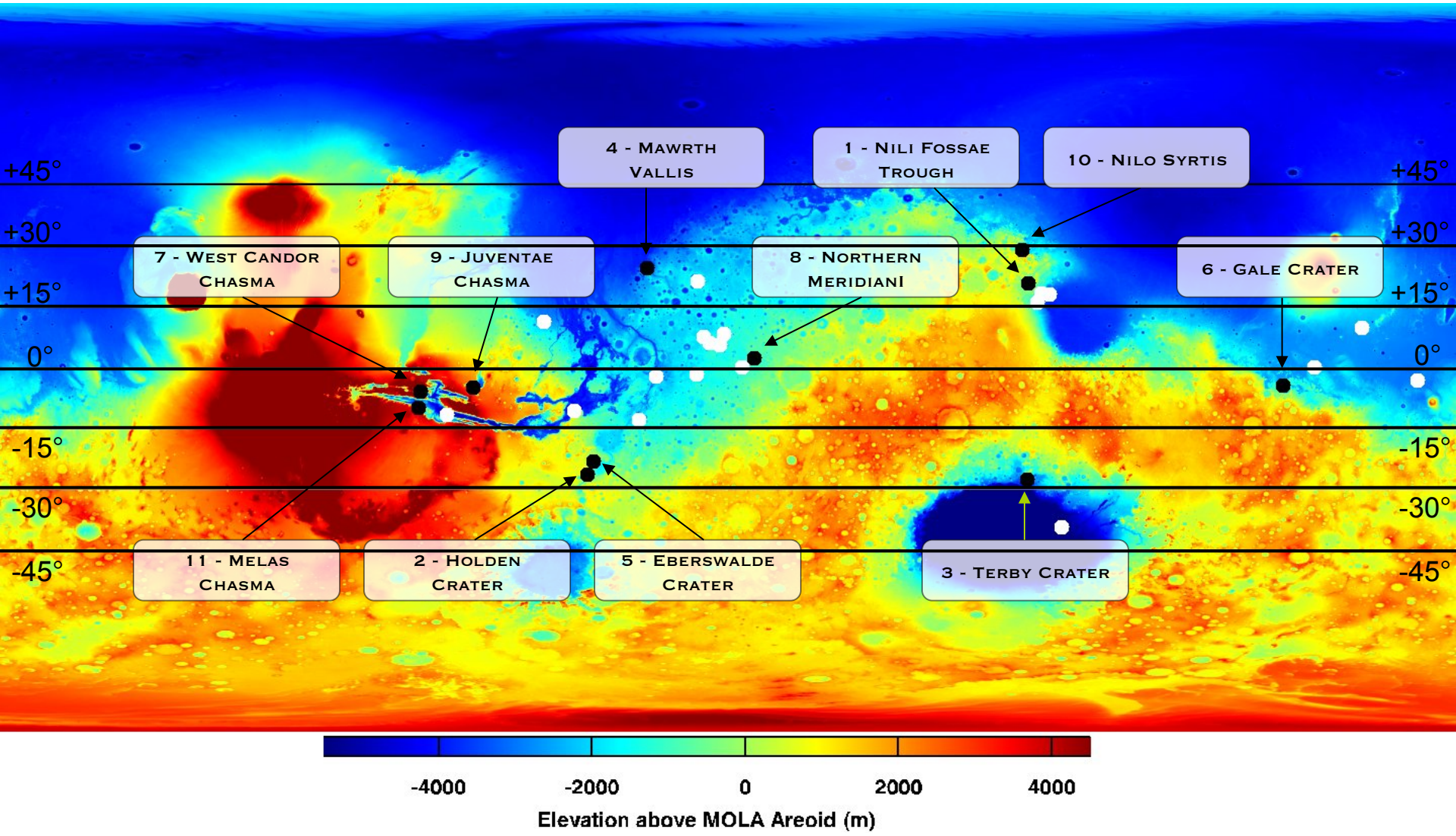
Skycrane Propulsive Landing

Long Distance Traverse Capability (20 km)

Flexible & Robust Sample Acquisition & Processing



Prioritized MSL Landing Sites



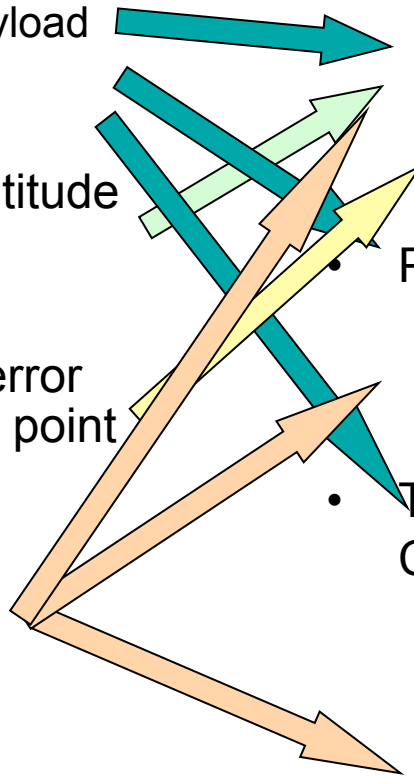
Higher-priority sites are black; others are white.

EDL Design

MSL EDL Driving Requirements

Key Driving EDL Requirements:

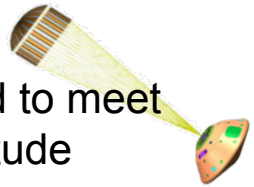
- Deliver 900 kg rover
  - Derived from Science payload Level 1 requirement
- 1.0 km MOLA or greater altitude
  - Level 1 requirement
- Landing with a maximum error of 10 km from the targeted point
  - Level 1 requirement
- Robust to environmental variation
  - Derived from discovery responsiveness



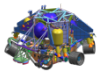
Key Design Responses:

- Guided Entry
  - Lifting entry and entry control to deliver mass to desired altitude
  - Entry guidance to meet landing precision requirement

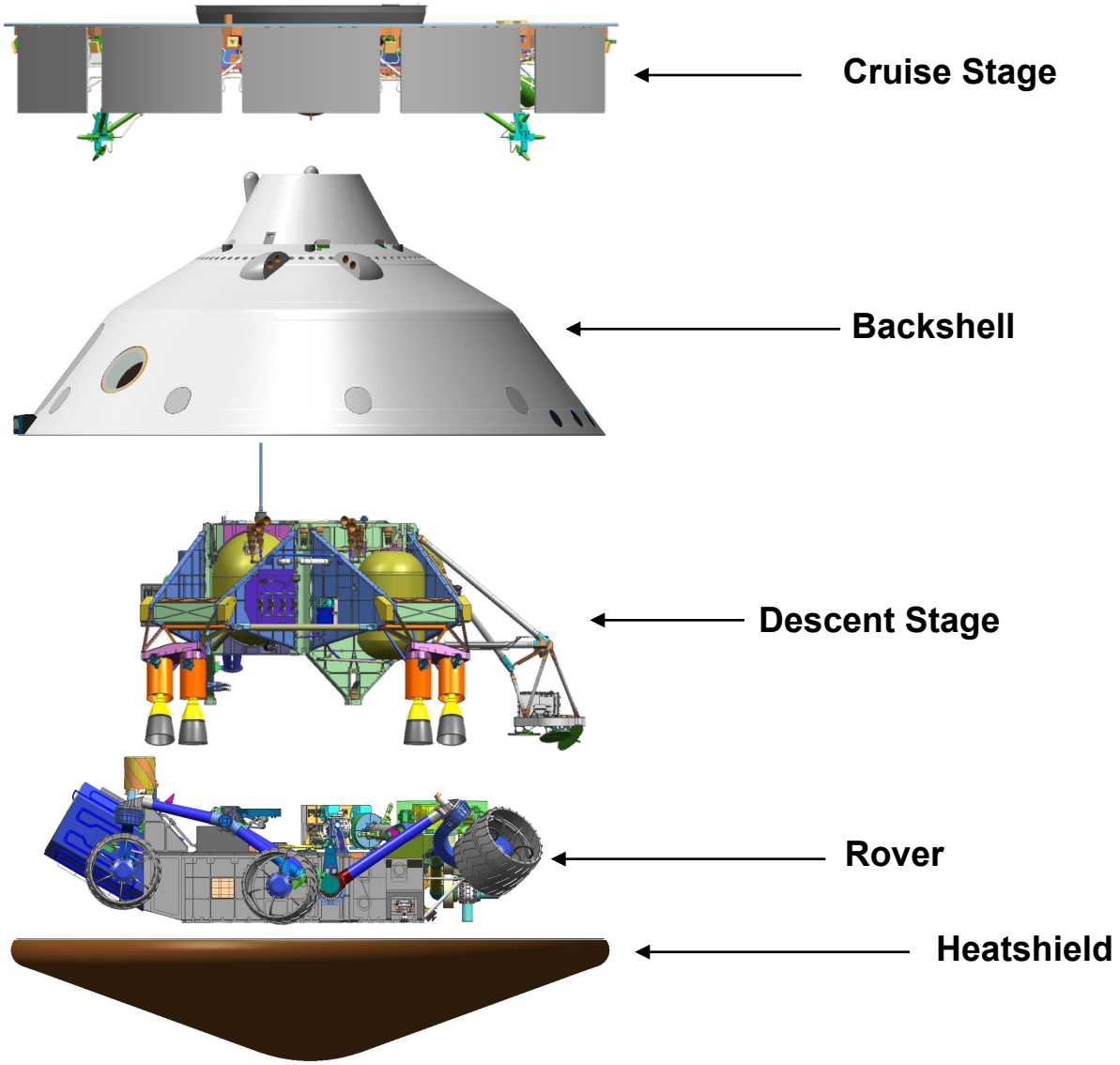
- Parachute
  - Parachute size selected to meet delivered mass and altitude requirements



- Throttled Powered Descent/Sky Crane
  - Delivered mass and interfaces eliminates use of airbag landing system
  - Terrain requirements drive powered descent profile and touchdown system architecture

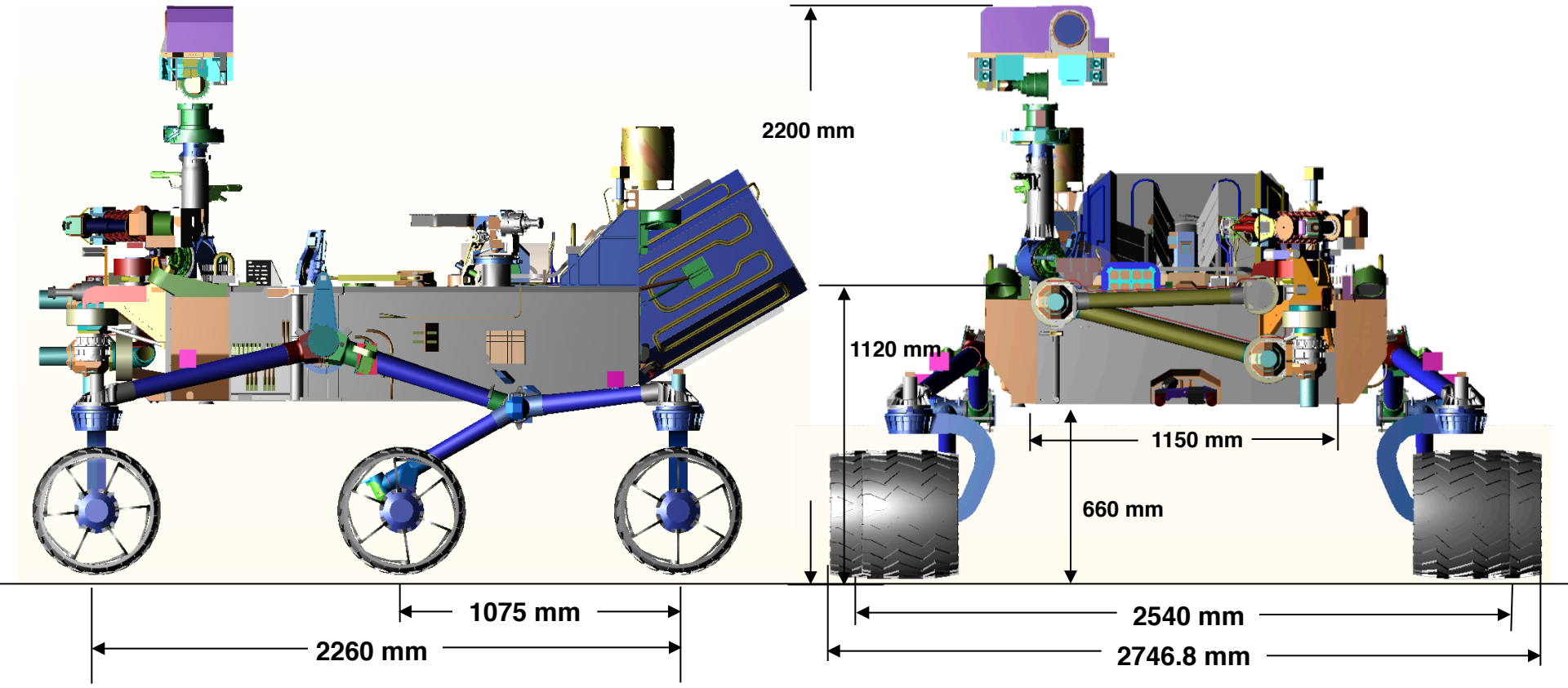


MSL Spacecraft Major Elements



Deployed Rover

Dimensions for Reference Only

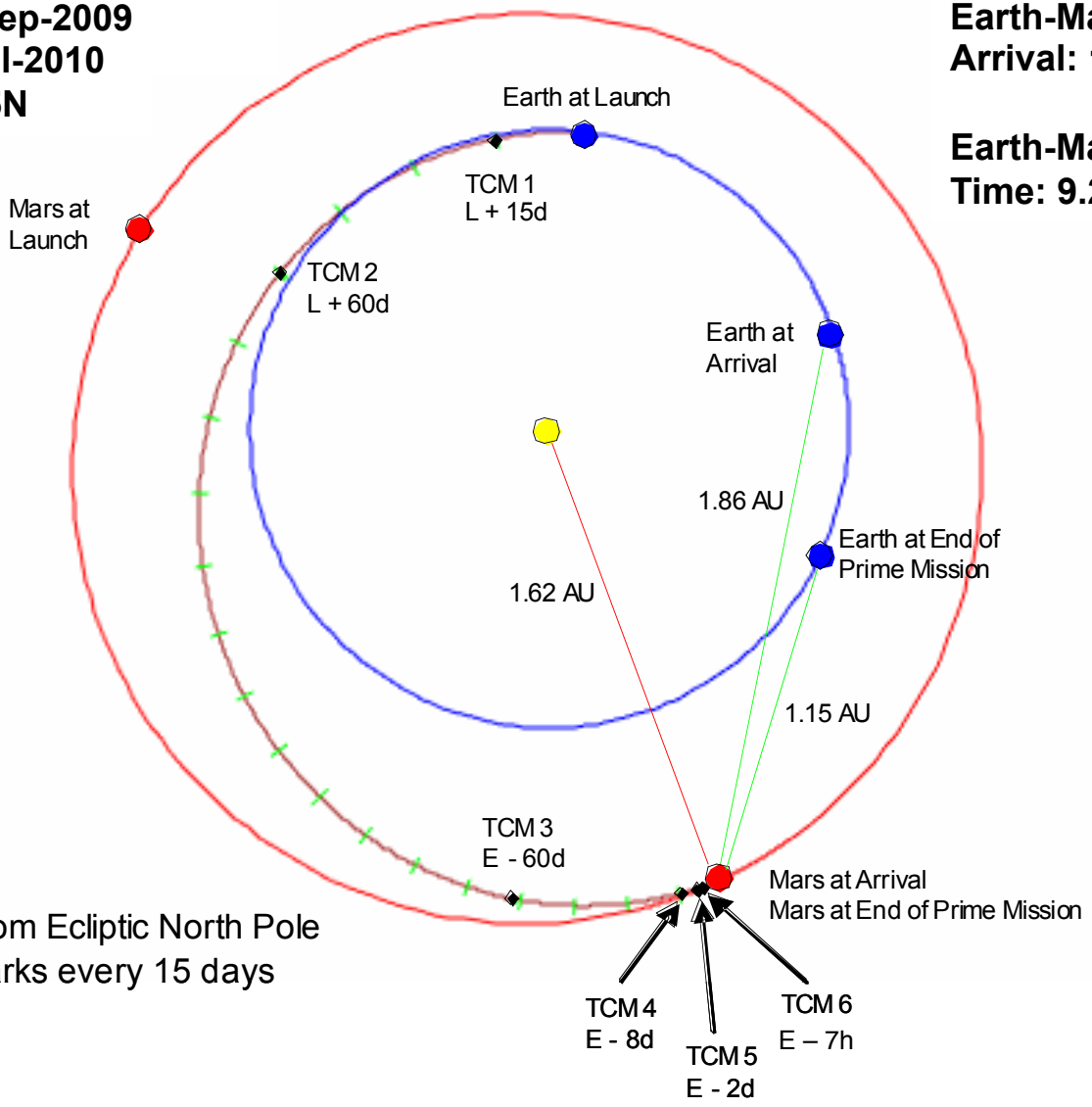


Cruise Phase

Launch = 15-Sep-2009
Arrival = 10-Jul-2010
MRO: 15S – 35N

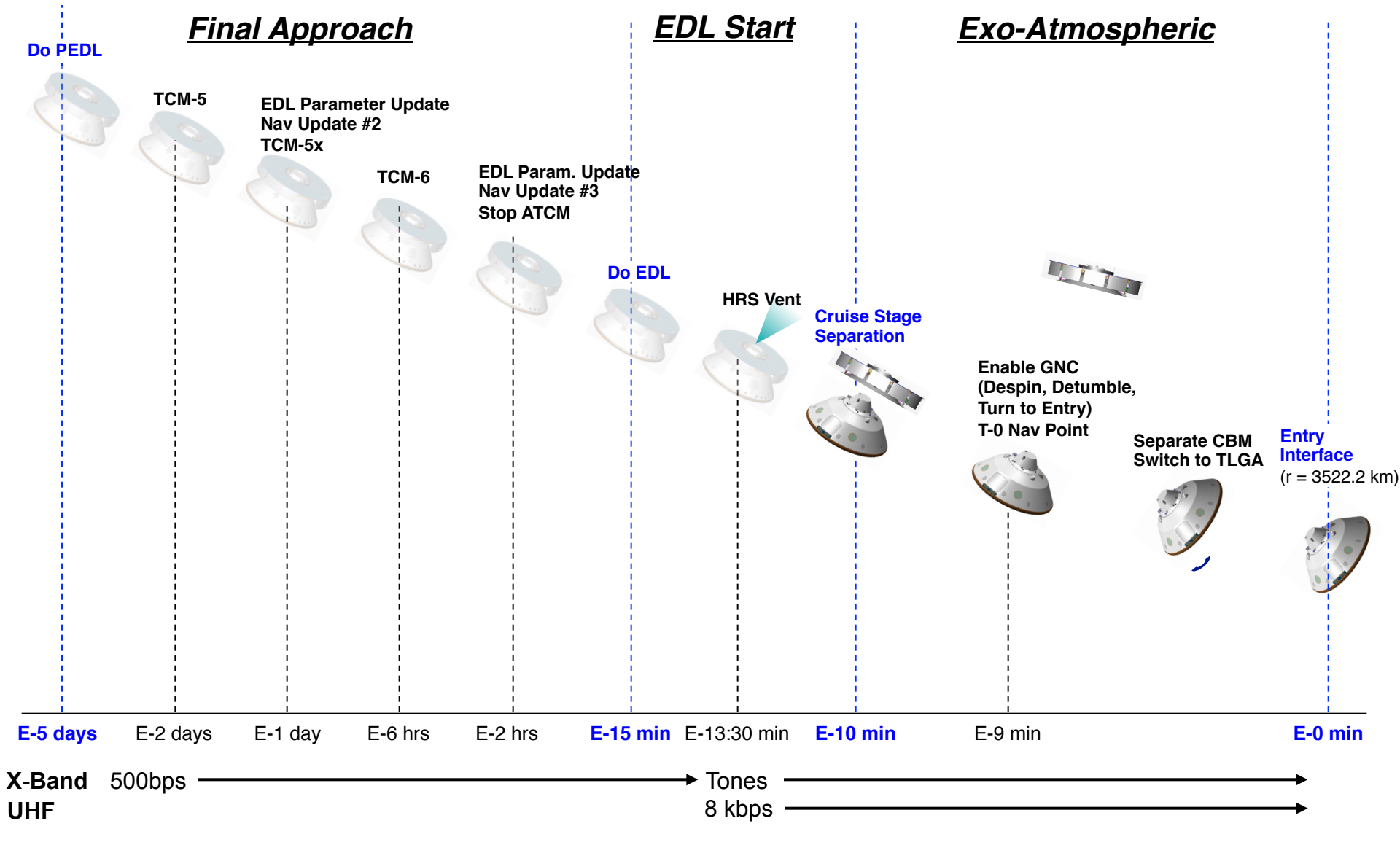
Earth-Mars Range at Arrival: 1.86 – 2.20 AU

Earth-Mars Transfer Time: 9.2 – 12.0 months

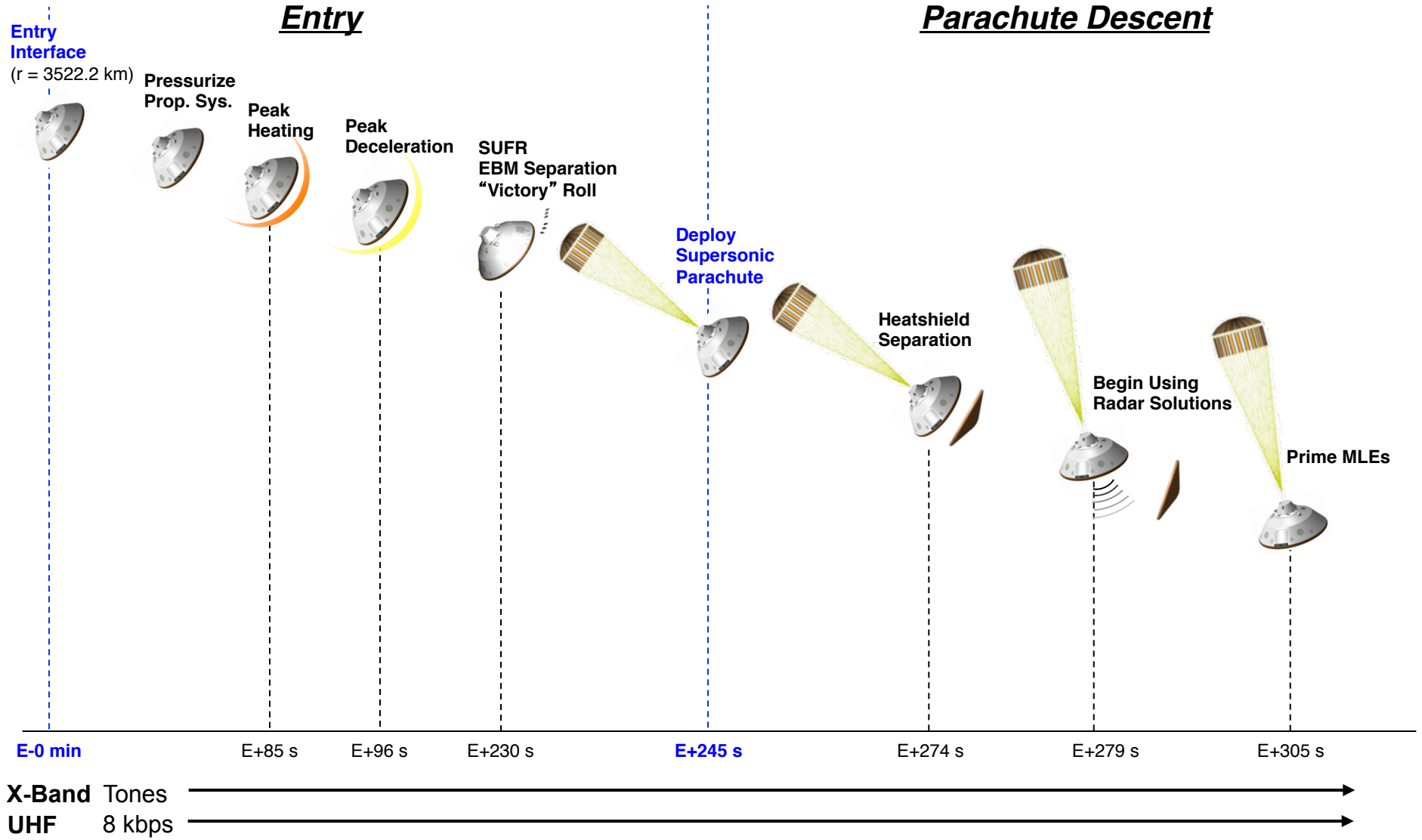


View from Ecliptic North Pole
Tick marks every 15 days

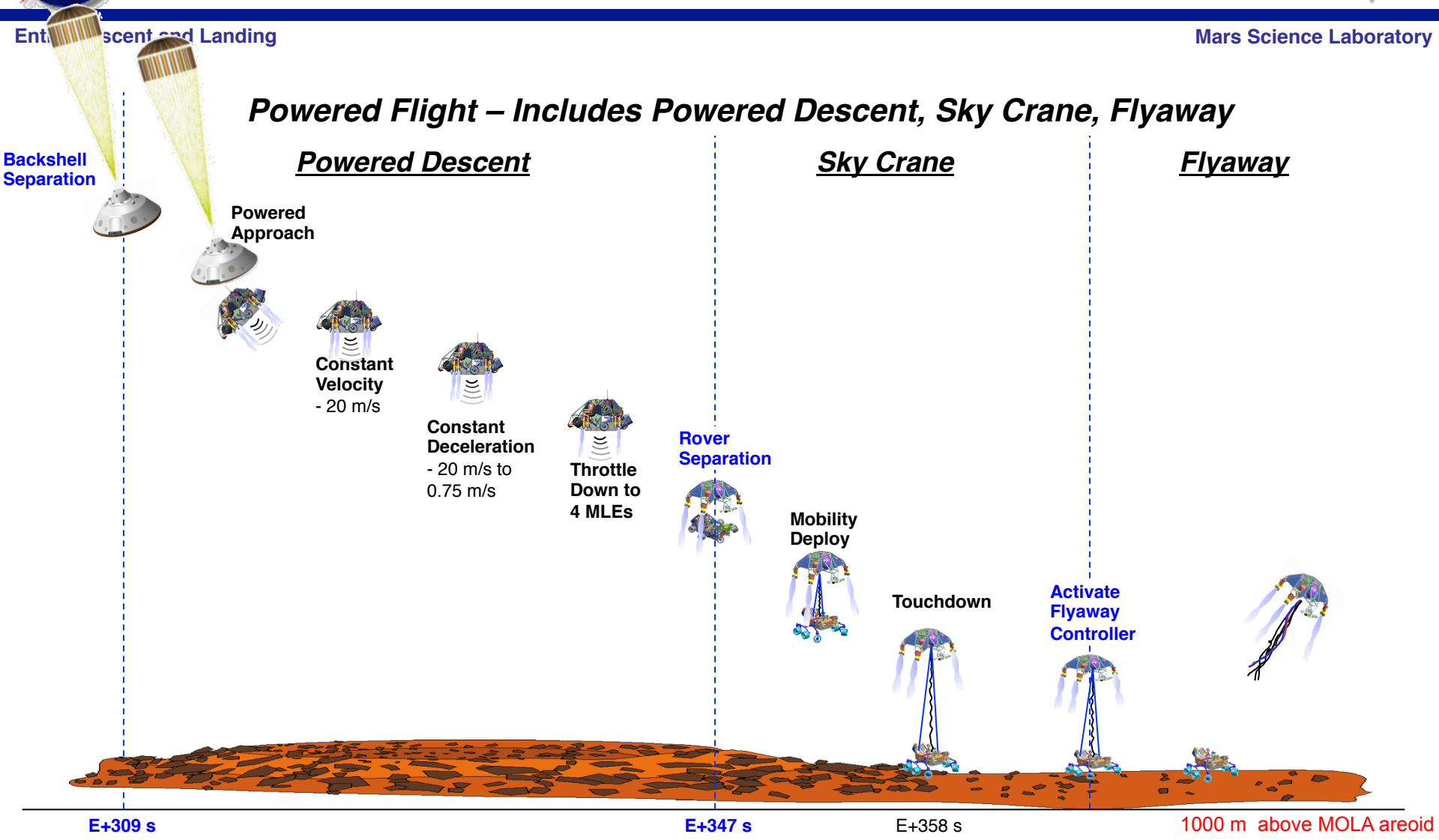
Event Timeline 1/3



Event Timeline 2/3

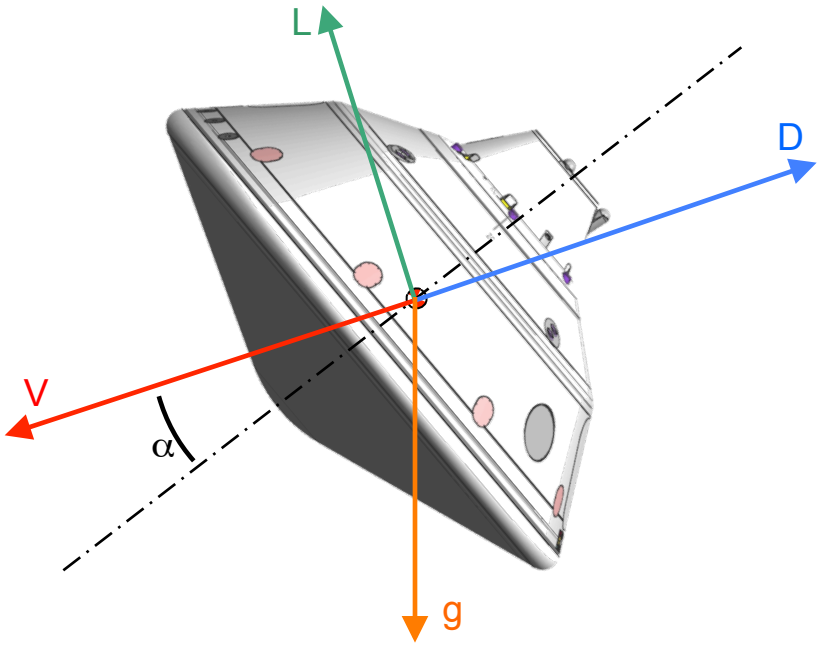


Event Timeline 3/3

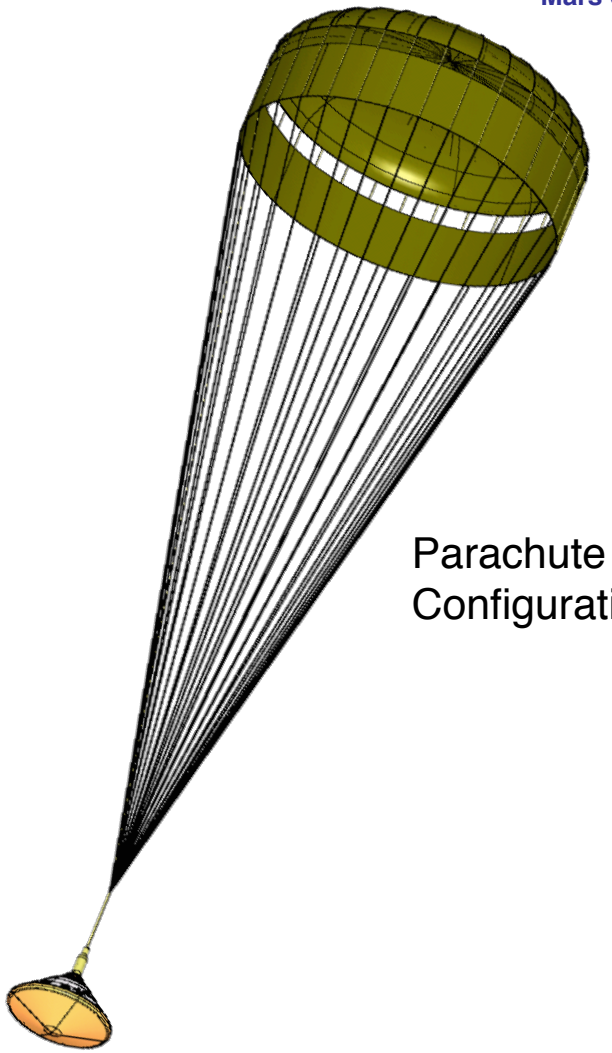


X-Band Tones
UHF 8 kbps

EDL Configurations (1/2)

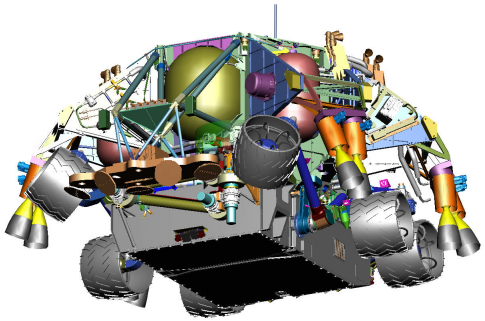


Entry Configuration

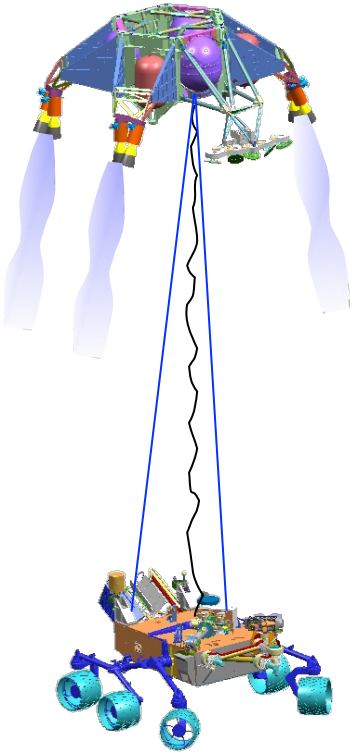


Parachute Descent Configuration

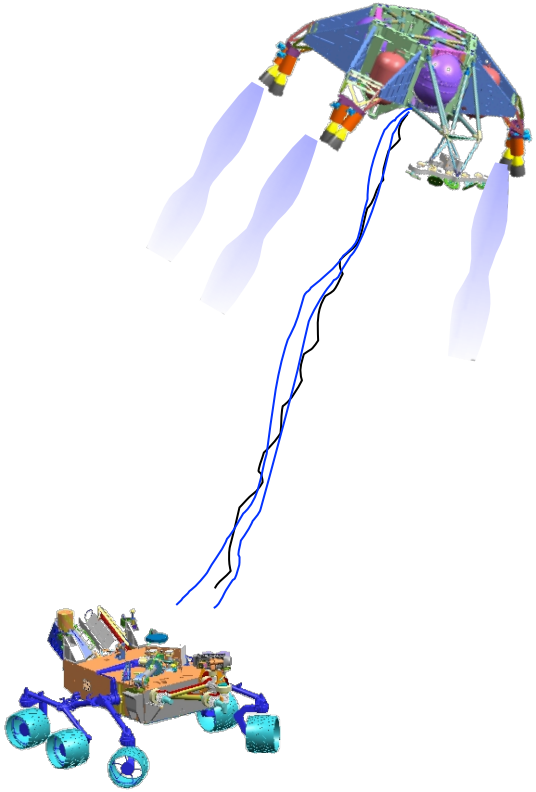
EDL Configurations (2/2)



Powered Descent Configuration



Skycrane Configuration



Flyaway Configuration

MSL Movie

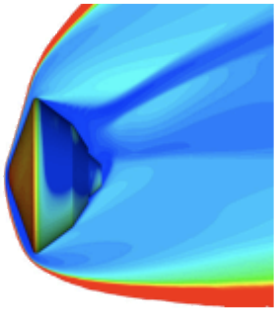
EDL Performance

Performance Assessment Overview

- EDL performance assessment is accomplished by end-to-end simulation
  - Part of ongoing performance assessment during project development
  - Continuously updated spacecraft models with improved fidelity as design matures
    - Updated design data (mass props, FSW releases, MLE performance, etc.)
    - Test and analysis results incorporated
  - Results from atmospheric modeling effort incorporated into performance analysis
    - Endemic wind results from atmospheric modeling used for all analyses
    - Site specific atmosphere models and winds used where possible
  - Range of possible landing sites sampled to-date:
    - Synthetic “Challenge” sites demonstrate Level 1 requirements
      - “Altitude Challenge”: Low entry velocity high altitude, southern latitude
    - Actual specific sites have been investigated
      - Terby Crater: Site specific custom atmosphere models and surface DEMs
      - Nili Fossae: Top ranked site and highest site in top 15

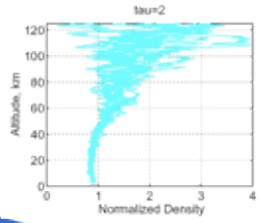
MSL POST2 Trajectory Simulation

Aerodynamics & Aerothermodynamics

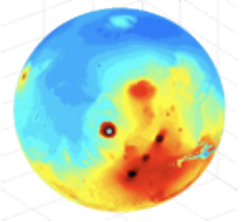


Mass Properties

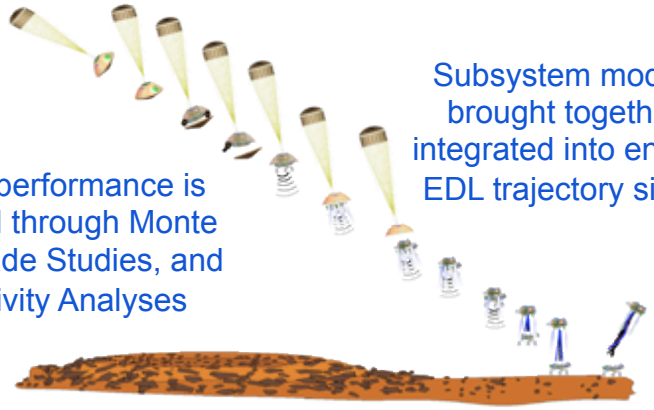
Atmosphere Model



Planet Model (MGS/MOLA)



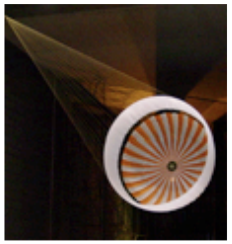
System performance is assessed through Monte Carlo, Trade Studies, and Sensitivity Analyses



Subsystem models are brought together and integrated into end-to-end EDL trajectory simulation

Initial Entry Conditions & Approach Navigation

Parachute Model

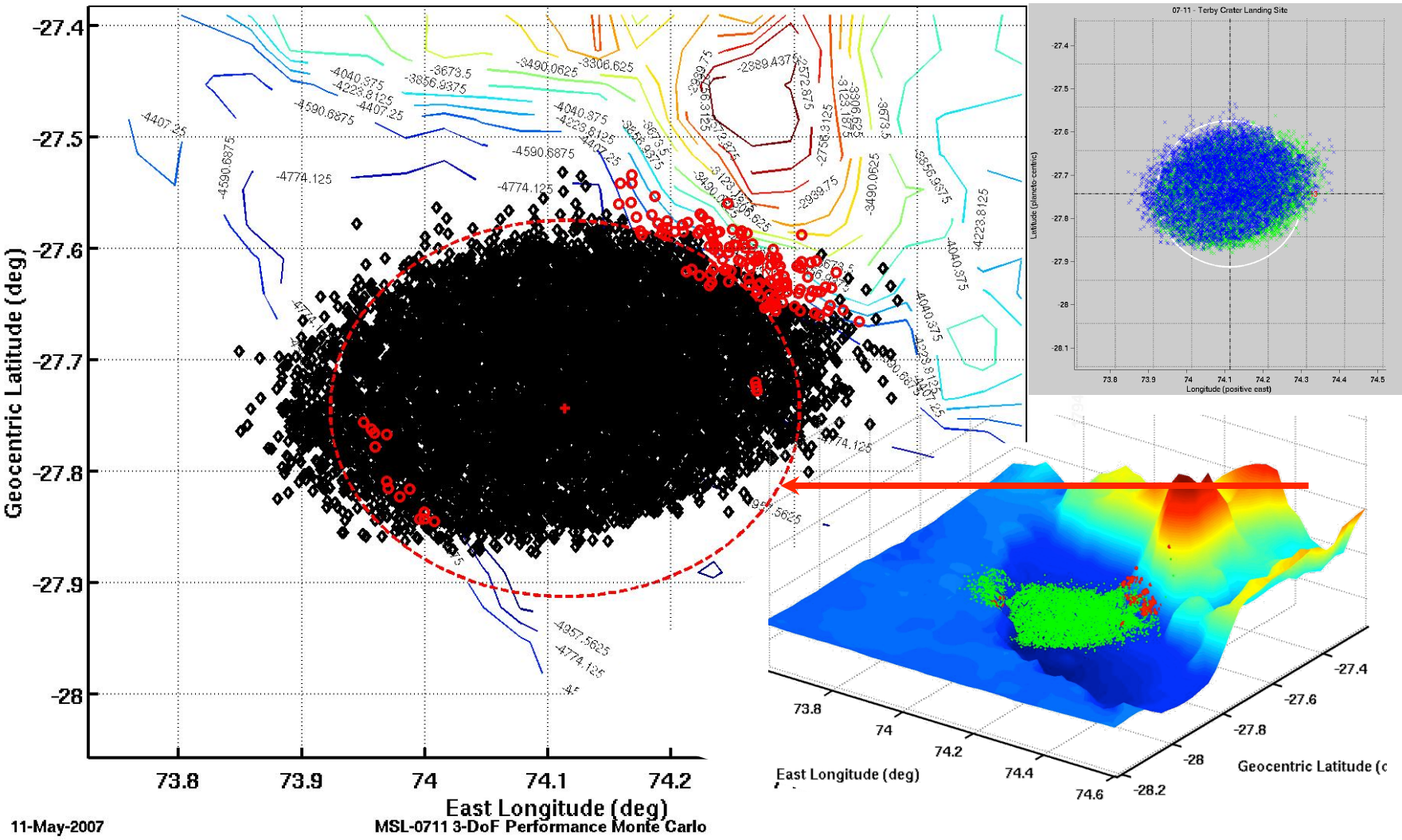


Propulsion

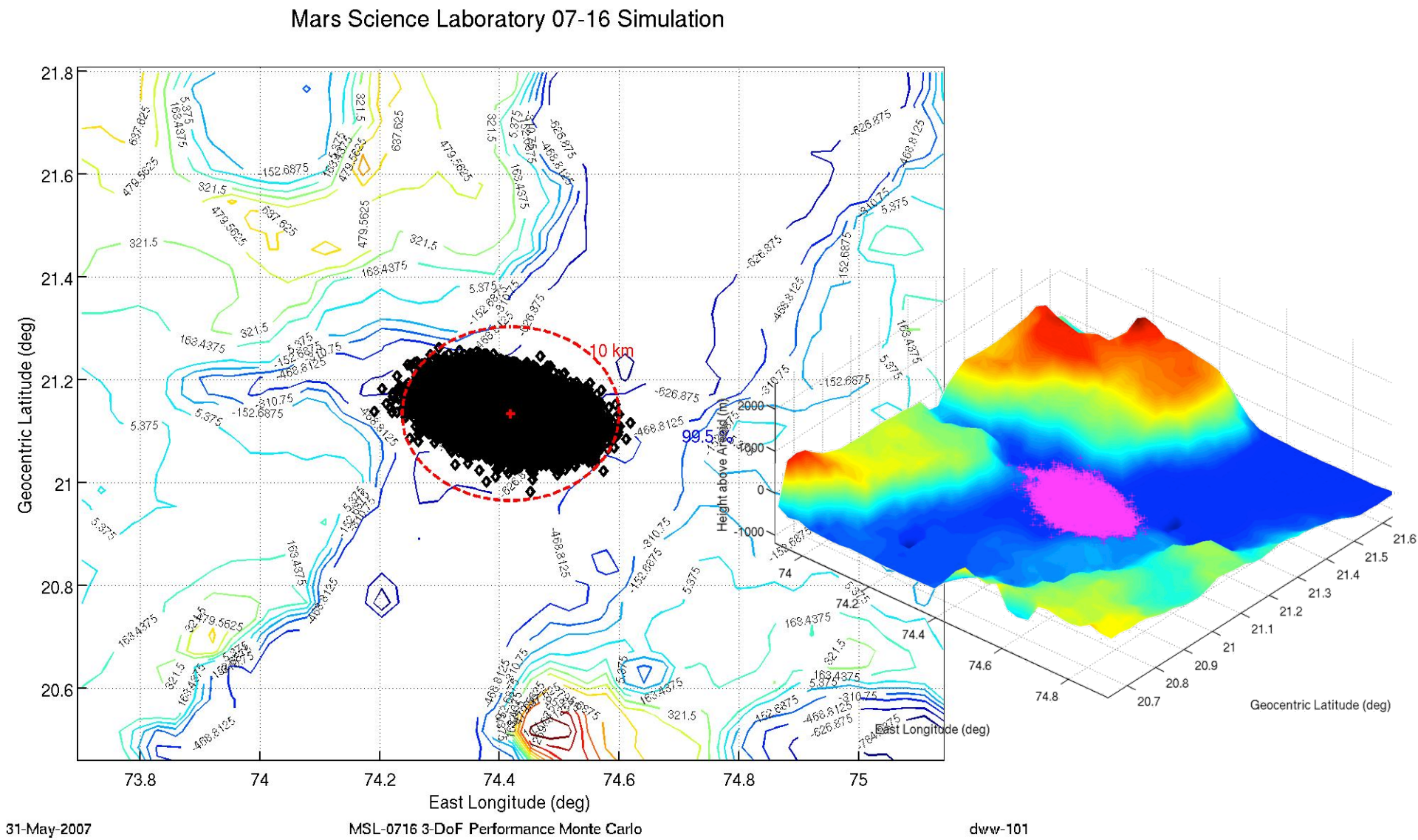
Guidance, Navigation, & Control

Example Result: Landing Footprint (Terby Crater)

with failed cases (147)



Example Result : Landing Footprint (Nili Fossae)



Summary

- The MSL EDL design is high performance entry system with several unique features
  - Guided Entry
  - Propulsive precision landing with Sky Crane system
  - Largest entry and landed mass of any Mars Lander

- MSL EDL design offers flexibility and access to a large portion of the Martian Surface
  - Latitudes from -45deg to +45deg
  - Landing site altitudes as high as +1 km MOLA

- The high performance and capabilities of the MSL EDL system maximize mission flexibility and science package delivered to the surface