Overview of Entry, Descent and Landing for Mars Science Laboratory

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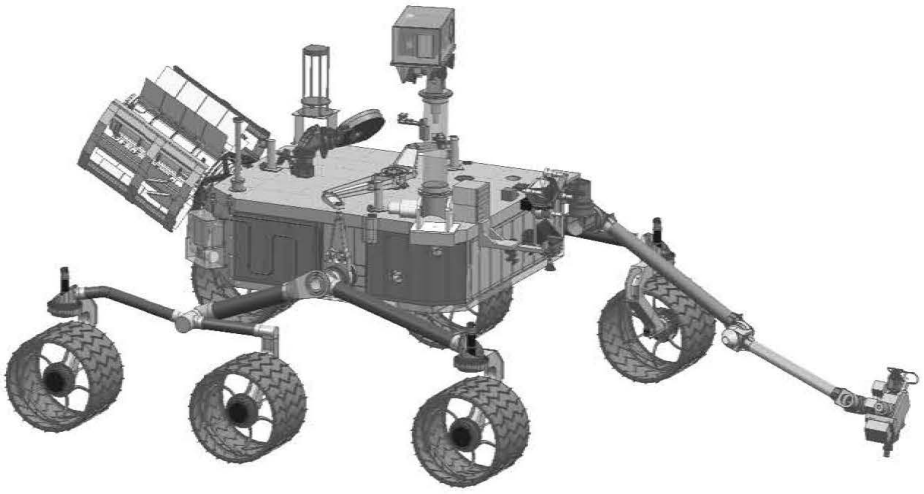
Agenda

- Project Overview
- Design Response to Driving Requirements
- Putting it all together: EDL event timeline

Project Overview

Science

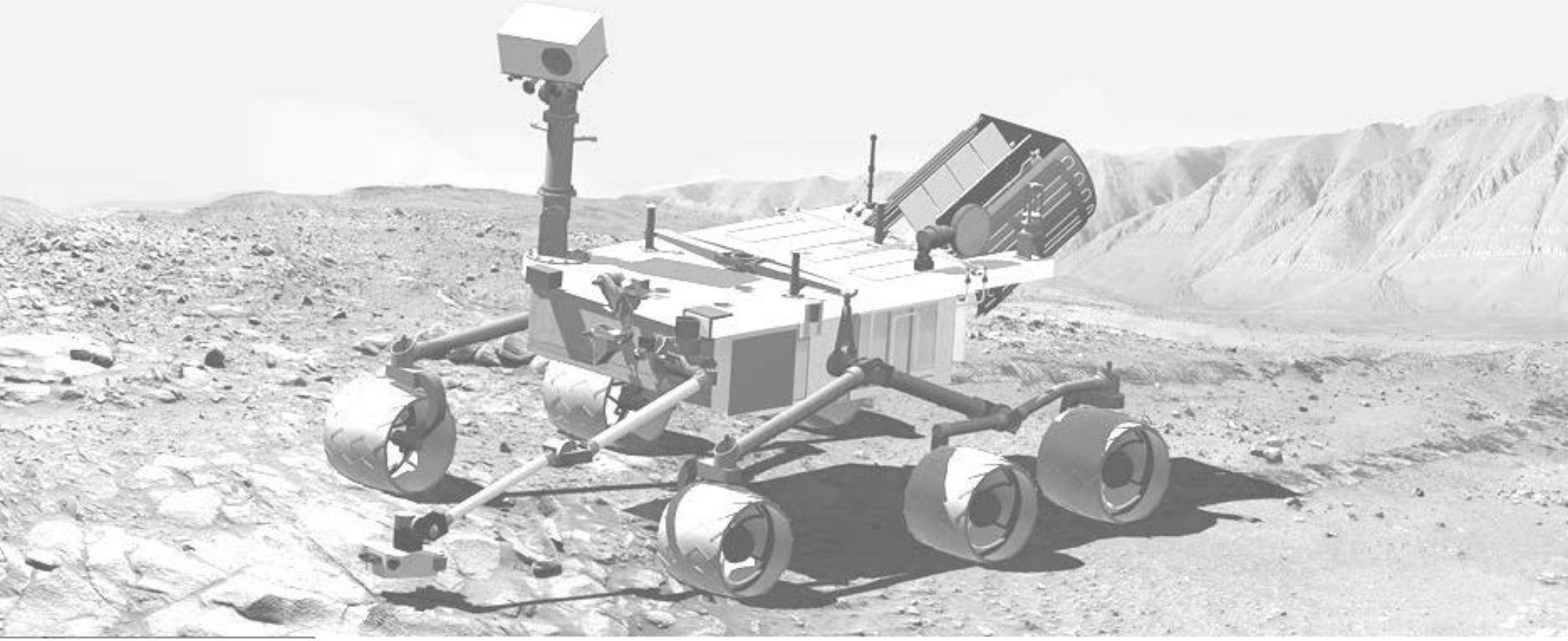
Focus on Past & Present Habitability of Mars
Highly Capable Analytical Laboratory
Next Generation Remote Sensing & Contact Investigations
Suite of Environmental Monitoring Instruments



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

	MSL	MER
LV/Launch Mass	Atlas V/3600 kg	Delta II/1050 kg
Redundancy	Dual String, Some SPFs	Limited/Dual Mission
Payload	10 instruments (75 kg)	5 instrument (~9 kg)
Sample Acq/Processing	Arm, Abrader, Corer, Scoop, Crusher	Arm, Abrader
EDL Architecture	Guided Entry/Skycrane	MPF Heritage/Airbags
EDL Comm	UHF + Partial DTE or DTE	DTE + Partial UHF
Rover Mass	800 kg (allocation)	170 kg (actual)
Surface Power	RTG*/2500 Whr/sol	Solar/<900 Whr/sol



Response to Driving Requirements

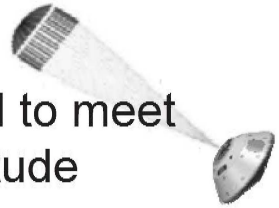
Key Driving EDL Requirements:

- Deliver 800 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

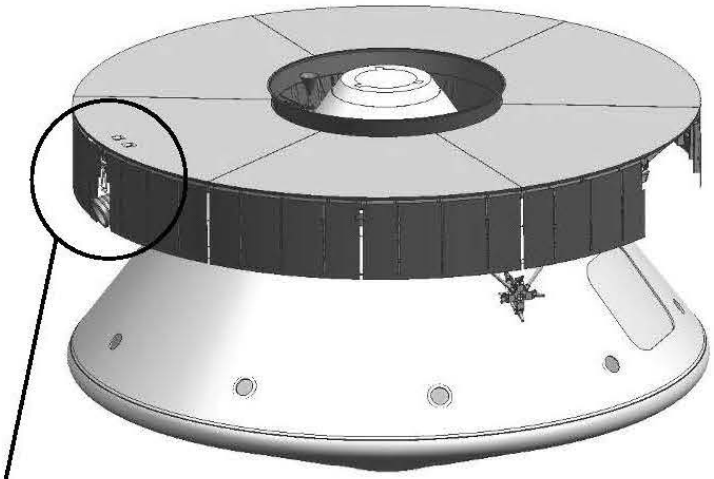
- Parachute
  - Parachute size selected to meet delivered mass and altitude requirements

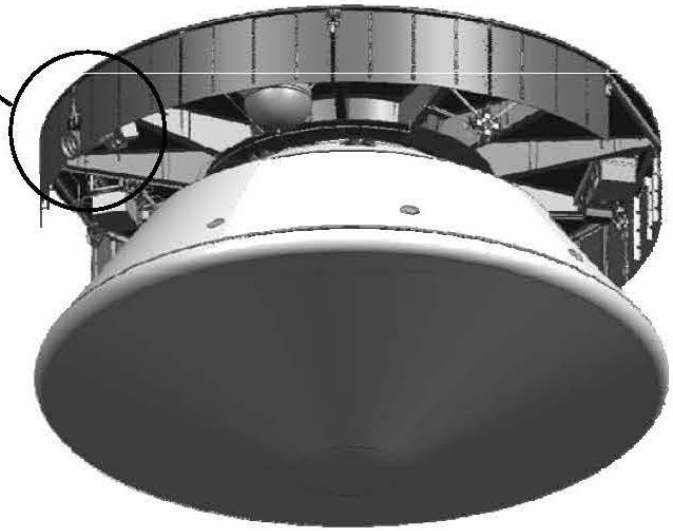


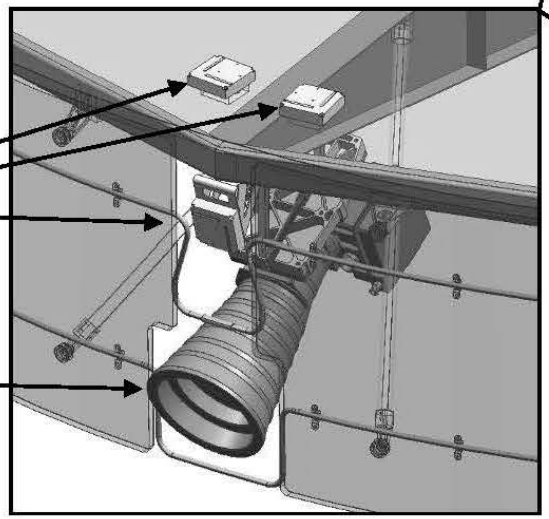
- Throttled Powered Descent/Sky Crane
  - Delivered mass and interfaces eliminates use of airbag landing system
  - Terrain requirements drive powered descent profile and touchdown system architecture

Cruise Configuration

- Spin rate of 2 RPM during cruise
- Driving functionality for EDL is alignment of GNC sensors
  - Star Scanner
  - Sun Sensors
- GNC sensors used for IMU calibration
  - MER alignment performance meets MSL requirements.

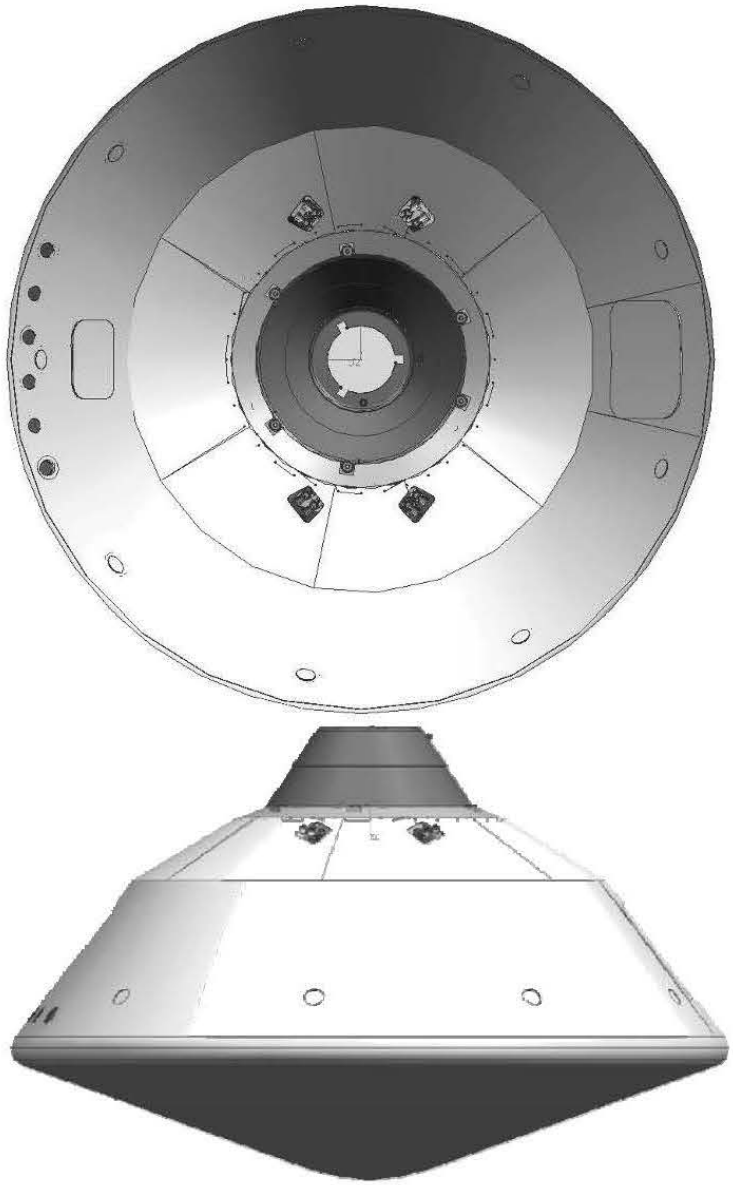






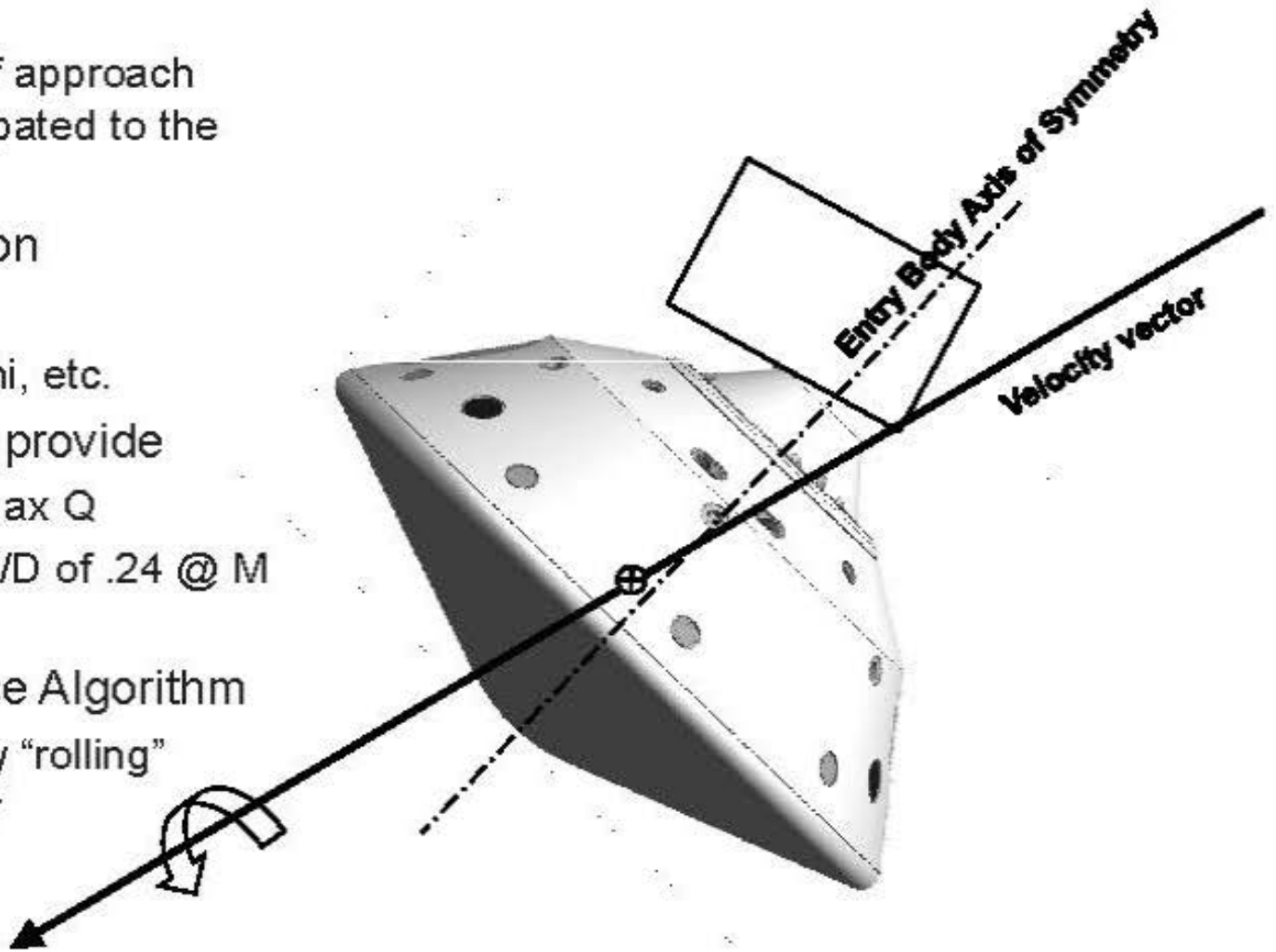
Entry Configuration

- De-spin using RCS thrusters
- Exo-atmospheric maneuvering done with the entry RCS thrusters
- After de-spin the cruise balance mass is ejected exo-atmospherically to move CG off of cruise centerline position.
- CM offset calculated to provide
  - 15 degree AOA @ Mach 24
  - 20 deg AOA @ parachute deploy
  - produces a nominal L/D of .24
- Entry Phase completed when the parachute is deployed



Entry: Aerodynamic Deceleration and Control

- Primary decelerator is entry body drag
  - Approximately 99% of approach kinetic energy is dissipated to the atmosphere
- Lifting entry configuration
  - Viking
  - Shuttle, Apollo, Gemini, etc.
- CM offset calculated to provide
  - ~15 degree AOA @ max Q
  - Produces a nominal L/D of .24 @ M 24
- Apollo-derived Guidance Algorithm
  - Guidance achieved by "rolling" around velocity vector
    - Apollo, Viking



Parachute Descent

- Secondary decelerator is Parachute drag
  - Approximately 95% of remaining Kinetic energy is dissipated to the atmosphere
- Viking configuration parachute
  - Larger diameter (19.7 m vs 16.1 m)
  - Modern materials (kevlar vs. polyester)
- Deployment conditions
  - Mach number < 2.15 (Viking)
  - Dynamic Pressure < 850 Pa (MER)
  - Deployment AoA @ deploy < 15 deg. (Viking)
- Parachute scaled to closely match Viking test post deployment flight conditions
  - Area ratios
  - On chute ballistic coefficient
  - Area oscillations matched

Sky Crane System Architecture

Two-Body Architecture
Decouples descent stage control from touchdown event and allows persistent touchdown signature

Prop and GNC Away from Surface
Closed loop during the touchdown event

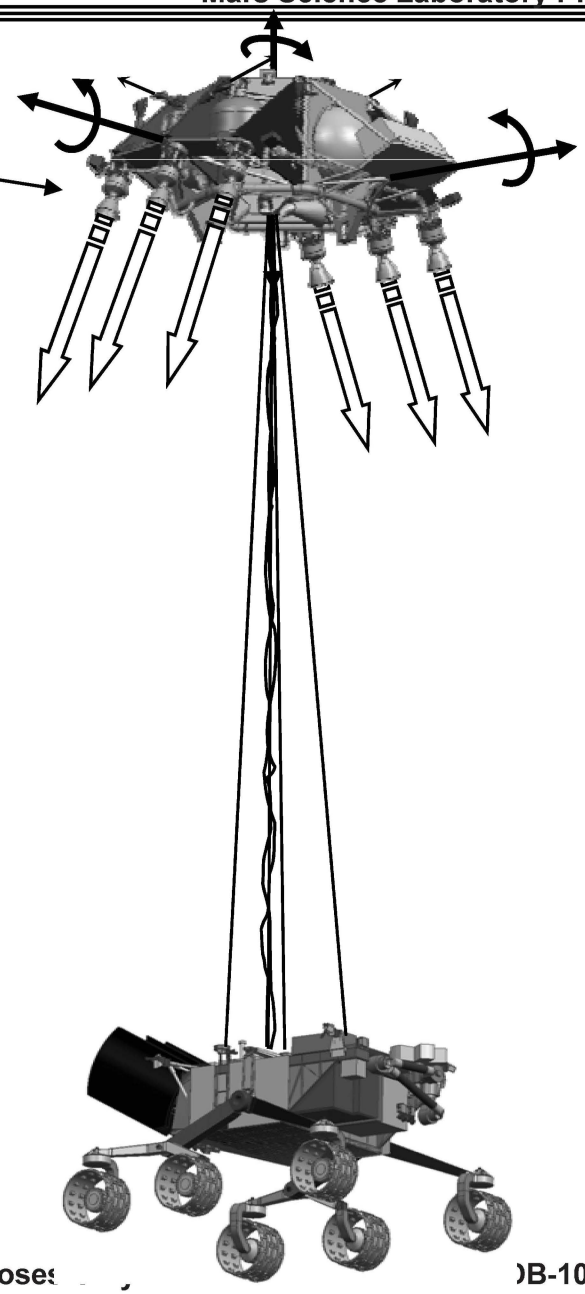
High Bandwidth Vertical Velocity Control
results in low and near constant D/S velocity

Higher Stability
Persistence of tethering during touchdown improves landing stability on rough terrain

Lower Loads
Low velocities
allows rover landing loads to be similar to the rovers driving loads

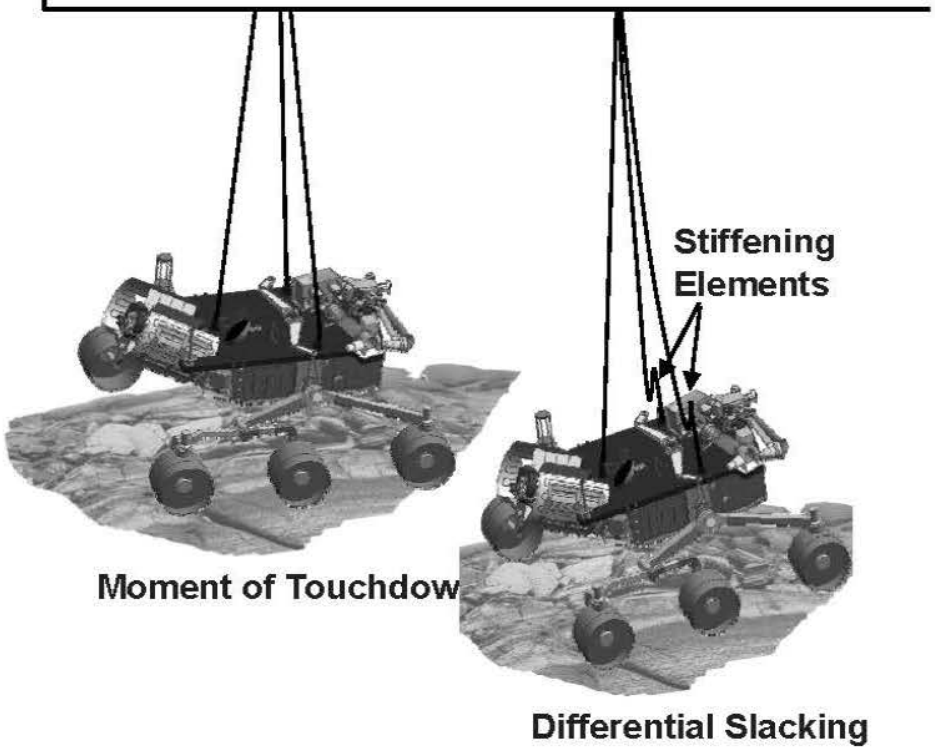
System Design
High stability and low landing loads mean:
- Separate TD system not required
- Egress system not required

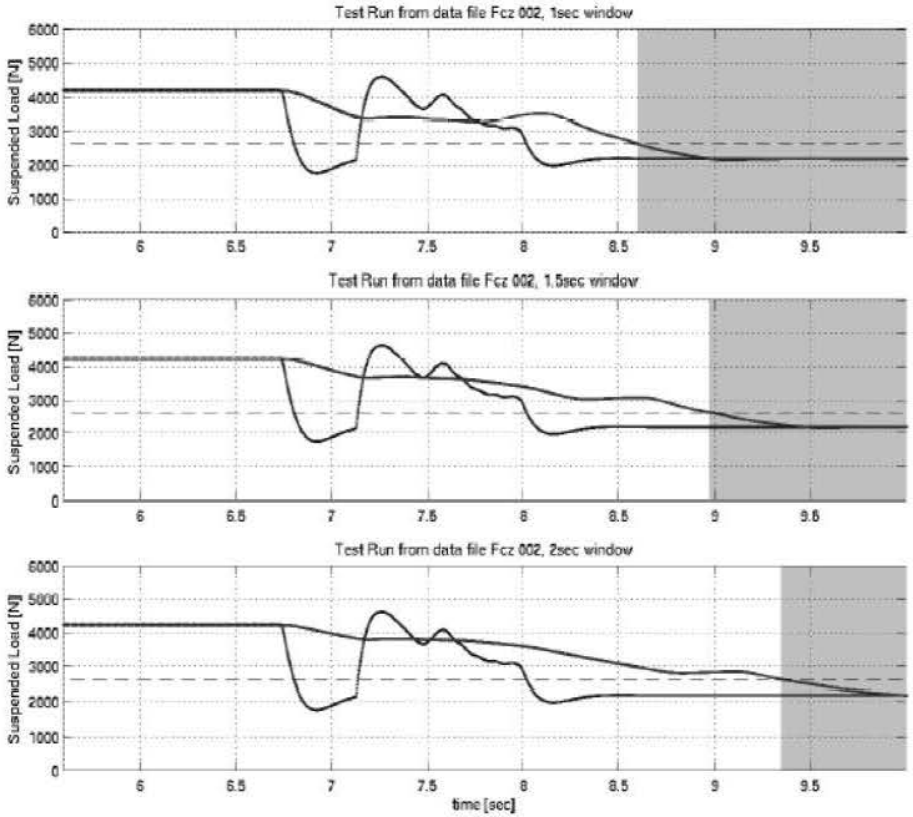
Rover Becomes the Touchdown System
Rover provides ground clearance, static stability, and terrain adaptation



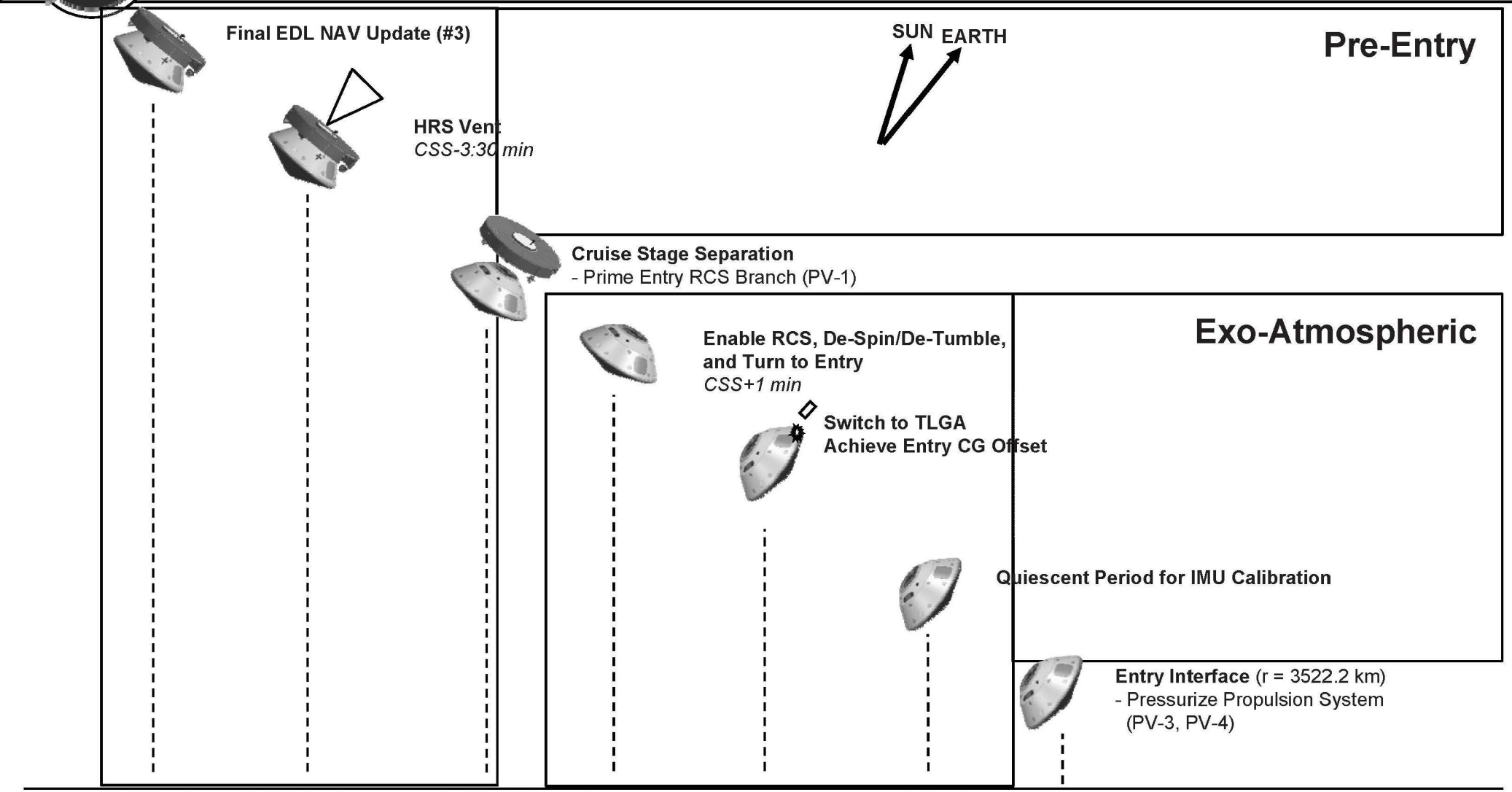
Sky Crane: Touchdown

- Touchdown is triggered from the ***post-touchdown state*** NOT the touchdown event
  - Design allows 1-2 seconds of persistence
- Slack is managed within bridle system
  - Descent stage can continue downward for 2-3 meters

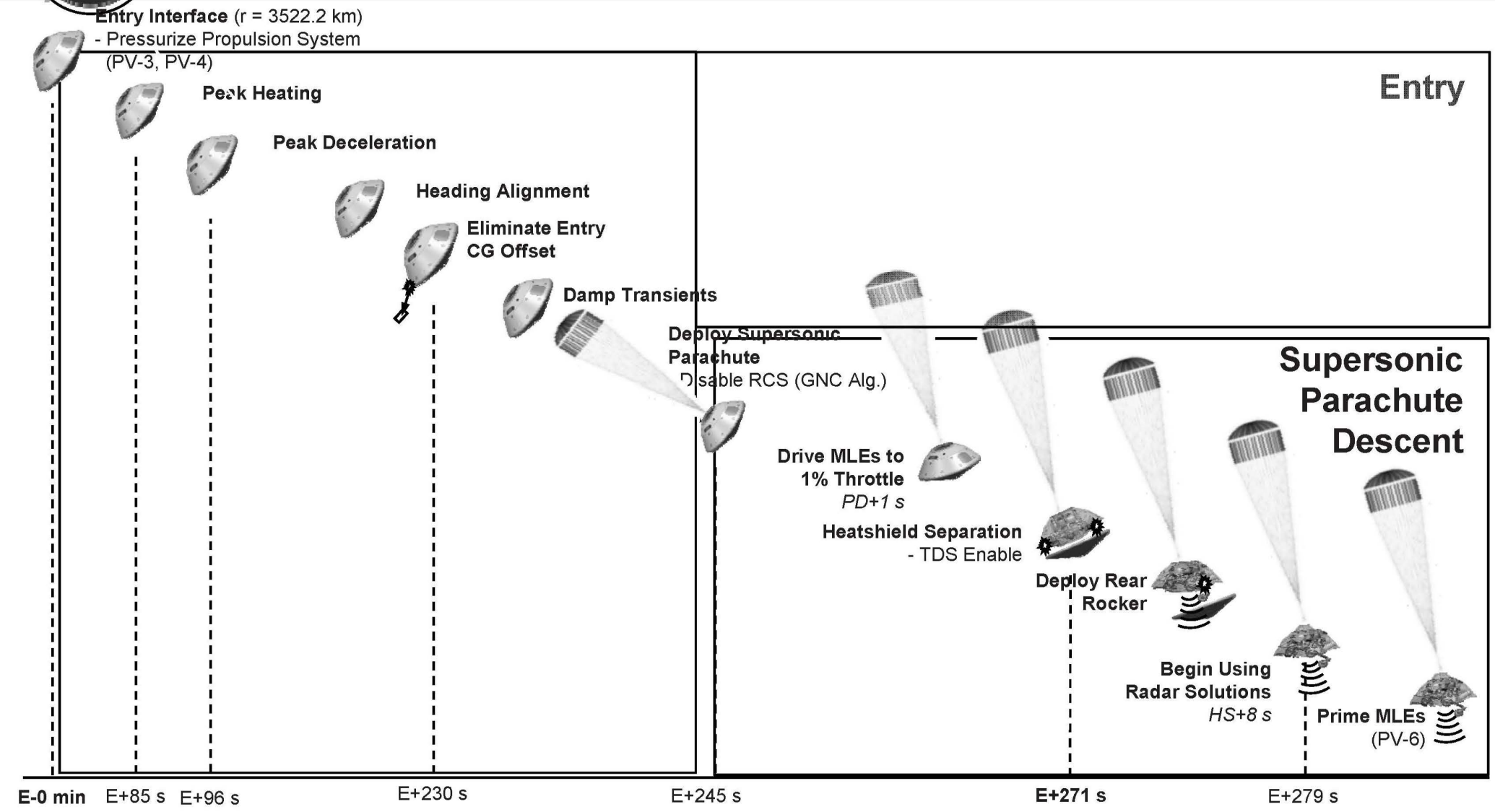




Notional Event Timeline 1/3



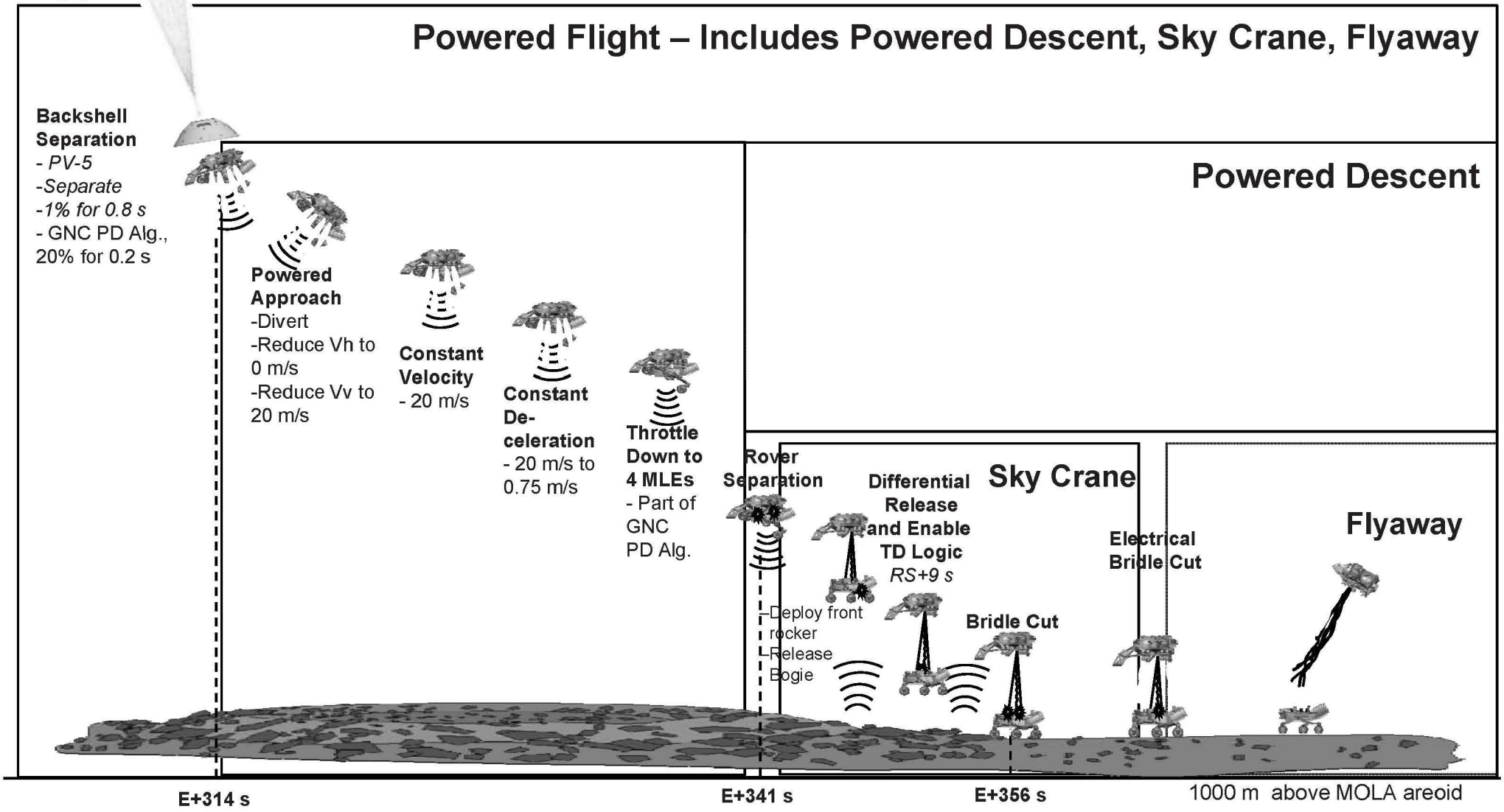
Notional Event Timeline 2/3



X-Band Tones →

UHF 2 kbps →

Notional Event Timeline 3/3



X-Band Tones →

UHF 2 kbps →

EDL Movie

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