Mars Science Laboratory Entry Descent and Landing Simulation Using DSENDS

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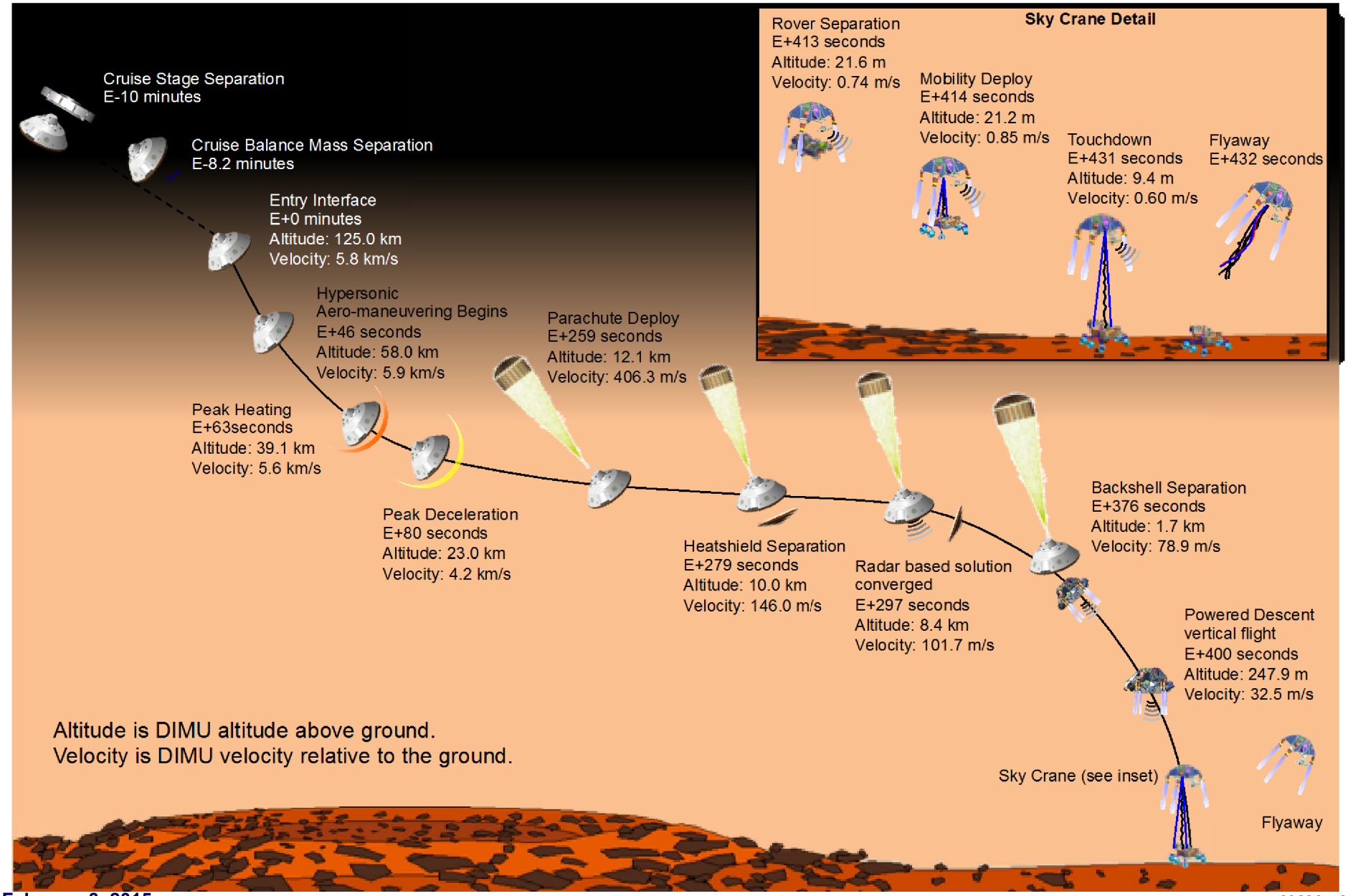
Overview

- **MSL EDL Overview**
- **DSENDS Description**
- **MSL Specific Models**
  - MSL Atmosphere Model
  - MSL Aerodynamics Model
  - Terrain Model
  - MSL Parachute Model
  - MSL Device Models (IMU, RCS, TDS, MLE)
  - MSL Flight Software
  - MSL Telecom Module
- **MSL High-Fidelity Simulation**
  - Simulation Initialization
  - EDL Trajectory Nominal Runs
  - EDL Monte Carlo Runs
- **DSENDS Independent V&V**
- **Summary and Conclusions**

Topics for this presentation
In paper but not discussed here

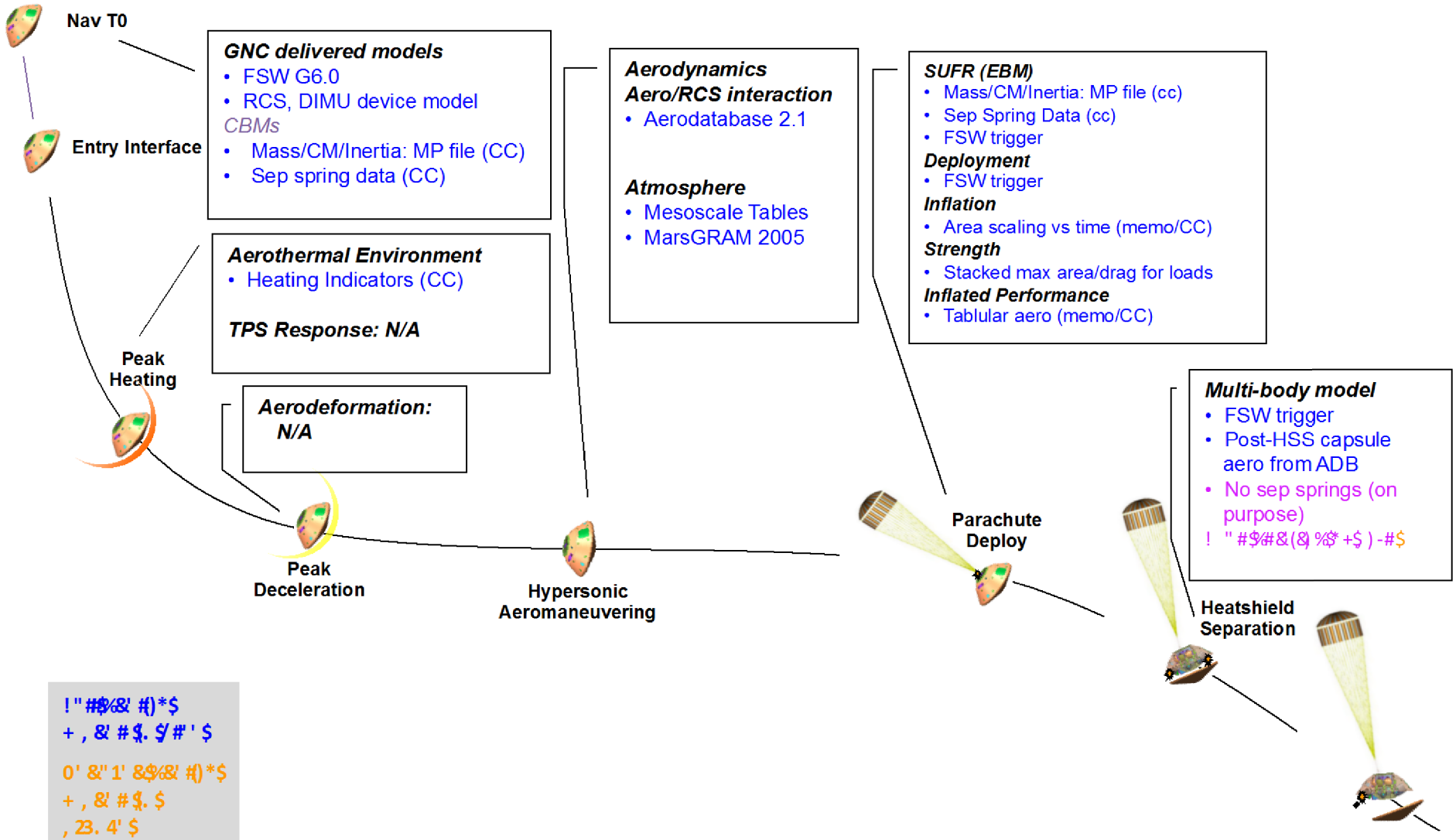
MSL EDL Overview



DSENDS Description

- **Dynamics Simulator for Entry, Descent and Surface landing**
- **Framework for modeling aero-assisted simulations from simple single-body systems to multi-body, flexible systems.**
- **Extensive library of models for sensors, actuators, environment, environment interaction, and avionics elements.**
  - Framework for linking user-supplied code and built-in functions to build a complete simulation.
  - Includes Monte Carlo and parametric simulation capability.
- **For MSL, core simulation functions were augmented with project-specific models**

MSL Specific Models (1/2)



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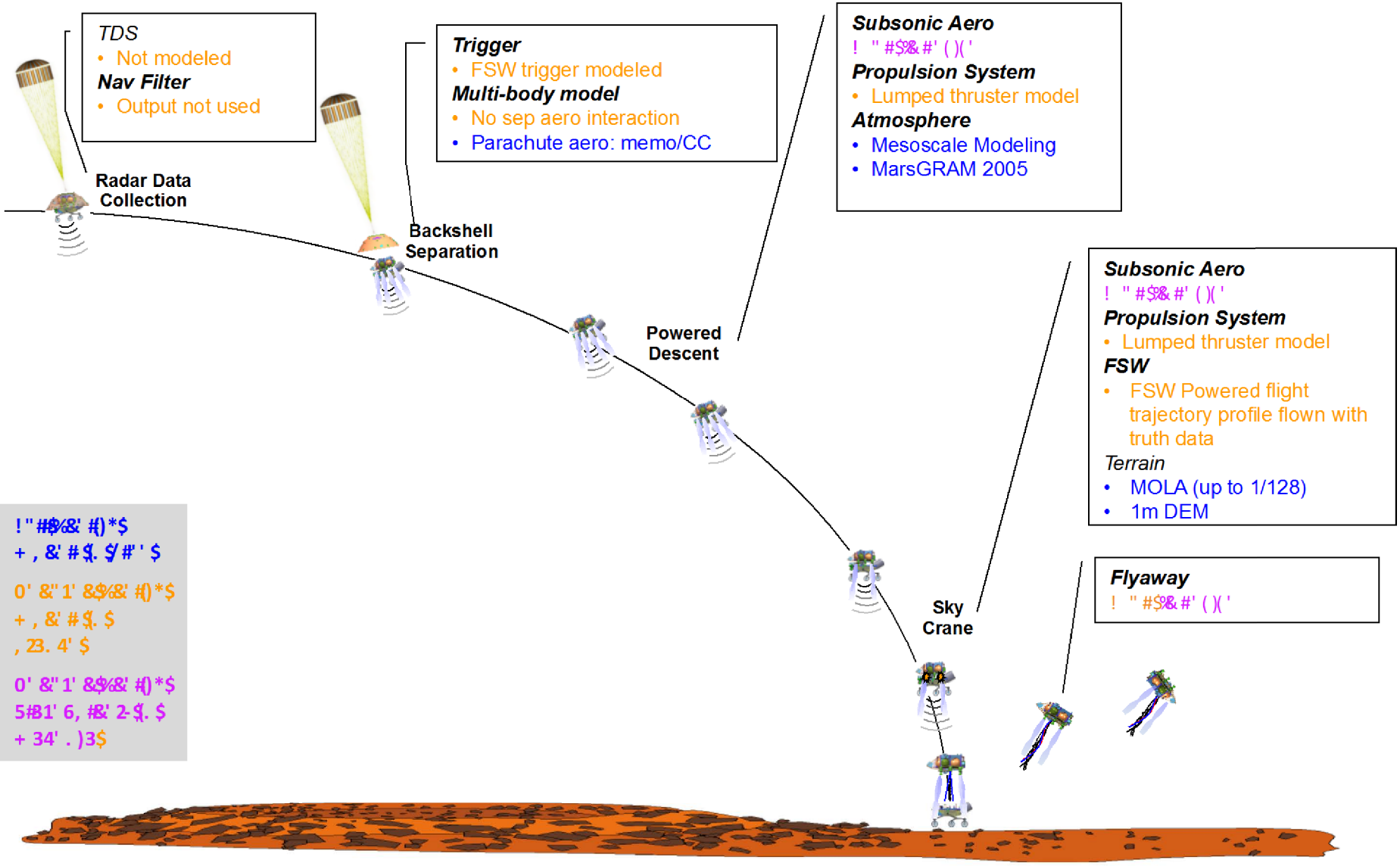
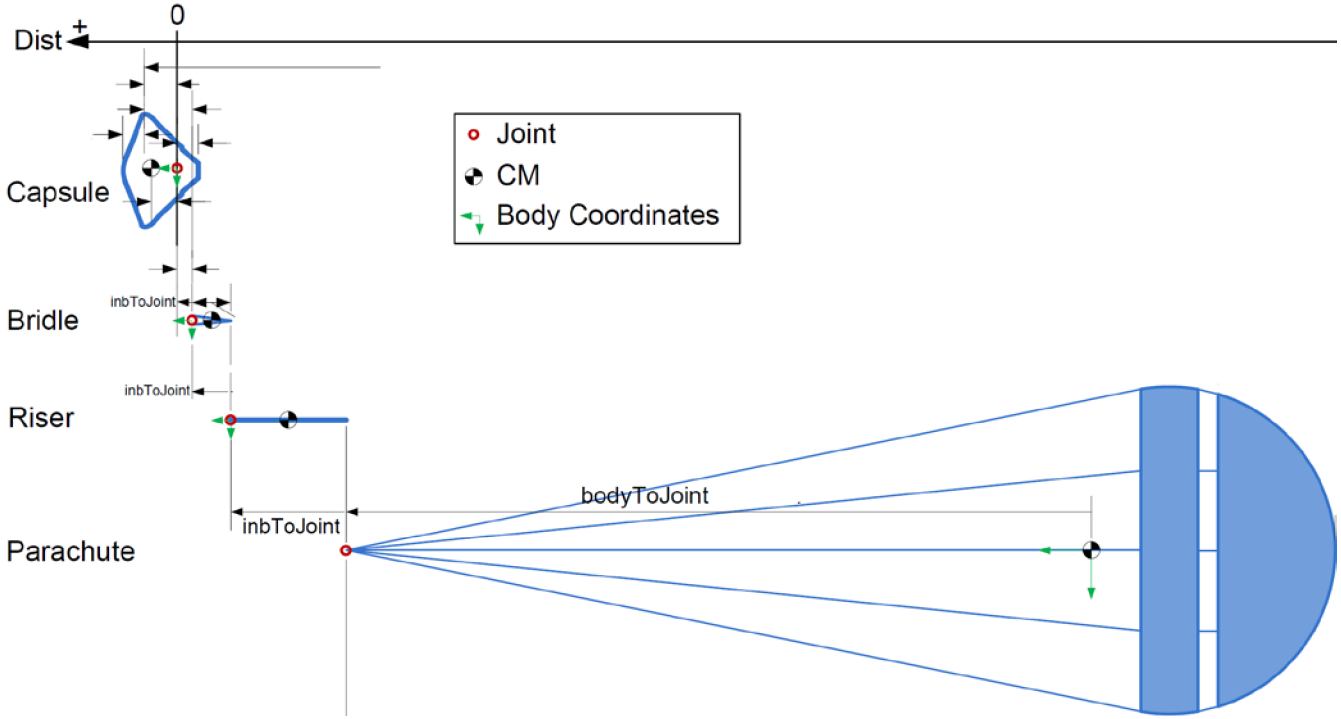
MSL Specific Models (2/2)

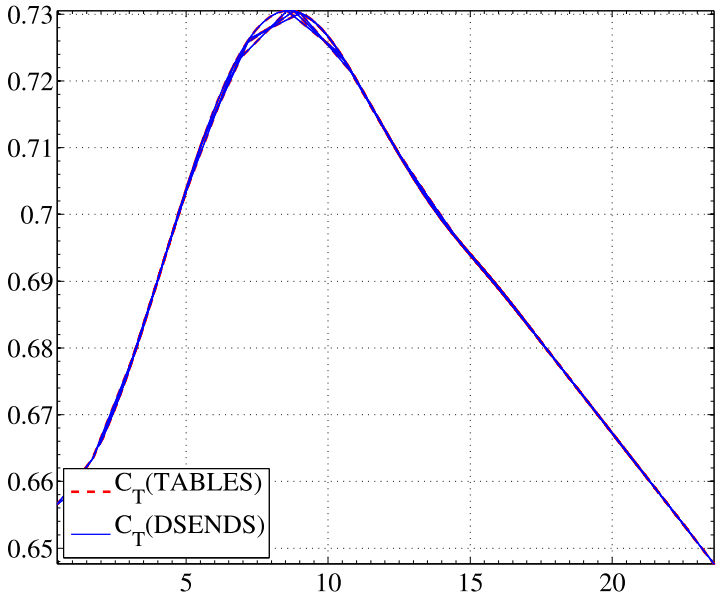


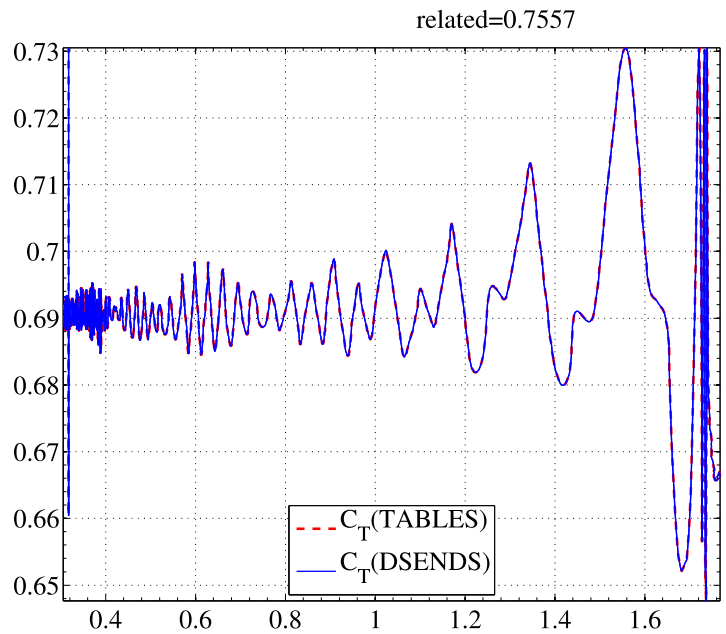
MSL Parachute Model



- **Components: triple bridle, single riser, canopy plus shroud lines**
  - Each is a rigid body connected to the adjoining body by a ball joint
    - Bodies can rotate in any direction, no relative translation
  - Joint between bridle and riser is free to move, all others locked
    - Two rigid bodies: capsule/bridle and riser/parachute

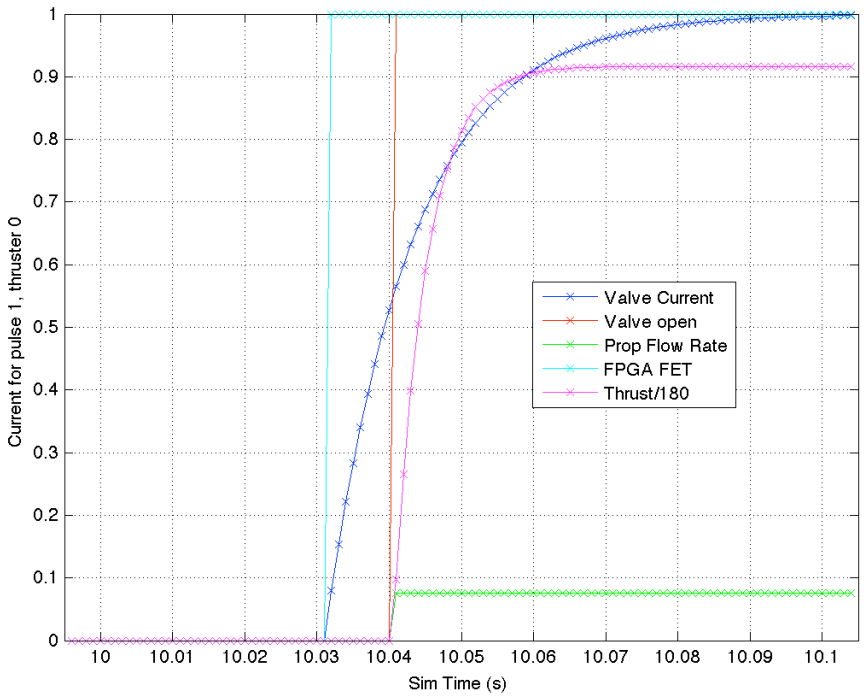
MSL Parachute Model

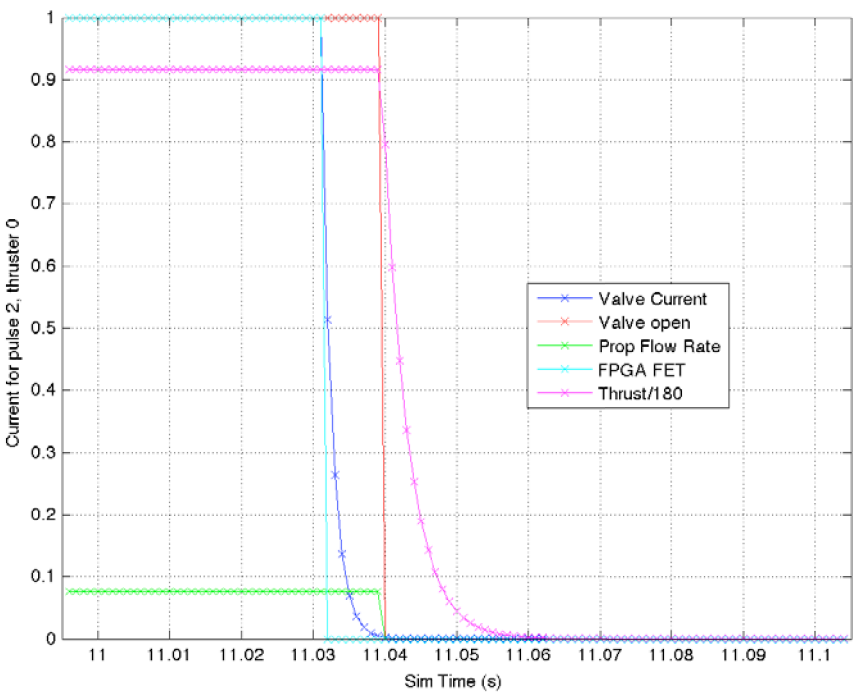




- **Built-in components with MSL-specific aerodynamics and mass properties**
- **Checkout example: compare simulation output aerodynamic axial coefficient with hand-computed values**

MSL RCS Model



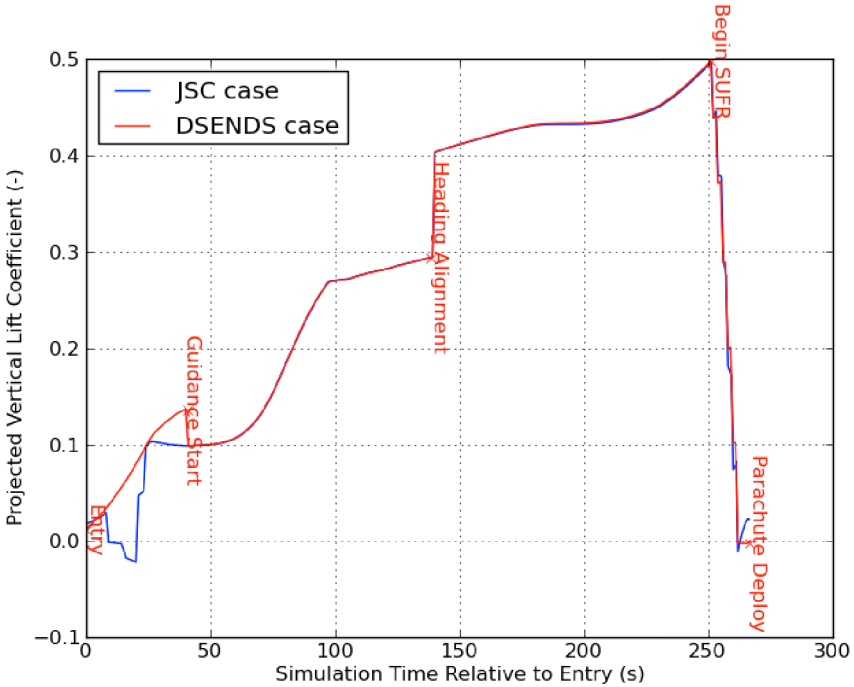


- **RCS stand-alone routine delivered and integrated into DSENDS**
- **Checkout example: fire a 1s pulse with a single thruster, compare performance with expected values (thrust, rise time, delay, etc)**

MSL Simulation

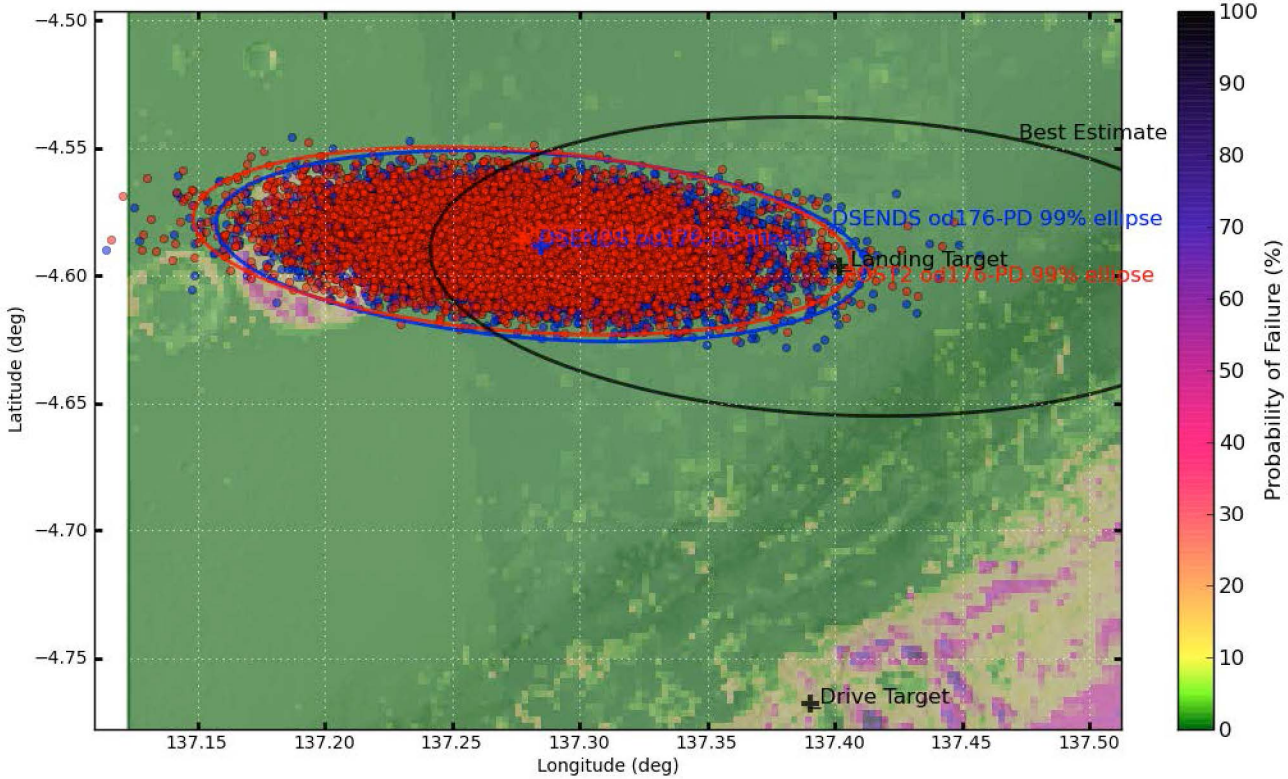
- **Full-fidelity simulation**
  - Single-run nominal cases and Monte Carlo
  - Results compared between POST and DSENDS at parachute deploy and landing
- **Targeting simulation**
  - 3DOF simulation without closed-loop functionality used for cruise maneuver design and real-time Doppler event detection
  - Entry guidance design using POST was performed using the trajectories from cruise maneuver design

DSENDS Independent V&V



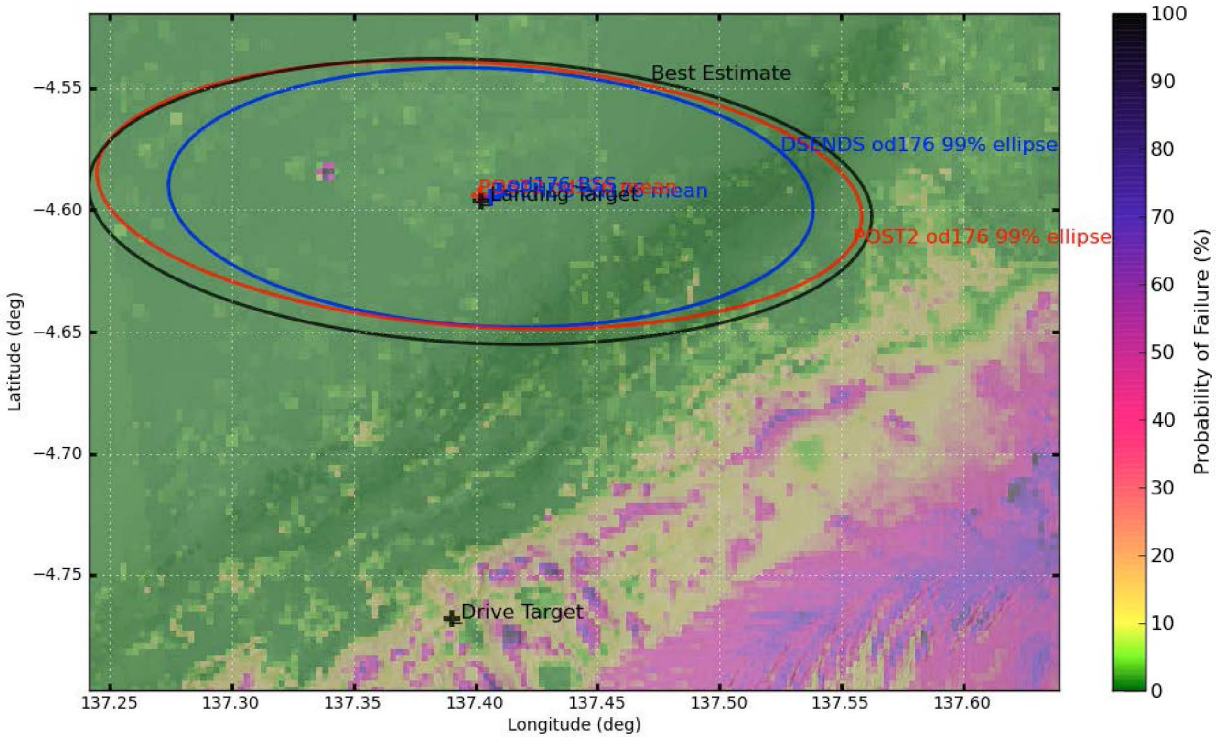
- **Open-loop comparison: As part of reference trajectory design, compare output from DSENDS with POST entry guidance design trajectories**
- **Common models: atmosphere and winds, capsule aerodatabase, mass properties**

DSENDS Independent V&V



- **Monte Carlo comparison at parachute deploy: equivalent modeling in both simulations to this point**
- **Small (400m) difference in mean values**

DSENDS Independent V&V



- **Monte Carlo comparison at landing**
- **Major modeling differences: parachute model, powered flight**

- **The MSL project concluded the independent V&V activity was successful.**