

STATUS OF THE INSIGHT ENTRY, DESCENT, AND LANDING SYSTEM



Brooke Harper, Rob Grover, Christine Szalai

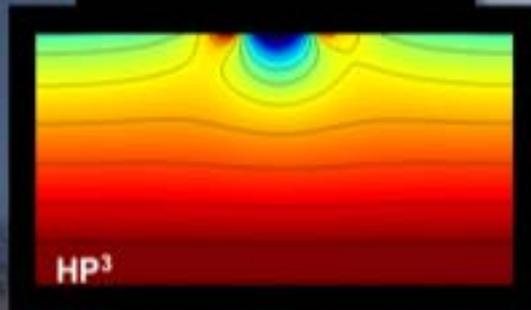
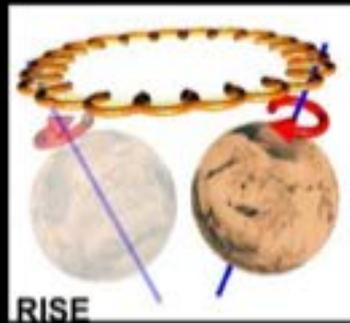
Jet Propulsion Laboratory, California Institute of Technology

Mark Johnson

Lockheed Martin Space Systems

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InSight Level 1 Science

Crust { Determine the crustal thickness
Detect any large-scale crustal layering

Mantle — Determine upper mantle seismic velocities

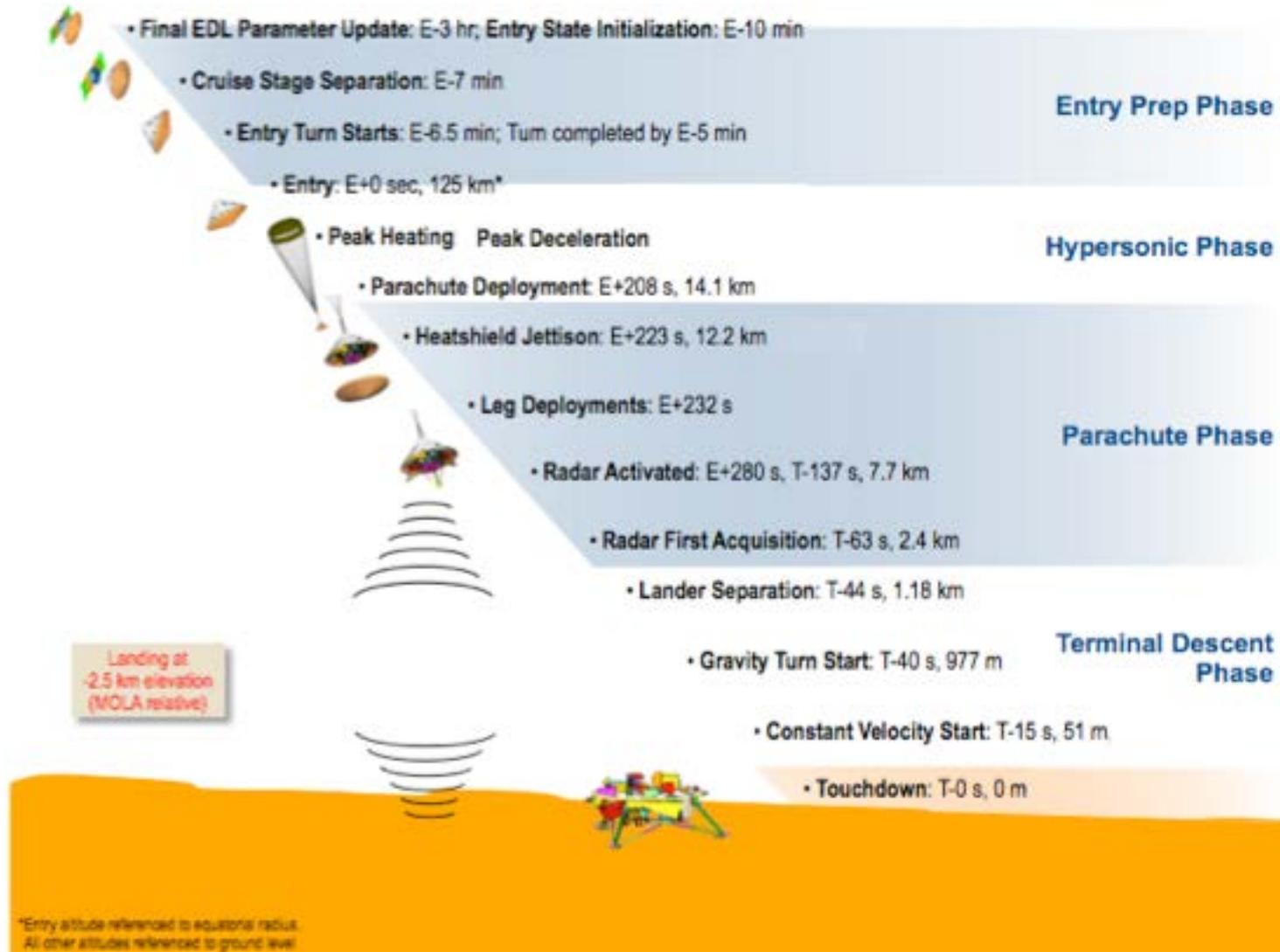
Core { Distinguish liquid vs. solid outer core
Determine the core radius
Determine the core density

Thermal Structure — Determine the heat flux

Activity { Determine the rate of seismic activity
Determine epicenter locations
Determine the rate of meteorite impacts

InSight observes the ‘Vital Signs’ of Mars: Structure, Temperature, and Reflexes to Understand the formation and evolution of terrestrial planets

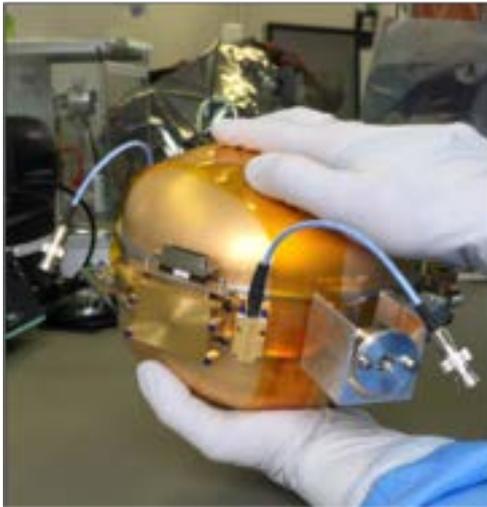
Entry, Descent, and Landing Overview



InSight EDL design is mature – minimal design changes from Phoenix

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 launch postponed to 2018 in order to resolve SEIS issue

- Successful rebuild, testing, and integration of SEIS
- Re-baselined EDL for the 2018 opportunity
 - Reassessed entry flight path angle to balance EDL margins across all critical metrics
 - Re-tuned parachute trigger
 - Implemented Mars Relative Descent frame initialization trigger
- ATLO 2.0
 - Redo System Verification, Operational Readiness, Separation, and Phasing tests
 - Many analyses redone given new opportunity (GNC, Thermal, Power, etc.)
 - Completed V&V efforts prior to launch!
- Responding to ESA's Schiaparelli failure

Schiaparelli Failure Summary of Events*

- ESA Council requested formulation of the Schiaparelli Inquiry Board (SIB) to establish root cause of the anomaly and provide recommendations for corrective actions
 - *more detailed account of Schiaparelli failure and all findings can be found in this public release: <http://exploration.esa.int/mars/59176-exomars-2016-schiaparelli-anomaly-inquiry/>
- Schiaparelli's trajectory and systems status were nominal up to parachute deployment at an altitude of ~11.5 km, AoA = 6.5 deg, M = 2.05
 - Believed the parachute deployed nominally
- Shortly after parachute inflation, the IMU measured a pitch angular rate larger than the IMU saturation limit
 - When saturated, the angular rate telemetry is replaced by a fixed value equal to the saturation limit and persisted for a full second
 - *Note: saturation flag persistence is a configurable parameter*
 - Integration of the constant angular rate led to an attitude knowledge error of ~165 deg and carried through the rest of the mission
- Nominal descent on the parachute, HSS, and radar power on
- GNC Software projected the radar range measurements with an erroneous off-vertical angle and deduced a negative altitude
 - Forced premature lander separation and extremely short thruster firing period
- Thrusters turned off at ~3.7 km, leading to a free fall of Schiaparelli and estimated impact velocity of ~150 m/s

- InSight's MIMU saturation limit is significantly larger than Schiaparelli's and we believe there is very low likelihood we would exceed it, however many of the observations from Schiaparelli are applicable to InSight
 - Effectively single string; If InSight were to saturate for the same duration as Schiaparelli it would likely have seen a similar failure
 - EDL is dependent on radar performance
 - Lander separation cannot occur until radar has achieved altitude convergence
 - IMU processing of radar data critically dependent on attitude knowledge
 - No algorithms, fault protection, or alternate means for reconstructing attitude knowledge if lost or corrupted
 - This is a conscious risk-based decision for this class of mission
 - Increases complexity of architecture significantly if implemented

Recommendations	InSight Response	Comments
Ensure parachute is modeled conservatively	Accepted	Scrub of multi-body model inputs; independent model analysis
Identify performance cliffs	Accepted	Performed multi-body sensitivity study
Verify IMU configuration	Accepted	Reviewed MIMU firmware configuration (no issues)
Avoid overly complex models of physical phenomena where little data exists for validation	Accepted	Multi-body parachute model does not attempt to model parachute dynamics itself, rather dynamic effects of parachute on the capsule

- Updated MIMU firmware with shortest saturation persistence setting
 - Conducted testing of saturation persistence options on EDU prior to selection of value – all performance was as predicted, so minimum value was selected
 - With reduction of the persistence setting, IMU saturation is not immediately fatal as once thought

InSight EDL system made more robust in light of the Schiaparelli failure

- InSight launched immediately at launch period open on May 5th, 2018 from Vandenberg AFB on Atlas V rocket
 - The first interplanetary mission launched from the west coast
- **NOVEMBER 26th, 2018 – EDL!**

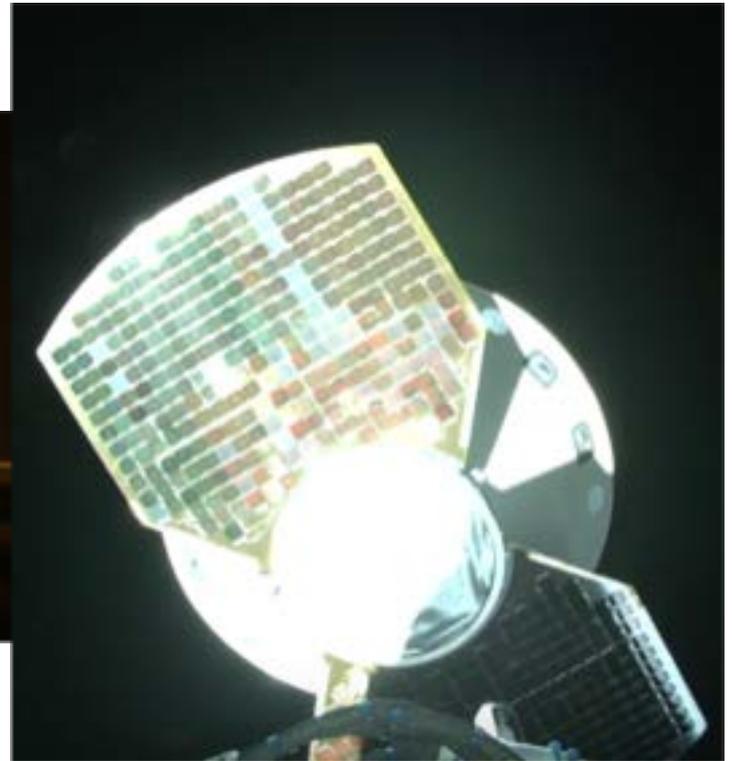


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