MSL EDL Landing Site Safety Assessment and Prelaunch Status

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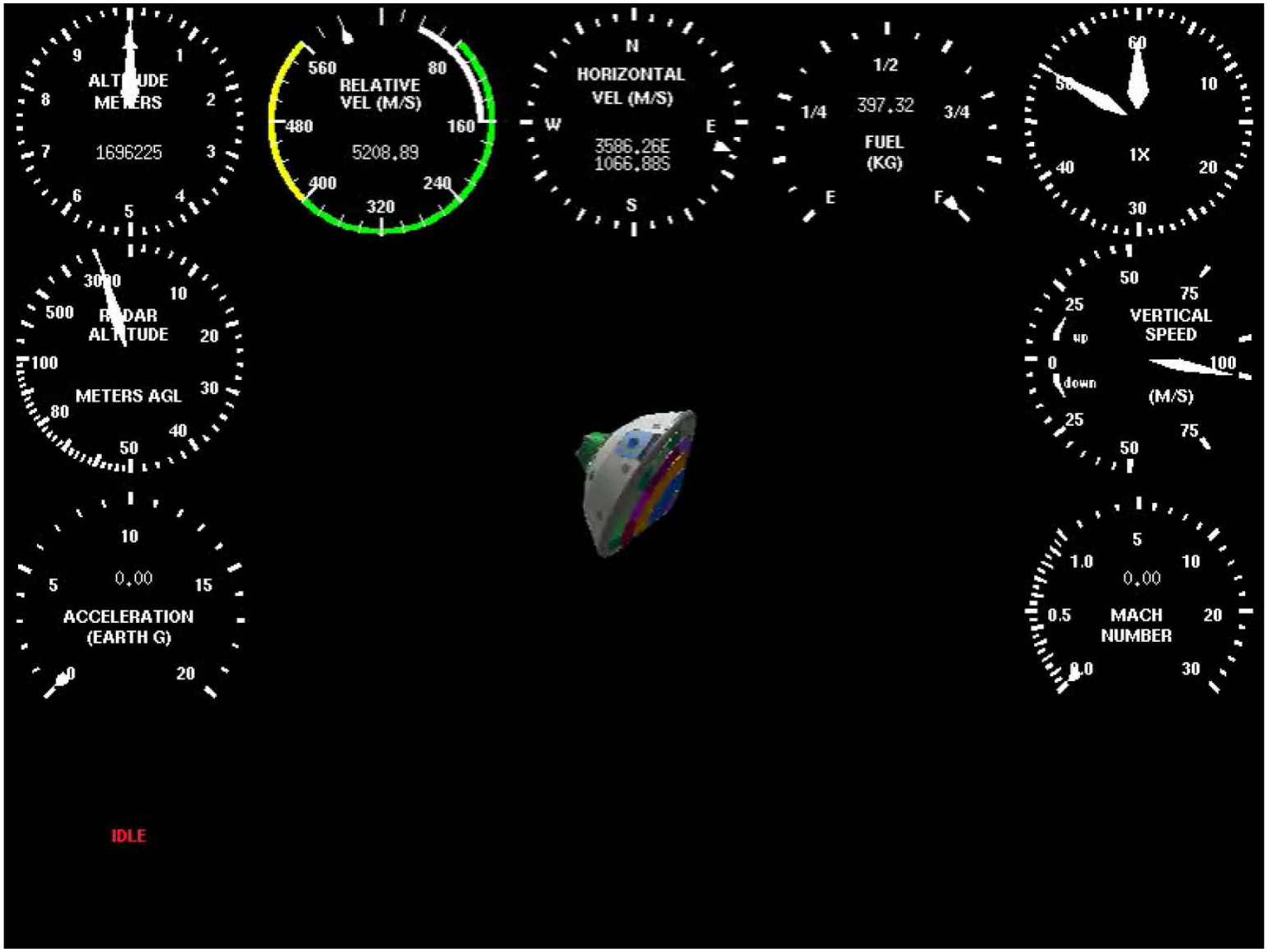
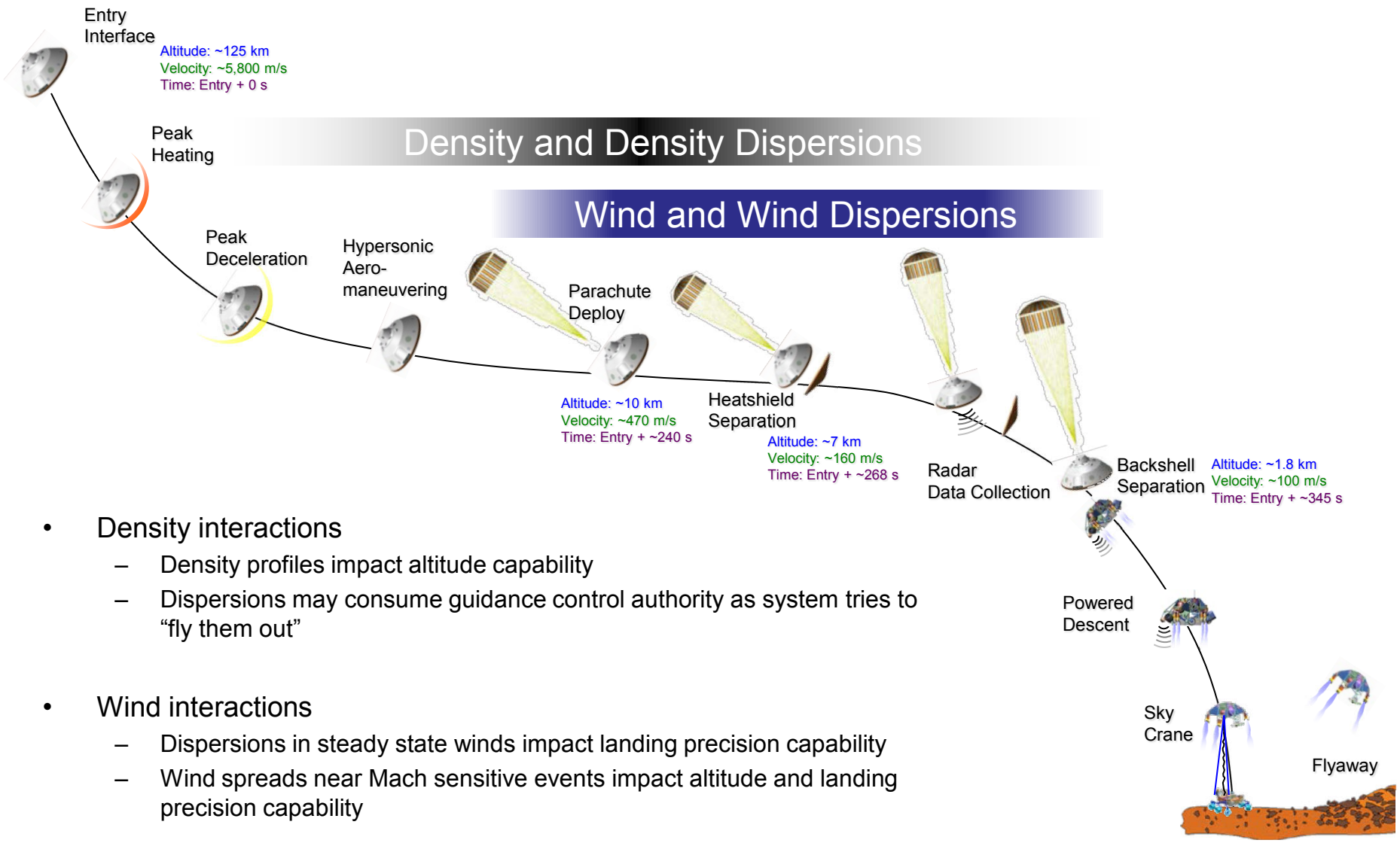
Introduction

- MSL EDL system is finishing its final V+V prior to launch in November 2011
- The system has passed it's S/W-H/W run-for-record in April
- EDL risk assessment has been performed at all landing sites to support site selection
  - All sites have very low EDL risk (< 2%)
- Margins comfortable at all sites
  - Gale has highest margins
  - Eberswalde has lowest margins
  - Under worst case conditions, all margins at all sites still acceptable
- External review of EDL landing site risk assessment has been conducted
  - Board concurs with EDL team's conclusions
- EDL design is nearing completion of V+V and the team is comfortable flying to any site

Animation


ALTITUDE
METERS
1696225
RELATIVE
VEL (M/S)
5208.89
HORIZONTAL
VEL (M/S)
3586.26E
1066.88S
N
W
E
S
1/2
1/4
3/4
397.32
FUEL
(KG)
E
F
1X
RADAR
ALTITUDE
METERS AGL
VERTICAL
SPEED
(M/S)
up
down
0.00
ACCELERATION
(EARTH G)
0.00
MACH
NUMBER
IDLE

EDL Atmosphere Interactions



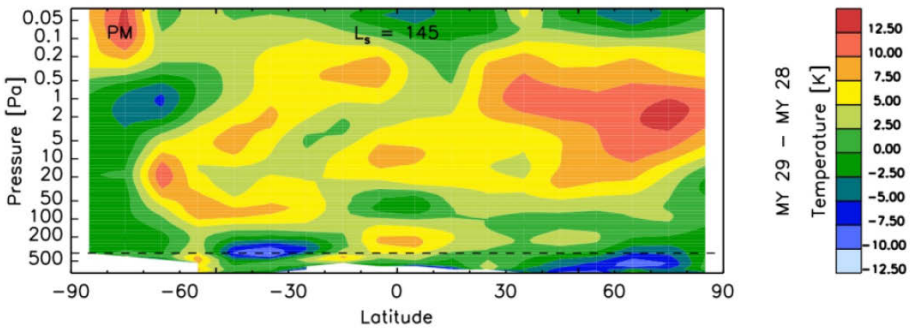
- Density interactions
  - Density profiles impact altitude capability
  - Dispersions may consume guidance control authority as system tries to "fly them out"
- Wind interactions
  - Dispersions in steady state winds impact landing precision capability
  - Wind spreads near Mach sensitive events impact altitude and landing precision capability

Atmosphere Characterization and Modeling Overview

- Atmosphere characterization approach unchanged
  - Updated and validated mesoscale models (OSU, SwRI) based on latest observations
  - Performed surface pressure normalization
  - Developed dust cases based on observed dust events
  - Updated model data integration approach and generated new nominal and dust case atmosphere tables
- Generated EDL performance results for all sites using updated atmosphere model results
- No further major atmosphere characterization activities planned prior to approach
  - Continuing nominal monitoring and model updates if necessary
  - Will execute additional local dust storm robustness work

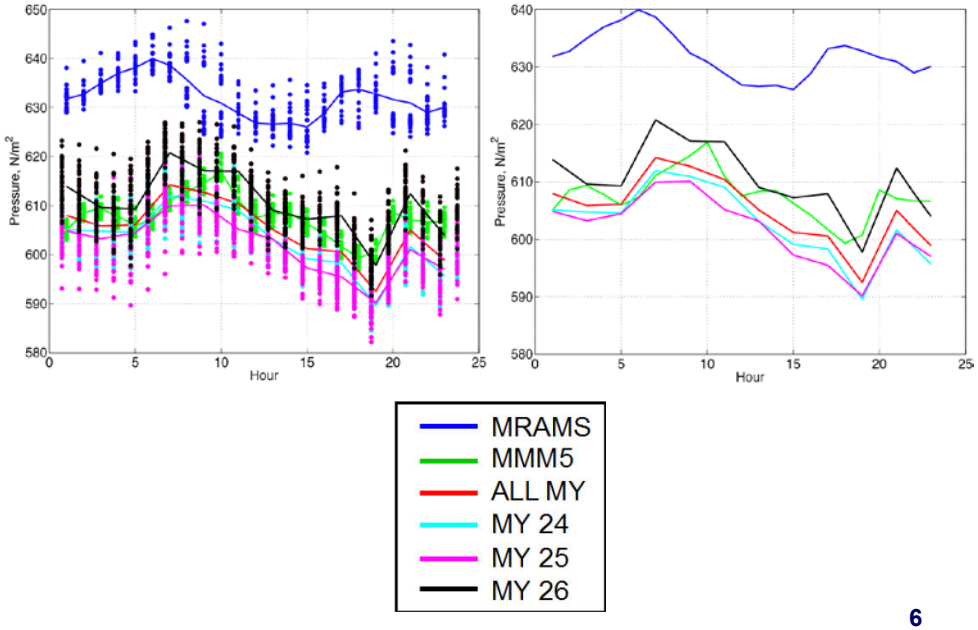
Executed As Planned Updates

- Updated and validated mesoscale models based on MCS measurements and interannual comparisons
  - Observed multiple local times at landing site regions during L-1 Mars year campaign (Fall 2010)



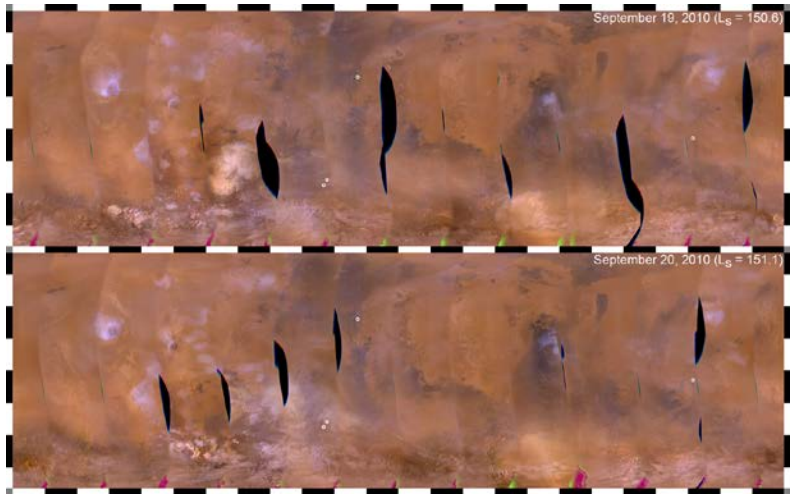
Daytime map of atmospheric temperature vs. height differenced between a year with (MY29) and without (MY28) a regional dust event.

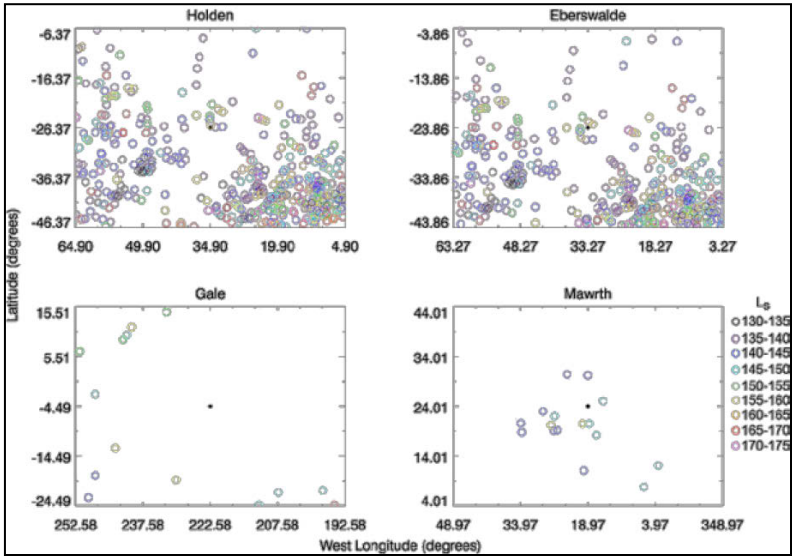
- Updated and corrected any systematic surface pressure biases in Ames GCM and mesoscale model runs
  - Used UK MGCM with TES data assimilation as source
    - Tuned to VL1 record
    - Closely fits radio occultation and Phoenix measurements
  - Used MOLA topography and model thermal structure to compute pressure at precise site elevations



Dust Observations

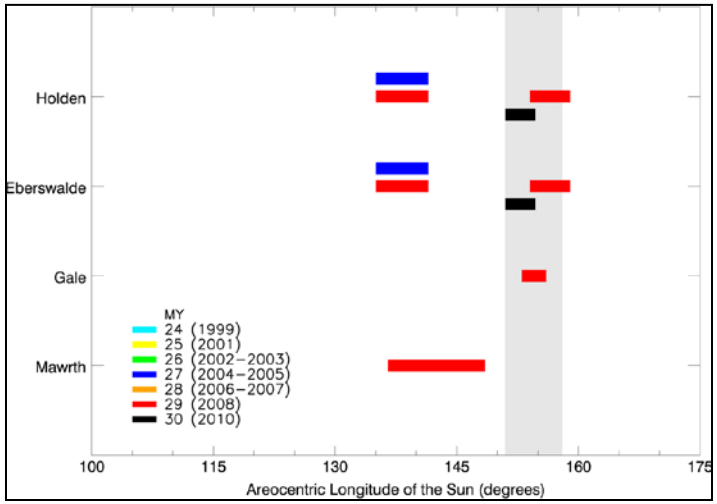
- Observed thermal anomalies associated with dust events via MCS
  - Used observations to validate dust distributions in models
- Commissioned survey of dust events from orbital imagery near sites and arrival season
  - Cantor (MSSS) analyzed 6 Mars years of MOC and MARCI data
  - Assessed likelihood of encountering local and regional dust events
  - Provided information to mesoscale modelers to model dust events
- Regional storm risk interrogated
  - Eberswalde, Holden impacted in 2 of 7 observed Mars years
  - Gale peripherally impacted in 1 of 7 observed Mars years
  - Mawrth impacted in 0 of 7 observed Mars Years
- Modeled regional storm and haze to assess impact on EDL system

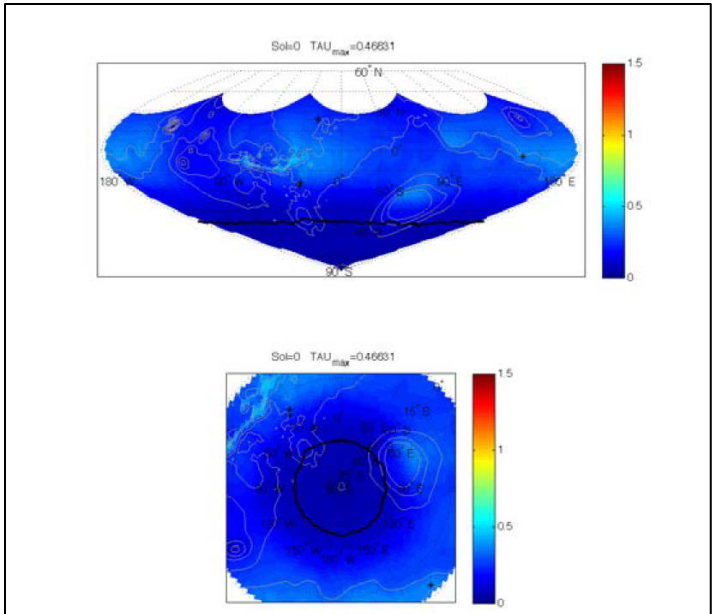




Dust Modeling

- Focused on regional events due to larger temporal and spatial likelihood of encounter
- Modeled MY29-like regional dust events in mesoscale models
  - Augmented nominal mesoscale runs with two types of higher dust cases
  - Dust "haze" mesoscale runs akin to MarsGRAM dusttau cases
  - Parameterized opacity variations in OSU model: "regional-scale dust bombs" designed to simulate observed regional storms
- Use regional dust event runs as part of landing site safety assessment process
  - Investigated sensitivity of zonal winds to dust loading
  - Evaluated an elevated well mixed dust case via mesoscale models
  - "Flew through" model results using same integration process used for nominal cases

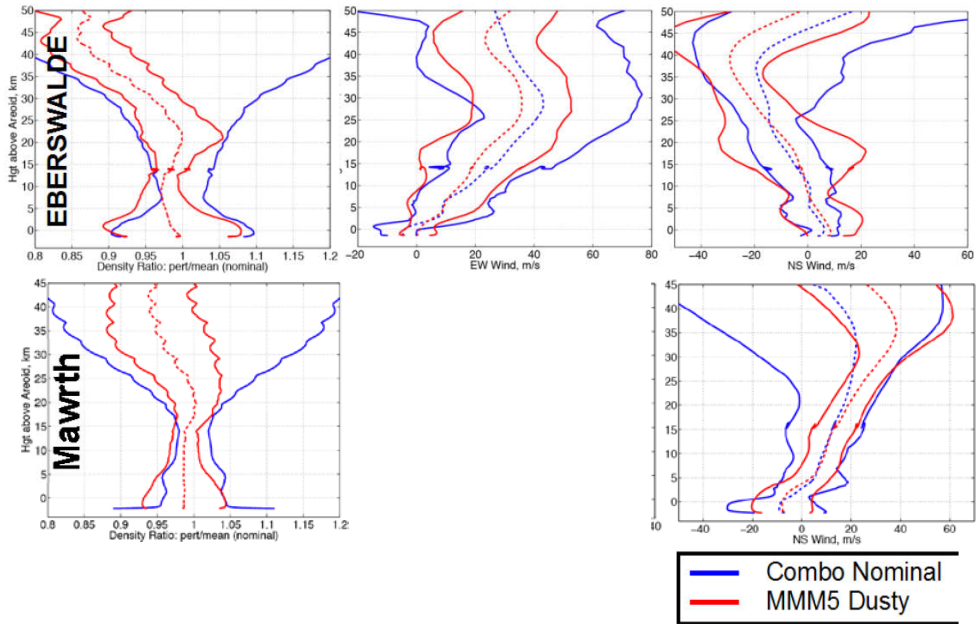




OSU Model Implementation of Southern-Hemisphere Regional Event

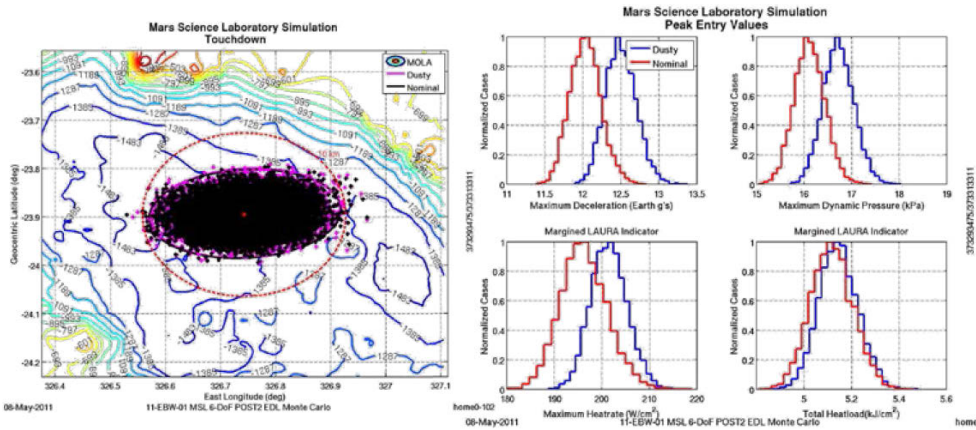
System Impact of Regional Dust Events

- Modeling results revealed dust-related density and wind perturbations to be on par with nominal uncertainties
  - Nominal uncertainties set conservatively using variability bounds of both mesoscale models
  - No significant differences at altitudes of interest



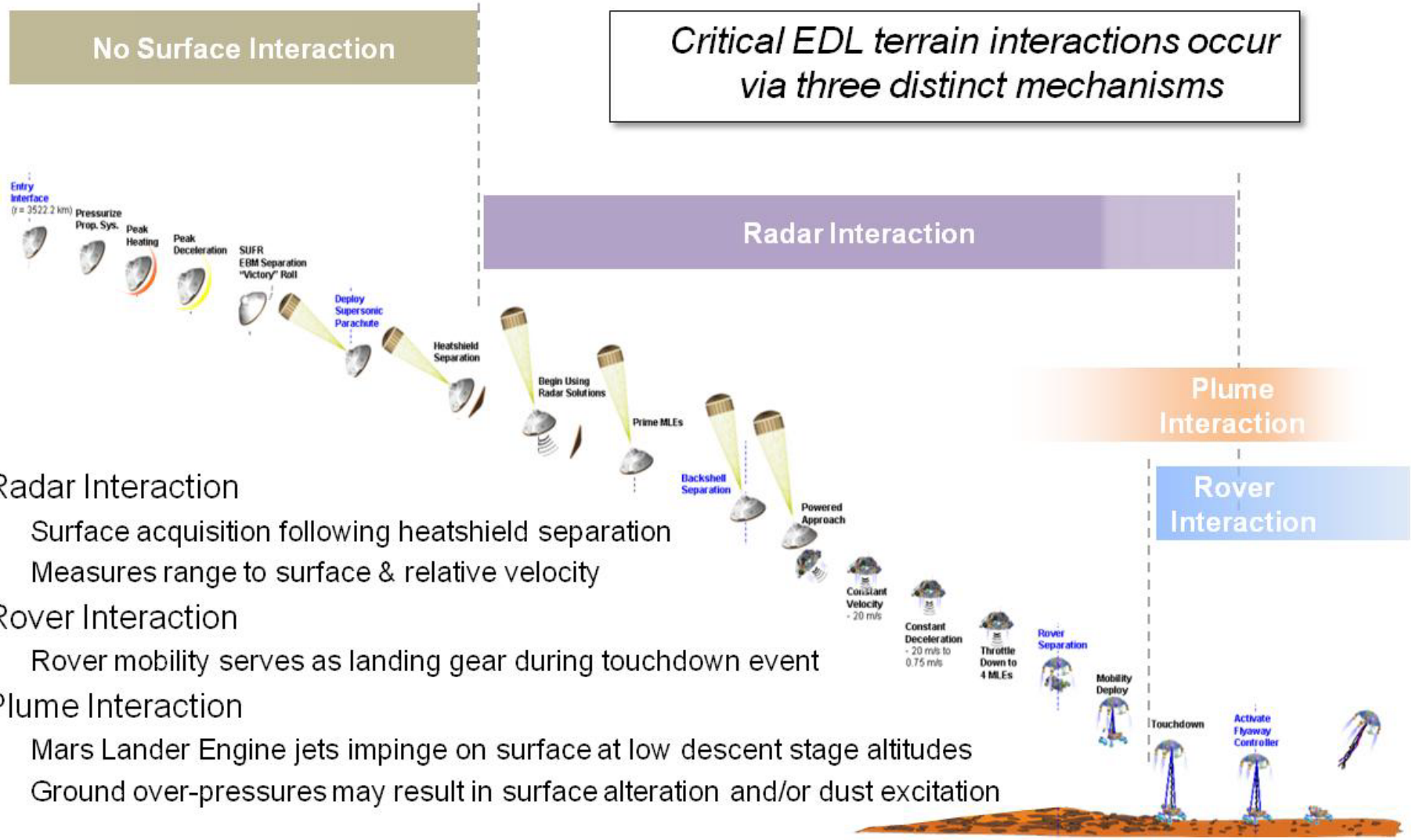
- EDL performance simulations show no significant loss of performance associated with dust

- EDL system is robust to as-modeled regional dust events



EDL Terrain Interactions

Critical EDL terrain interactions occur via three distinct mechanisms



Radar Interaction

- Surface acquisition following heatshield separation
- Measures range to surface & relative velocity

Rover Interaction

- Rover mobility serves as landing gear during touchdown event

Plume Interaction

- Mars Lander Engine jets impinge on surface at low descent stage altitudes
- Ground over-pressures may result in surface alteration and/or dust excitation

Terrain Interaction Assessment Matrix

Biggest Drivers

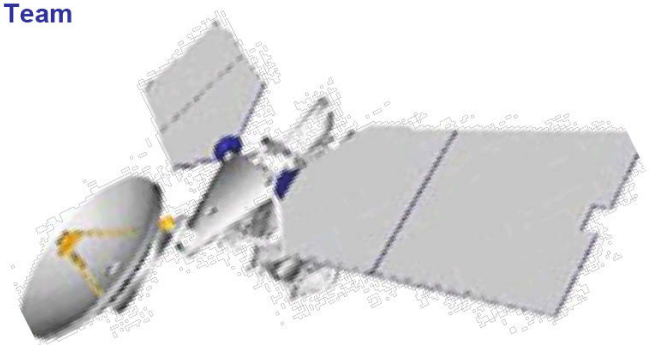
Interaction Category	Description	Primary Analysis Method	Confirming Method
Touchdown Loads	*Rover/Mobility margins during touchdown*	*ADAMS*	Test
Touchdown Stability	*Rover dynamic stability (tip-over)*	*ADAMS*	Test
Terrain Relief	Accordions not sized properly to account for terrain relief	Bounding Analysis	POST/Sulcata
RF (TDS Performance)	TDS rage and velocimetry data inaccurate outside of the expected TDS performance	Simulations (POST/Sulcata)	Field Test
Touchdown Trigger Spoofing	Prolonged Rover-DS interaction (retensioning of the bridle) could preclude timely detection of the post-touchdown state and cause the DS to approach too close to the surface	Bounding Analysis	ADAMS
Propellant Usage (during TD)	Extended touchdown event due to large slope	Bounding Analysis	ADAMS (time)
Loaded Bridle Contact	Tensioned bridles coming into contact with top deck hardware during the touchdown event.	Bounding Analysis	ADAMS
Direct Plume Impingement	Thermal and physical damage caused by direct plume impingement on the rover during the touchdown event	Bounding Analysis – Through TD Offline Sim – Flyaway	ADAMS – Through TD POST – Flyaway
Indirect Plume Impingement	Sandblasting/covering the rover with entrained surface particulates	Bounding Analysis	N/A
Telecom / Thermal	Rover left in a state such that basic surface operation functions can be carried out	Engineering Assessment	N/A
Trafficability	Rover is left in a state where traverse is possible	Engineering Assessment	N/A

Radar
Plume
Direct

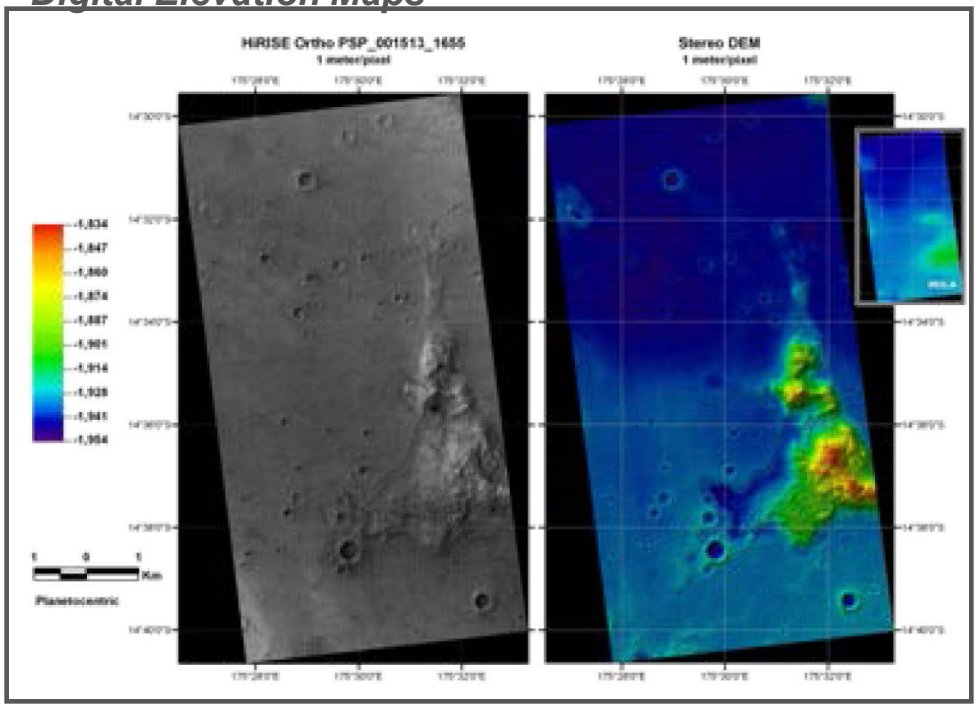
Complete
In-Process

“Direct” Interaction

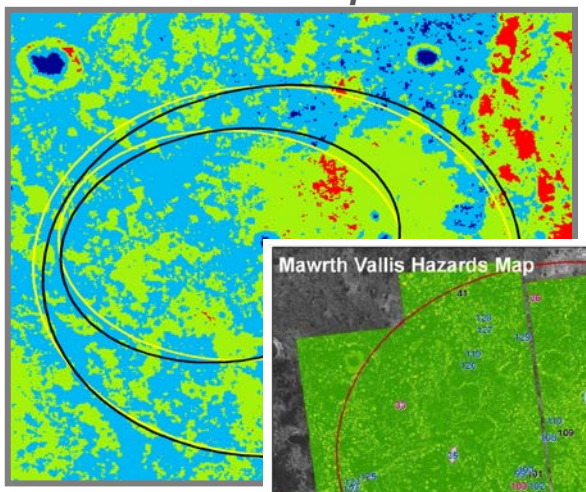
Critical Terrain Data Sets

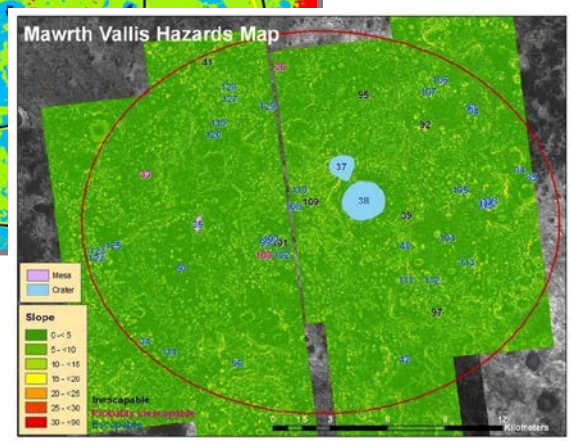


Digital Elevation Maps

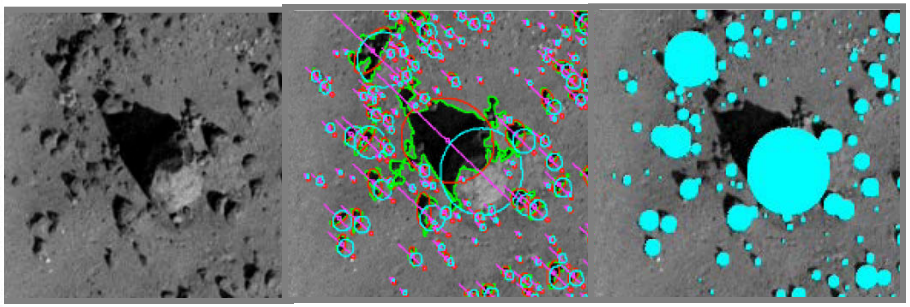


Surface Material Maps



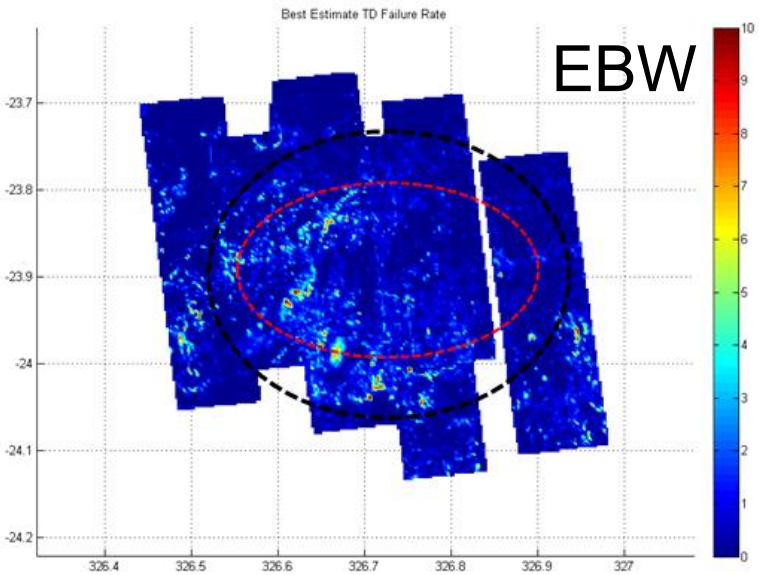


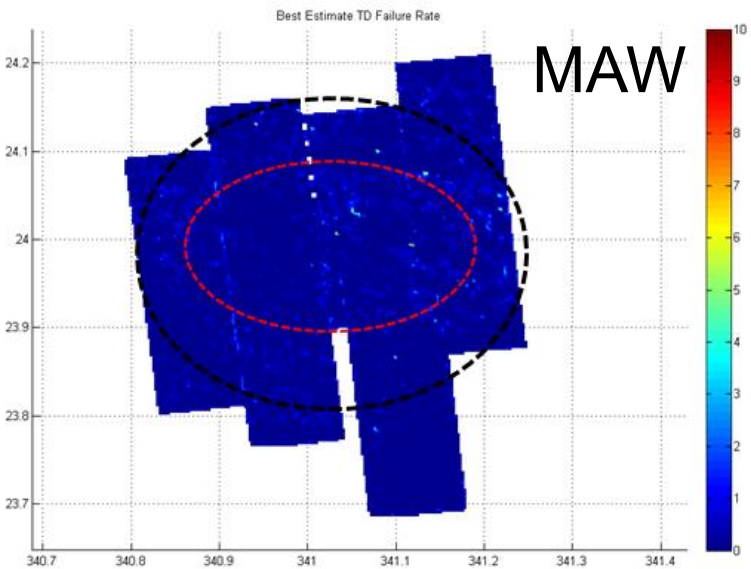
Inescapable Hazard Maps

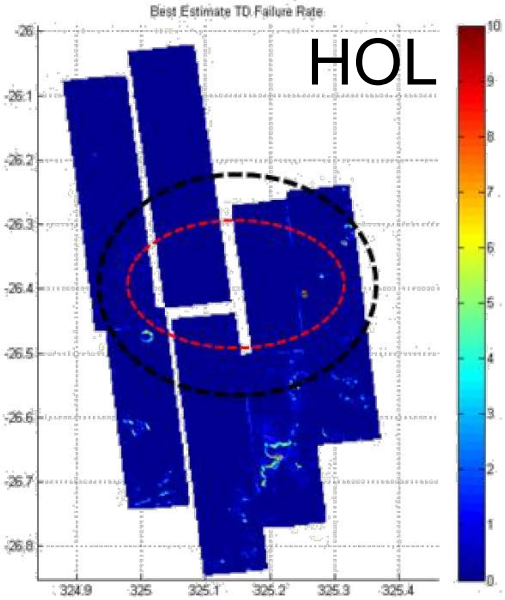


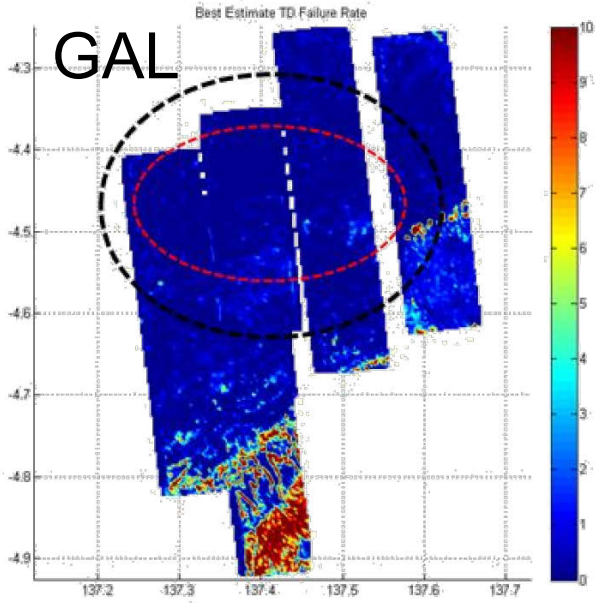
Rock Maps

Touchdown Hazard Maps

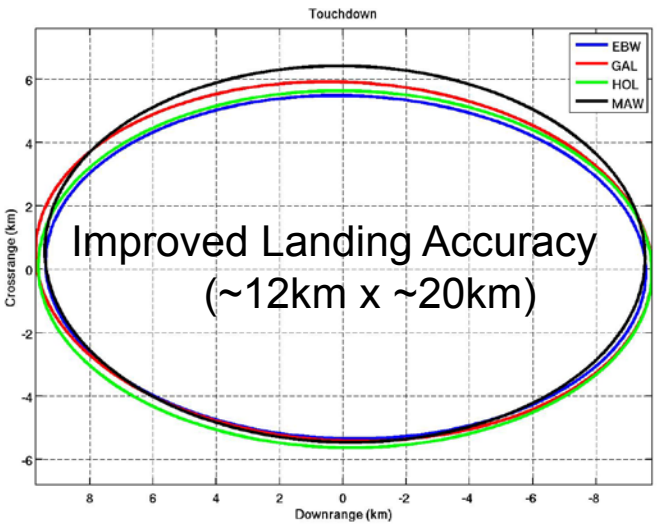




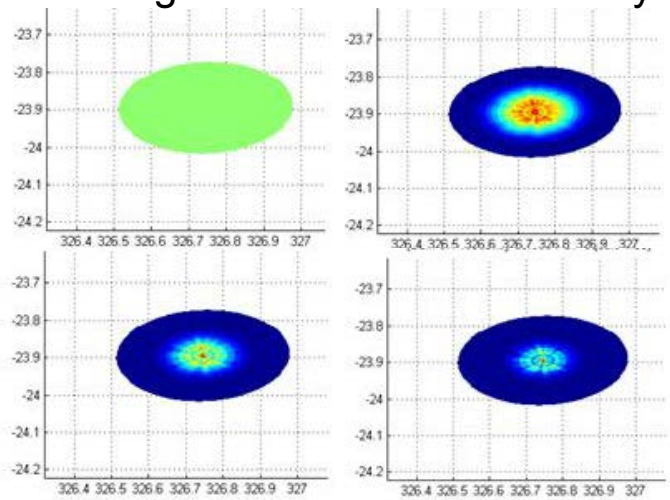


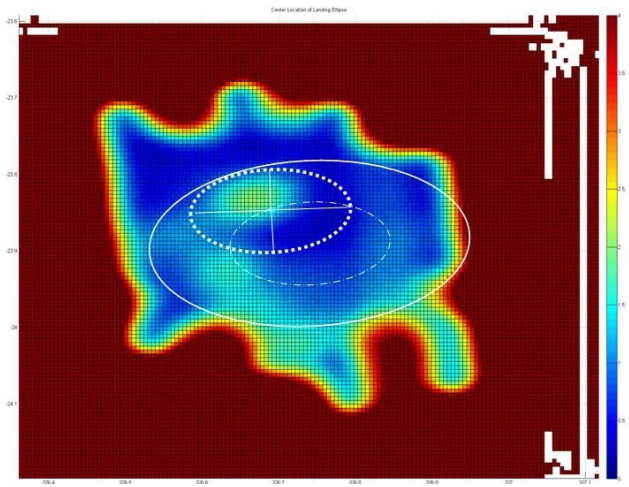


Ellipse Sensitivities



Landing Points Distribution Study

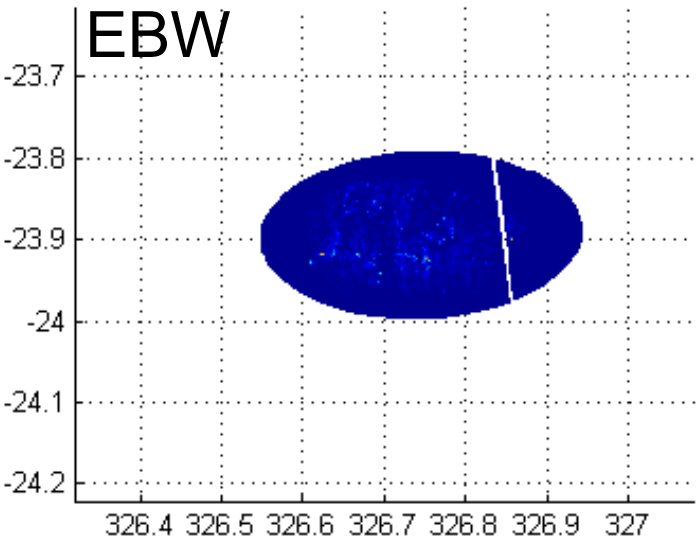


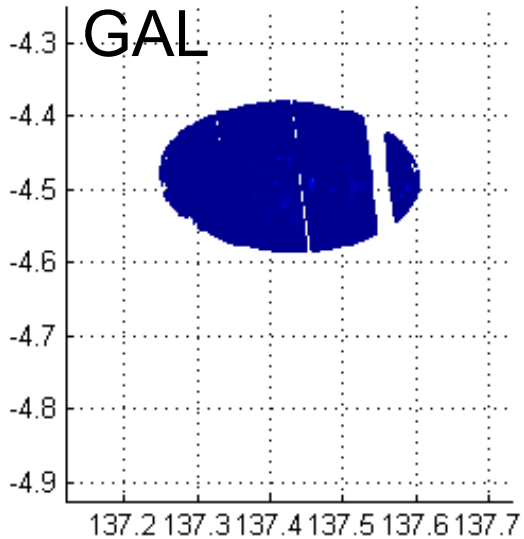


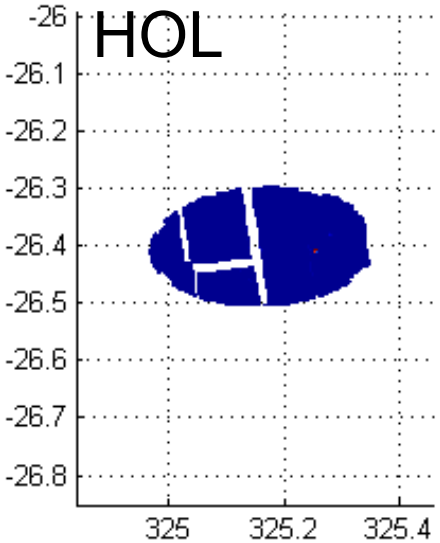
Ellipse Size / Targeting Study

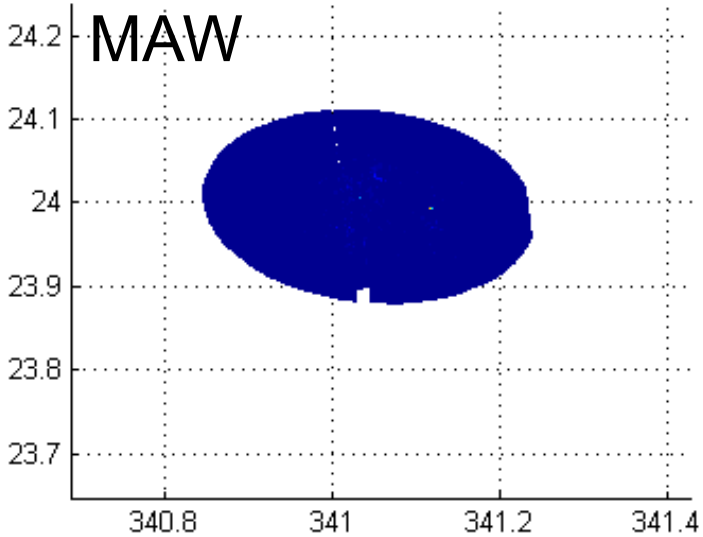
- Risk assessment at all sites is robust to variations in landing points distributions / ellipse size
- Risk assessment process and tools enable optimal ellipse placement to minimize EDL risk
  - Small motions relative to current targets (<5km)

Convolution of Landing Points/Hazards









	EDL Terrain Success Rate
Eberswalde	99.36%
Gale	99.79%
Mawrth	99.79%
Holden	99.86%

Conclusions

UPDATE

- EDL risk assessment has been performed at all sites
  - Preliminary EDL tuning is complete
- External review of EDL landing site risk assessment has been conducted
  - Board concurs with EDL team's conclusions
- All sites have low EDL risk
  - Sites have differing levels of risk, but differences are small
- Margins comfortable at all sites
  - Gale has highest margins
  - Eberswalde has lowest margins
  - Under worst case conditions, all margins at all sites still acceptable
- EDL team is comfortable flying to any site