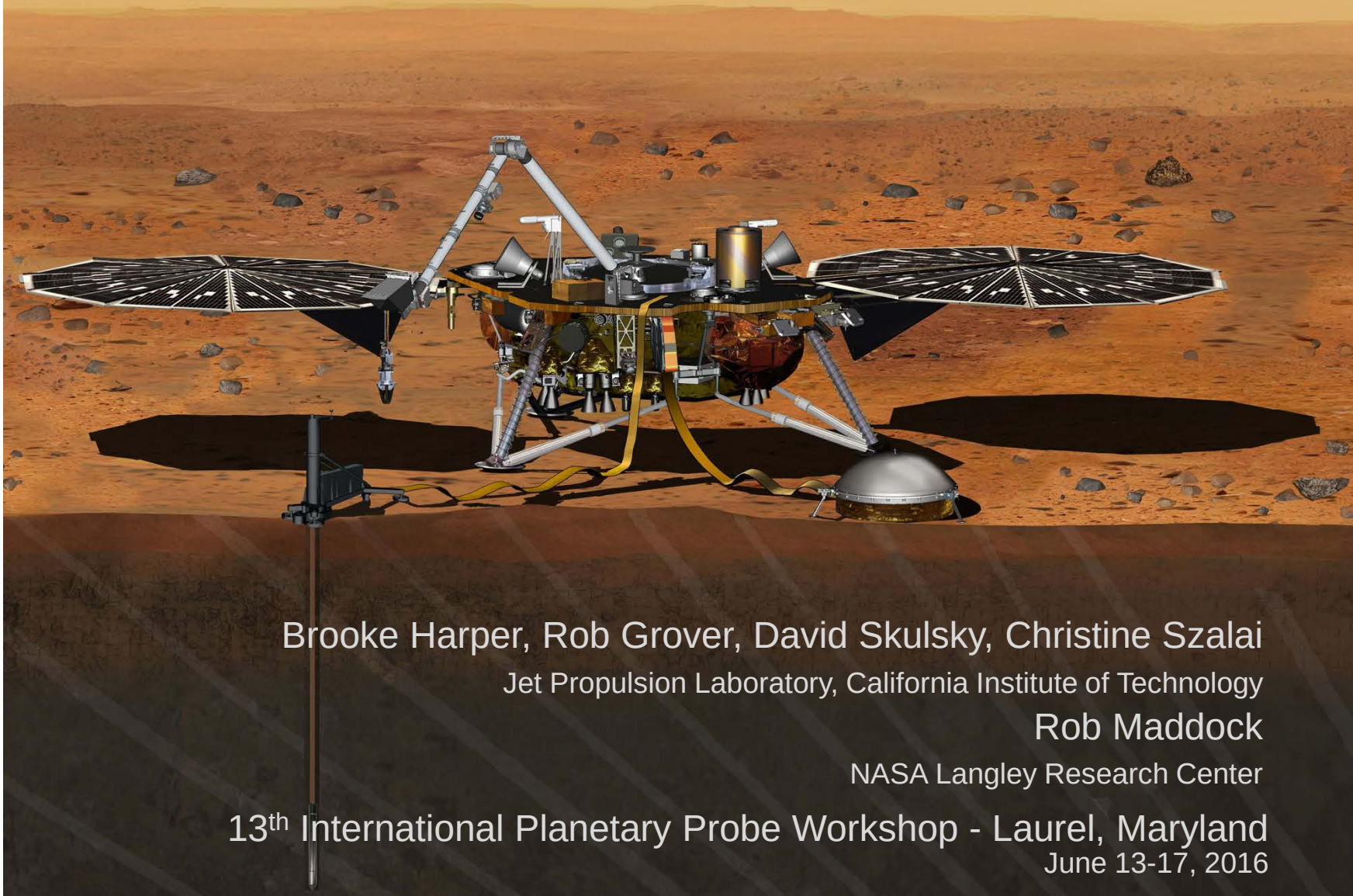
Status of InSight Entry, Descent, and Landing for 2018 Launch Opportunity



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13th International Planetary Probe Workshop - Laurel, Maryland

June 13-17, 2016

InSight Mission

Science Goals:

1. Understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars
   - » Seismology
   - » Precision Tracking
   - » Heat Flow
2. Determine the present level of tectonic activity and meteorite impact rate on Mars

- InSight is a Mars lander based on Phoenix heritage
- 6.5-month cruise
- Ballistic entry
- One Martian year of science measurements on the surface

Comparison to Phoenix

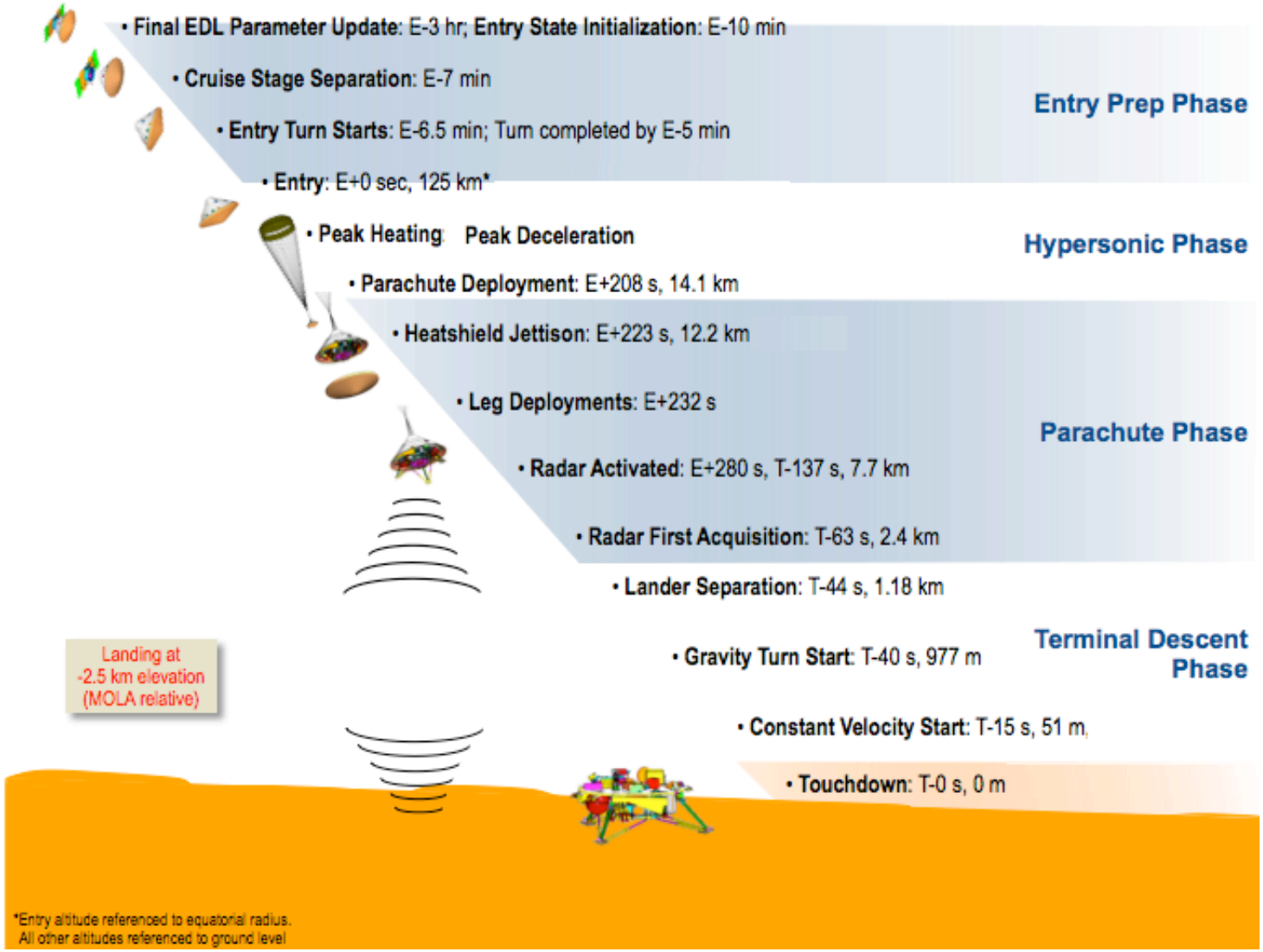
	Phoenix	2016 InSight
Launch Window	August 3-24, 2007	March 4-30, 2016
Arrival Date	May 25, 2008	September 28, 2016
Entry Vehicle Mass	572.7 kg	612.2 kg*
Inertial Entry Velocity	5.6 km/s	6.02 km/s
Entry Flight Path Angle	-13.0 ± 0.27° (3σ)	-12.5° ± 0.21° (3σ)
Landing Site Latitude	68°N	4.46°N
Max Landing Site Elevation	-4.1 km (wrt MOLA)	-2.5 km (wrt MOLA)
Ls / Dust Season	76.7° (late Northern Hemisphere Spring/not dust season)	231° (Southern Mid-Spring/Global dust storm season)
Surface Characteristics	Sub-surface ice	Smooth, flat surface / broken up regolith

*Maximum expected value (MEV) from November 2015

InSight has to decelerate more mass from a greater velocity through less atmosphere than Phoenix

Entry, Descent, and Landing Overview

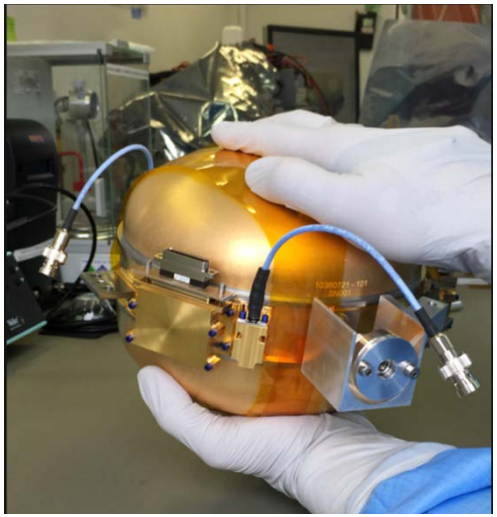
- InSight EDL design is mature – minimal design changes from Phoenix



Development Challenges

SEIS: the primary payload for the InSight mission

- Very sensitive seismometer designed to measure Martian ground motions as small as the diameter of an atom
- Sensors must be contained in a near vacuum
- Vacuum container developed a leak and there was insufficient time to resolve the leak in support of a March 2016 launch opportunity



InSight was suspended December 22nd, 2015

Onward to 2018!

- Science goals of InSight are compelling and the plans to overcome the SEIS technical challenges are sound

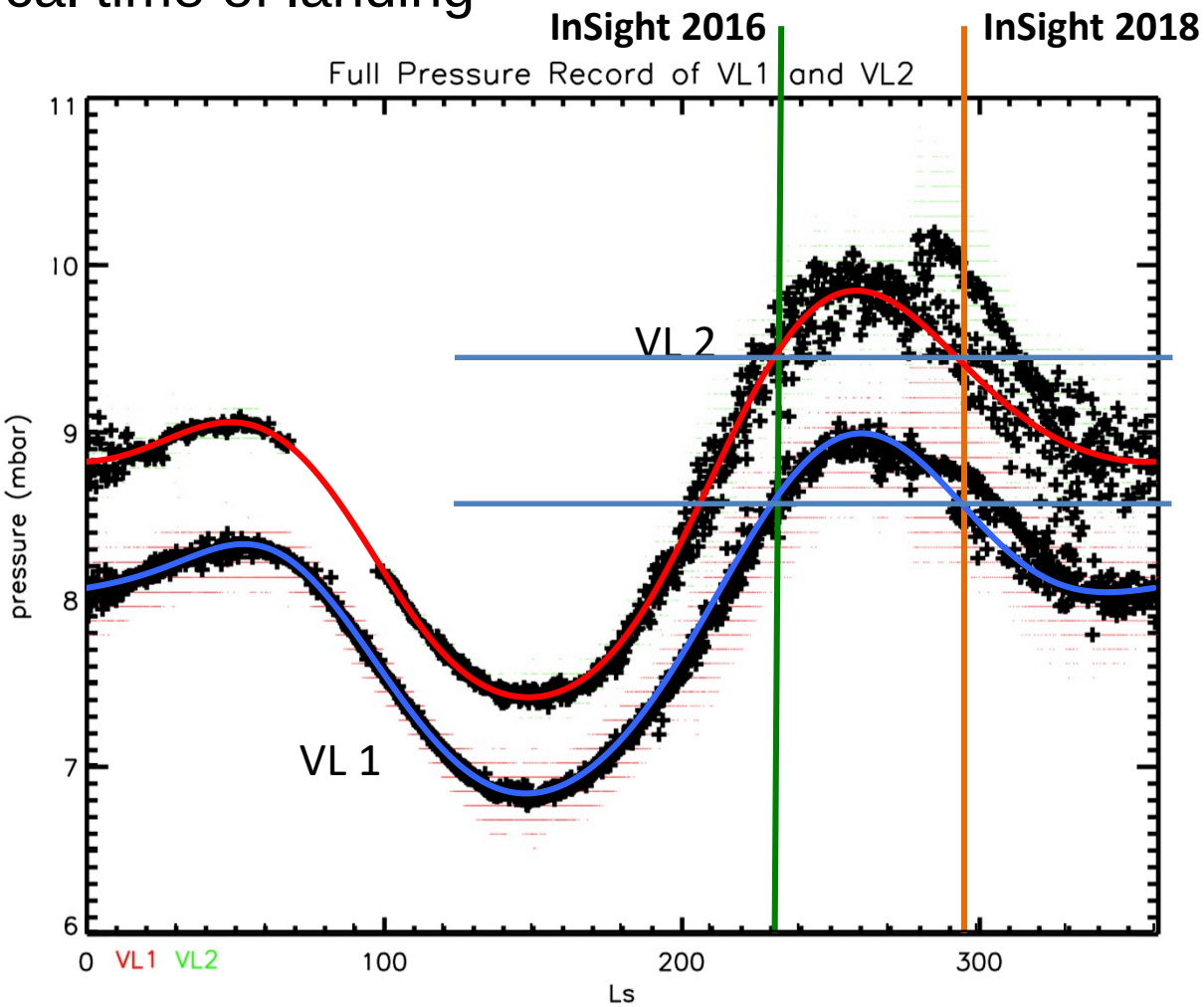
NASA targeting a new launch opportunity beginning May 5, 2018

	2016 InSight	2018 InSight
Launch Period	March 4-30, 2016	**May 5-June 8, 2018**
Arrival Date	September 28, 2016	**November 26, 2018**
Entry Vehicle Mass	612.2 kg*	No change
Inertial Entry Velocity	6.02 km/s	**5.63 km/s**
Entry Flight Path Angle	-12.5° ± 0.21° (3σ)	**12.0 ± 0.21° (3σ)**
Landing Site Latitude	4.46°N	No change
Max Landing Site Elevation	-2.5 km (wrt MOLA)	No change
Ls / Dust Season	231° (Southern Mid-Spring/Global dust storm season)	**295° (Early Southern Summer/tapering Global dust storm season)**
Surface Characteristics	Smooth, flat surface / broken up regolith	No change

*Maximum expected value (MEV) from November 2015

Surface Pressure at Ls 295°

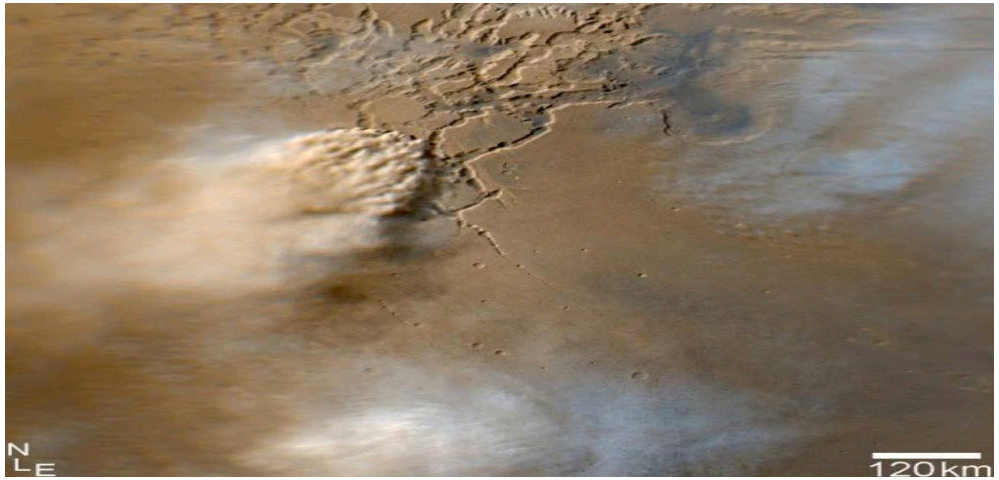
- Ls 295° has a 0.4% higher pressure than Ls 231°
  - At the local time of landing



EDL Challenge

Atmospheric Modeling: As was the case in 2016, InSight is landing during dust storm season

- Multiple InSight landing site specific models necessary
- Very few existing wind measurements
  - Standard wind profiles are uncertain to a factor of ~2
  - Outlier wind profiles account for model uncertainty
- Maturity of atmosphere modeling for 2018 is the most significant lien against EDL system performance



Preliminary EDL Simulation Results for 2018

- Retained baseline EFPA = -12.5°
- Monte Carlo Results compared to 2016
  - Aeroheating significantly reduced
    - ~10 W/cm^2 reduction in peak heating and ~600 J/cm^2 reduction in heat load
  - Landing ellipses smaller by about 10-15km in major axis and 1-3km in minor axis
  - Parachute Inflation load only slightly increased
  - Timeline margin decreased due to lower mean altitude at parachute deploy

Improved heating margins allow consideration of alternate EFPAs to balance EDL margins across the board

2018 EDL EFPA Trade Summary

Performance Metric	Metric Stat	Units	EFPA = -11.75°	EFPA = -12.0°	EFPA = -12.5°	EFPA = -13.0°
Peak Heat Rate	99%	W/cm2	-6.02%	-3.95%	-	3.65%
Integrated Heat Load	99%	J/cm2	7.56%	4.83%	-	-3.83%
Peak Deceleration	99%	Earth g	-13.67%	-8.93%	-	8.70%
Mach at Parachute Deploy (H)	99%	Mach No.	0.52%	0.00%	-	-1.04%
Mach at Parachute Deploy (L)	1%	Mach No.	5.88%	3.27%	-	-3.27%
Inflation Load at Parachute Deploy Indicator	99%	kips	-1.22%	-0.74%	-	0.54%
Low Altitude at Parachute Deploy	99%	m	15.75%	9.66%	-	-8.84%
High Altitude at Parachute Deploy	1%	m	3.95%	2.83%	-	-3.68%
Peak Attitude Rate Amplitude at HS Sep	99%	deg/s	11.39%	6.68%	-	-7.43%
Peak Attitude Rate Amplitude at Leg Deploy	99%	deg/s	34.23%	15.89%	-	-18.21%
Vertical Velocity at Touchdown (H)	99%	m/s	0.36%	0.00%	-	0.00%
Vertical Velocity at Touchdown (L)	1%	m/s	0.00%	0.00%	-	0.00%
Horizontal Velocity at Touchdown	1%	m/s	0.00%	-1.92%	-	-1.92%

- Percent change relative to the EFPA = -12.5°

Shallowing the EFPA from -12.5° to -12.0° recommended baseline

Historical Comparison of EDL Performance Metrics

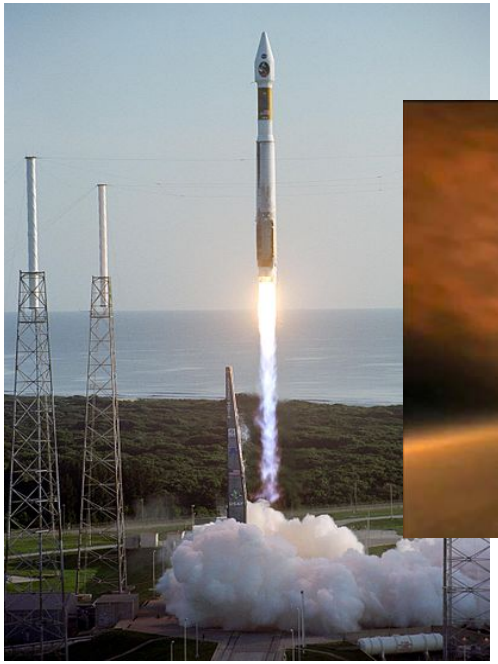
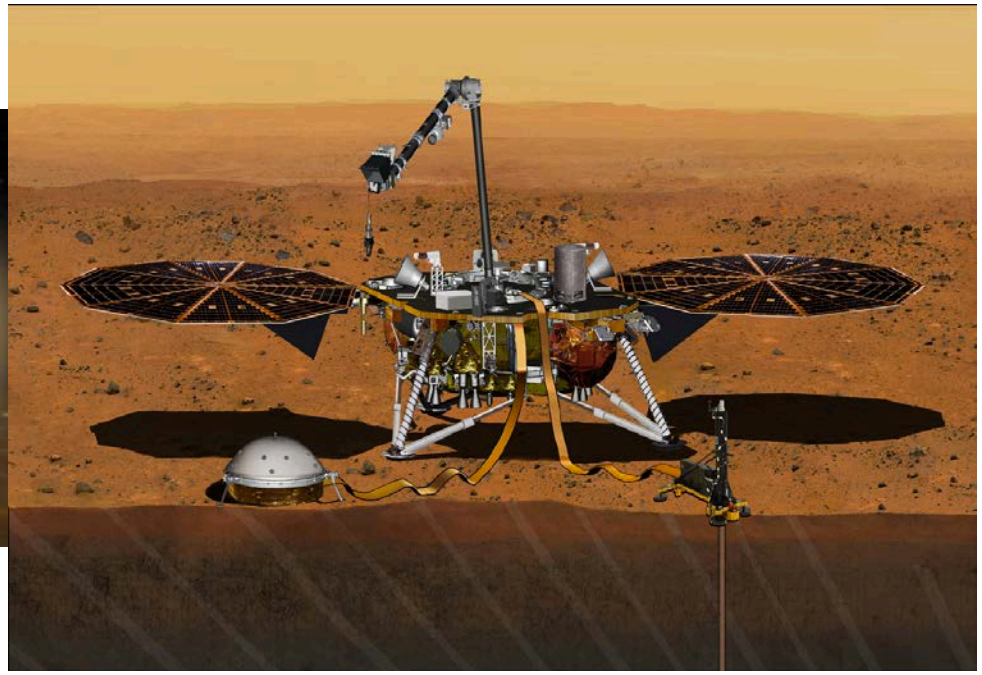
Performance Metric	Metric Stat	Units	Phoenix	2016 Baseline	2016 Outlier Winds	2018 Baseline	2018 Outlier Winds
Entry Flight Path Angle (shallow)	+3-sig	deg	-3.1%	-	-	4.1%	4.1%
Entry Flight Path Angle (steep)	-3-sig	deg	-2.5%	-	-	4.0%	4.0%
Peak Heat Rate	99%	W/cm2	-23.7%	-	6.5%	-19.3%	-14.1%
Integrated Heat Load	99%	J/cm2	-23.7%	-	3.8%	-10.2%	-6.6%
Peak Deceleration	99%	Earth g	-2.8%	-	0.1%	-14.5%	-14.5%
Mach at Parachute Deploy (high)	99%	Mach No.	-6.0%	-	1.1%	-	1.4%
Mach at Parachute Deploy (low)	1%	Mach No.	-4.4%	-	0.6%	2.0%	2.5%
Inflation Load at Parachute Deploy Indicator	99%	kips	-31.6%	-	0.5%	-0.6%	-0.4%
Peak Attitude Rate Amplitude at HS Sep	99%	deg/s	-38.9%	-	1.3%	1.9%	5.6%
Peak Attitude Rate Amplitude at Leg Deploy	99%	deg/s	-30.2%	-	1.7%	2.8%	4.0%
Vertical Velocity at Touchdown (high)	99%	m/s	-3.9%	-	0.5%	-0.4%	-0.6%
Vertical Velocity at Touchdown (low)	1%	m/s	-8.1%	-	-0.2%	0.3%	-0.1%
Horizontal Velocity at Touchdown	1%	m/s	63.2%	-	0.26	-14.3%	12.2%

- Percent change relative to the 2016 baseline
- Background atmosphere, close launch period

2018 opportunity is better (in general) than the 2016 opportunity from an EDL perspective

Assembly, Test and Launch Operations 2.0

- SEIS integration
- Spacecraft has been environmentally qualified in Phase 1 ATLO, Phase 2 ATLO will perform one-each workmanship environment test of the Launch configuration (Acoustic) and the Lander configuration (Thermal)
- Redo System Verification Tests, Operations Readiness Tests, separation, and phasing tests
- Closeout remaining V&V activities and requirements

Project Milestones: Finish and Fly

- Start of One Year Hiatus – 4/25/2016
- Functional SEIS to ATLO – 4/30/2017
- ATLO Re-Start – 7/11/2017
- Spacecraft to Vandenberg Air Force Base – 2/28/2018
- Launch Period – 5/5/2018 to 6/8/2018
- InSight EDL – 11/26/2018