



16th International Planetary Probe Workshop

InSight Entry, Descent and Landing Post-Flight Simulation Assessment

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Central Question

How well did our pre-flight estimates of what should happen during entry, descent, and landing (EDL) match the “as-flown” (reconstructed) trajectory?

Trajectory Reconstruction

The “As-flown” EDL trajectory was reconstructed based on high rate (200 Hz) telemetry data collected during the flight.

- Initial conditions based on final / pre-entry orbit determination solution
- Density profile provided by atmosphere team 2 days prior to entry
- Mean wind profile of 8001 dispersed profiles provided by atmosphere team
- Vehicle mass also estimated based on telemetry data (e.g. fuel usage)

Comparison: Final Prediction vs Reconstruction

In general, the final prediction from the simulation compared very well against what was reconstructed during flight. However, there are a few parameters that fell outside of what was expected. Namely,

Peak G's

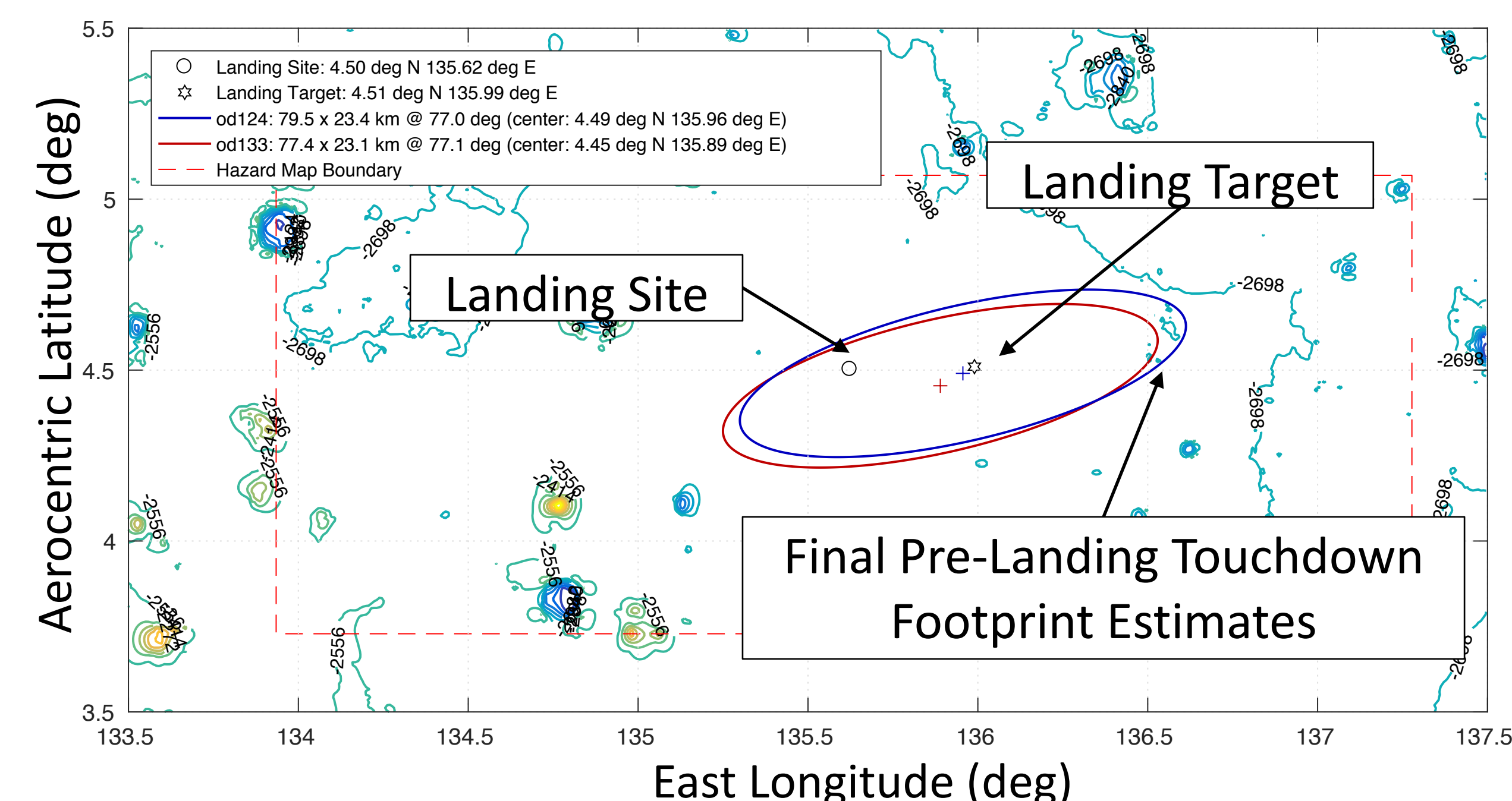
- The vehicle reached a peak g-load of 8.25 g's (+3.1 sigma)

Timeline

- The EDL duration was 5 min 48s (-1.6 sigma), almost 41 seconds shorter than expected.

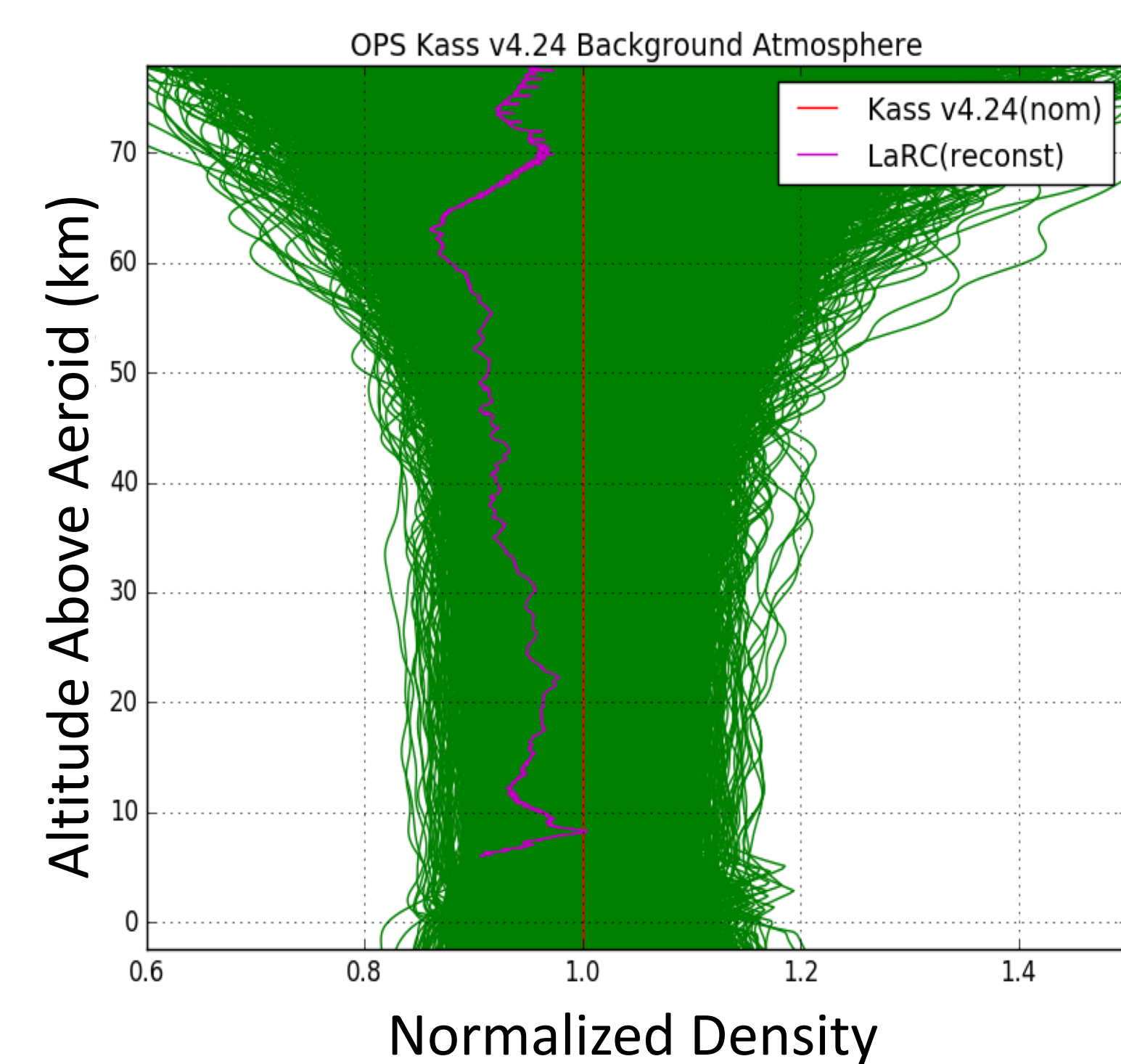
Landing Location

- The vehicle landed 12.3 km uprange with a 6.1 km crossrange error, or 13.9 km from the center of the final predicted landing ellipse

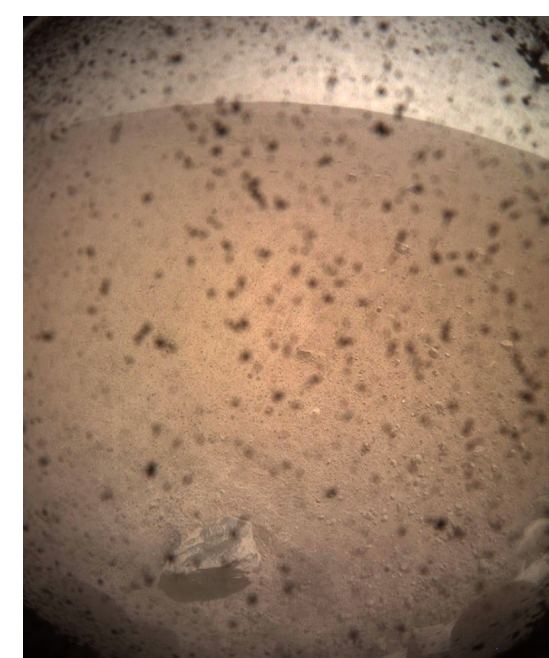


Low-Density Atmosphere

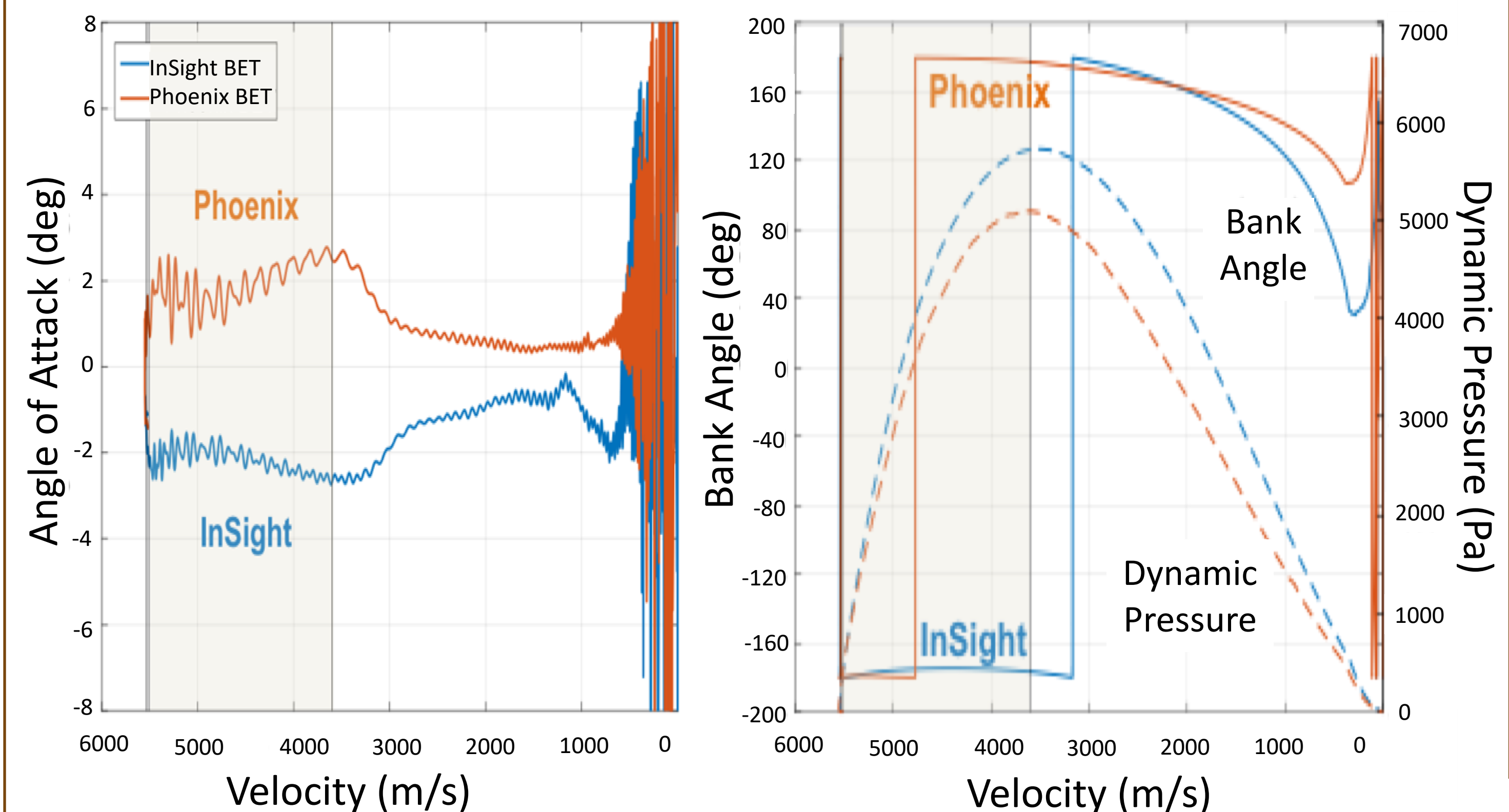
The reconstructed atmosphere shows that on the day of landing the density of the atmosphere was on the 1-sigma low end of the prediction.



A lower-than-expected density means the vehicle would be decelerating deeper in the atmosphere than predicted and would in part explain why the timeline was shorter and the peak g's were higher than expected.



Non-Zero Angle of Attack

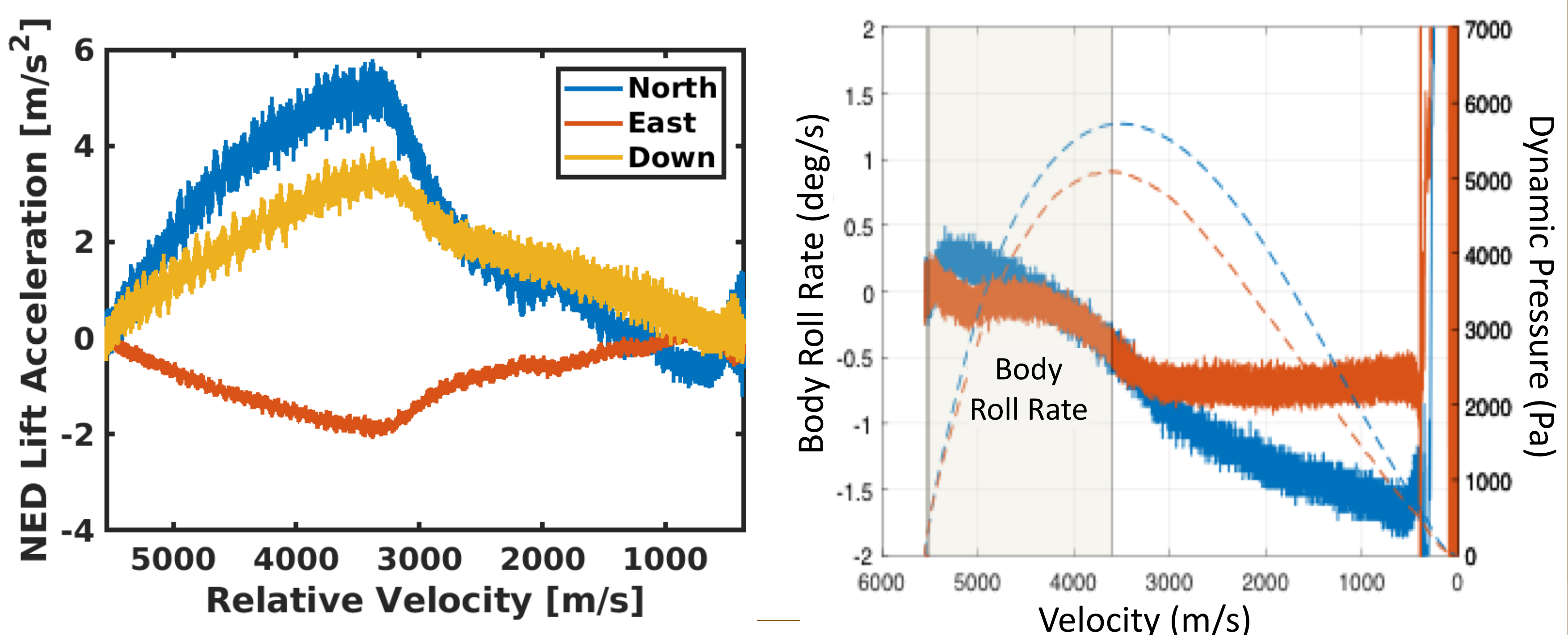


Despite the fact that InSight was designed to fly a ballistic trajectory (by definition, non-lifting), a non-zero angle of attack and side-slip angle (max 4 deg) was observed. A negative angle of attack and a bank angle of roughly 180 deg translates to a lift vector pointed down. Flying lift-down would in part explain the short timeline and landing location.

* Due to the similarities between InSight and Phoenix, Phoenix reconstruction data is provided as a point of comparison.

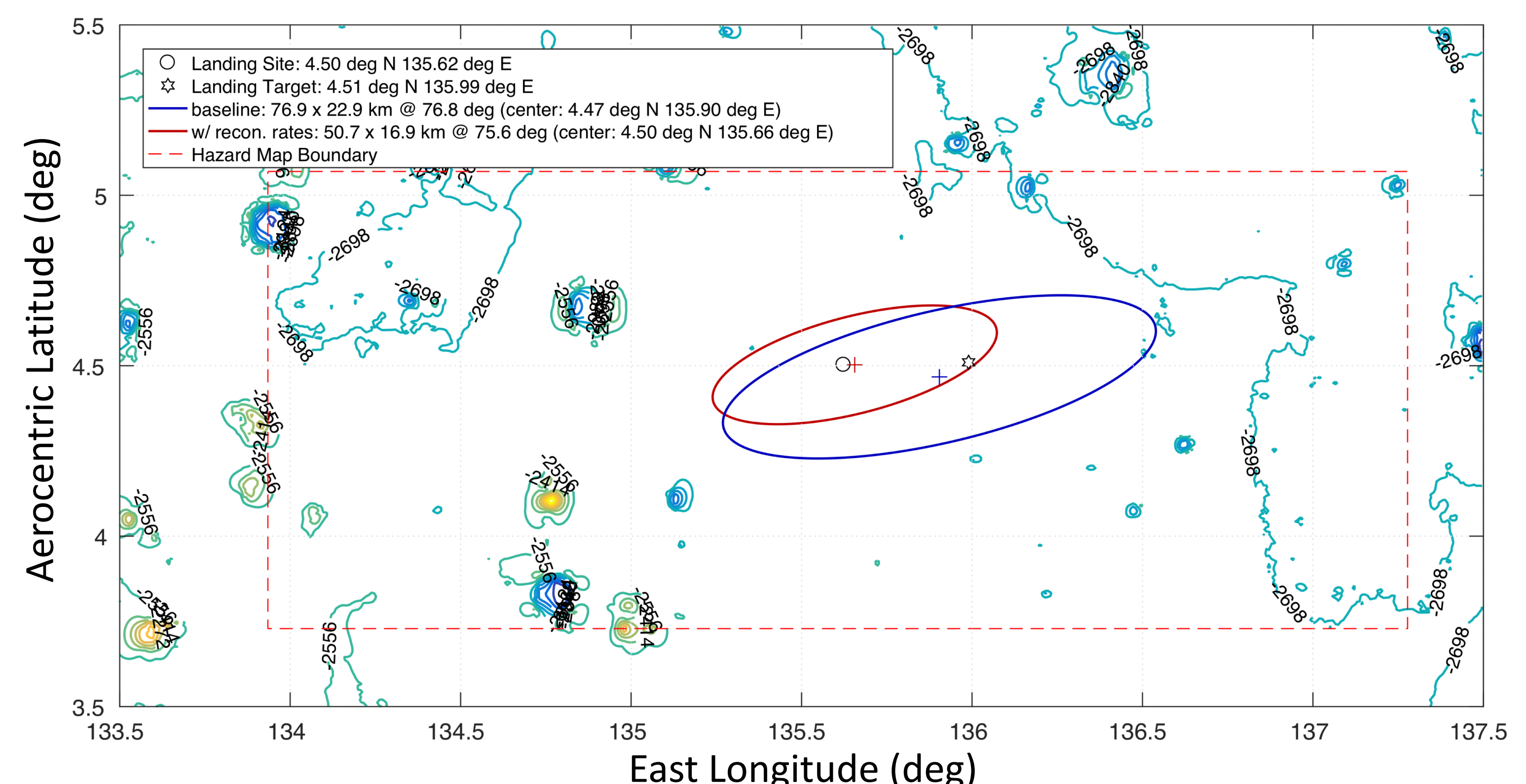
Vehicle Roll

A slow clockwise roll (coinciding with peak dynamic pressure) followed by a reversal to a slow counter-clockwise roll was observed in the reconstructed trajectory.



This slow roll motion is likely a bi-product of flying a “knuckleball” (non-spinning) ballistic entry. While the change in bank angle is small, the resulting lift cross-track component during peak dynamic pressure may have been sufficient to push the vehicle to the left of the landing target.

A prescribed roll rate matching the reconstructed value was enforced in the LaRC POST2 simulation and the predicted touchdown footprint using this enforced roll rate is centered around the landing location. The roll motion is the most likely explanation for why the vehicle landed short and to the left of the target.



Conclusion

A combination of atmosphere (low density), aerodynamics (a lift-down entry and unmodeled roll behavior) and mass properties (i.e. unknown c.g. offset) likely contributed to the high entry load, short timeline and “off-center” landing location. Due to a lack of heatshield instrumentation, it is impossible to determine the exact contributions of each. It is also likely that if the InSight entry vehicle were spin stabilized, the pre-flight predictions would have been improved.