# InSight Mission Description

## Mission Overview

InSight is part of NASA’s Discovery Program. InSight is a mission dedicated to NASA’s efforts to understand the fundamental processes of terrestrial-planet formation and evolution by performing a comprehensive surface-based geophysical investigation of Mars. InSight will provide key information on the composition and structure of an Earth-like planet that has gone through most of the evolutionary stages of the Earth up to, but not including, plate tectonics. Thus, the traces of this history are still contained in the basic parameters of Mars: the size, state and composition of the core, the composition and layering of the mantle, the thickness and layering of the crust, and the thermal flux from the interior. These science objectives could be accomplished by landing nearly anywhere on the surface of Mars.

InSight will launch on March 4, 2016 with a 23-day launch period duration, on an Atlas V-401 from the Vandenberg Air Force Base (VAFB) launch facility on a Type 1 trajectory to Mars. After a 7-month cruise, InSight will land on the surface of Mars on September 28, 2016. Following landing there is a period of approximate 69 sols for the deployment and characterization of the instruments. After successful deployment of the instruments, InSight will perform science surface monitoring operations for one Mars year (two Earth years—September 2016 to September 2018).

InSight will address the mission science objectives by focusing on three scientific investigations: seismology, precision-tracking and heat-flow measurements. In order to obtain this information, InSight will use two scientific instruments: a seismometer and a self-penetrating mole trailing an instrumented tether for determining heat flux. In addition, InSight uses an X-band transponder (part of the Spacecraft Telecom Subsystem) to enable two-way precision Doppler tracking of the planet’s rotation. A suite of auxiliary sensors and payload elements, described below, support these measurements.

Instruments

The Lander will place two instrument packages on the surface of Mars with the aid of the Instrument Deployment System (IDS):

* The IDS is composed of a robotic arm called the Instrument Deployment Arm (IDA), an Instrument Deployment Camera (IDC) located in the forearm of the IDS, and an Instrument Context Camera (ICC) located under the Lander’s deck right underneath the IDA’s base. All the components of the IDS are built and operated by the Jet Propulsion Laboratory (JPL).
* The SEIS (Seismic Experiment for Interior Structure) is a seismometer that monitors seismic activity and tidal displacements and is built and operated by the French space agency CNES (Centre National d’Études Spatiales) and their partners. It also includes the APSS (Auxiliary Payload Sensor Suite), which consist of the Temperature and Wind Sensor (TWINS), Pressure Sensor (PS), and the InSight Flux Gate (IFG -- a magnetometer).
* The HP3 (Heat-Flow and Physical Properties Package) determines the geothermal heat flux by penetrating down into the surface of Mars by at least 3 meters and is built and operated by the German aerospace agency (Deutsches Zentrum für Luft- und Raumfahrt, DLR). The HP3 also includes a radiometer (RAD).

Over the course of a Martian year (~23 Earth months) the SEIS and HP3 instruments, in conjunction with an X-band radio Doppler tracking science investigation that measures rotational variations (Rotation and Interior Structure Experiment [RISE]), will achieve InSight’s science primary objectives. The IDC, APSS, and RAD support the deployment and data reduction for SEIS and HP3. Additionally, this sensor suite will enable a wide range of ancillary science.

SEIS (Seismic Experiment for Interior Structure)

The purpose of the SEIS instrument is to measure the surface ground velocity by a set of seismometers covering the 0.01-10 Hz frequency bandwidth for the 3 axis Very Broad Band (VBB) sensors and 0.1-50 Hz for the 3 axis Short Period (SP) sensors. These measurements are augmented by a gravity output of the VBBs (down to 50 mHz, the Phobos tide frequency), an overlap of the VBB and SP seismic sensors bandwidth outside their nominal bandwidth and by additional measurements enabling a better characterization and possibly mitigation of the lander and atmospheric generated noises.

The SEIS sensors will be deployed on the Mars surface by a robotic arm and will then operate almost continuously until end of mission. In summary, the instrument consists of the following functional subunits:

* SEIS Acquisition and Control Electronics (SEIS-AC), located in the lander warm electronics box
* Sensor Assembly (SA) (including the Leveling System (LVL), the VBBs, the SPs, a set of temperature and tilt sensors and the Thermal Blanket (TBK). The SA will be deployed onto the surface.
* SEIS Tether system, which connects the SEIS-AC and the SA and is made of a tether, a tether box, and of a service loop and associated release shunt.
* A SEIS cradle, staying on the lander and locking the SA prior its deployment to the lander
* A Wind and Thermal Shield (WTS), deployed over the SA and providing thermal and wind protection.

In addition, SEIS will be supported by the Auxiliary Payload Support System (APSS), which will provide additional measurements of the magnetic field using the 3-axis InSight Flux Gate (IFG) magnetometer, of the pressure field with a micro barometer sensor, and Temperature and Winds for InSight (TWINS) sensors.

APSS (Auxiliary Payload Sensor Suite)

The Auxiliary Payload Sensor Suite (APSS) is a set of sensors consisting of the Pressure Sensor (PS), Temperature and Winds for InSight (TWINS), and the InSight Flux Gate magnetometer (IFG), all controlled by the Payload Auxiliary Electronics (PAE). These sensors provide environmental information that will be used in planning spacecraft operations (including instrument deployment) as well as to support SEIS (Seismic Experiment for Interior Structure) data analysis, and for their own scientific objectives.

Like the SEIS instrument, the APSS is designed to run continuously, and to record data without gaps at a high enough sampling rate to aid SEIS data analysis in search of seismic signals. In addition to being the first instance of a magnetometer at the surface of Mars, APSS will also be the first continuous and high frequency record of pressure, air temperature and winds at the surface of Mars.

*TWINS (Temperature and Winds for InSight)*

TWINS is composed of two essentially identical sensor booms placed horizontally and diametrically opposite and parallel to one another on top of the lander deck. Each boom is a modified Mars Science Laboratory (MSL) Rover Environmental Monitoring Station (REMS) boom, and contains sensors for both 3-D wind and air temperature measurements. The deck placement is intended to minimize the effects of wind-flow perturbations induced by the other elements on the lander top deck by ensuring that at least one of the booms will be windward of the bulk of the lander body for nearly any given wind direction

TWINS’ primary requirement is to support SEIS by indicating when the winds are above 5m/s, representing a state when wind perturbations are likely significantly degrading the signal to noise ratio of the SEIS measurements. However, in addition to this crude indicator of SEIS data quality, TWINS will supply the time-resolved 3-D wind vector in the vicinity of the InSight lander, which can be used to estimate the detailed wind perturbations on the SEIS measurements. Additionally, TWINS will be used to characterize the local wind behavior at the landing site prior to and during the timeframe when the Instrument Deployment Arm (IDA) is moving the SEIS, WTS, and HP 3 (Heat flow and Physical Properties Package) instruments to the surface to choose the best possible conditions and times, and to ensure the safety of that operation.

TWINS data will also be used for other science goals beyond those of SEIS. For example, TWINS data will be key in characterizing the local meteorology of the landing site, including diurnal tides, mesoscale circulations, seasonal variations, slope winds, and perhaps even transient waves. Dust devils are expected to be found at the InSight landing site, and TWINS data will be valuable in characterizing them. Because TWINS will be recording data continuously, it is uniquely valuable in quantifying wind thresholds for aeolian change and solar panel dust removal events. Additionally, simultaneous measurements from REMS at Gale Crater (data available through the Planetary Data System – atmospheric node) and TWINS at InSight’s landing site will help validate and improve meteorological models.

*PS (Pressure Sensor)*

The PS is a pressure transducer manufactured by TAVIS Corporation, located in the lander body, and connected to the ambient atmosphere with an inlet on the lander top deck. The inlet is specifically designed to minimize the effects of wind on the pressure measurement, with a design similar to the “Quad-Disc” design developed for single inlet microbarometric measurements terrestrially (Nishiyama & Bedard, 1991). Before deployment, the WTS (Wind & Thermal Shield) will cover the Quad-Disc inlet for the PS. The Pressure Sensor’s sensitivity to winds may be increased (likely <1Pa for 7m/s winds) until WTS is deployed, but the pressure measurements will likely still be meteorologically useful during this pre-deployment timeframe.

The pressure sensor’s main purpose on InSight is to supply high-frequency, high-precision pressure measurements for use in decorrelating atmospheric pressure-induced noise from the SEIS measurements.

It will also be used to pursue atmospheric science objectives. For example, as the fastest-response, highest-sensitivity continuously sampling pressure sensor ever sent to the surface of Mars, it is expected to contribute in dust devil, bolide, gravity wave and infrasound searches, and perhaps in other ways not anticipated.

*IFG (InSight Flux Gate)*

The IFG is a three-axis fluxgate magnetometer manufactured by UCLA, located beneath the lander platform on the main lander body. It will measure the magnetic field vector in addition to the temperature of the sensor. The magnetic field measured by IFG consists of contributions from naturally occurring sources (Mars’ fields) and magnetic fields generated by the lander. The main purpose of the IFG is to enable removal of the effects of the local magnetic fields (irrespective of their origin) on the SEIS recordings.

The IFG’s prime function is to provide magnetic field data for decorrelation of the SEIS signals and will run continuously, recording data at a sufficiently high rate to aid SEIS investigations. It will also contribute to InSight science by providing the first surface measurements of Mars’ magnetic field. As such it will provide a record of the time-varying Martian magnetic field in the vicinity of the lander. IFG data are expected to contribute to understanding of the ionosphere including its coupling to the neutral atmosphere and the interaction with the solar wind, and on the interior structure of Mars. Naturally occurring sources include contributions from the ionosphere, crustal fields and possibly induced fields. The magnetic field from crustal magnetization provides indirect information on crustal properties such as magnetic mineralogy and thermal structure (e.g., Purucker, 2000; Arkani-Hamed, 2002a,b; Langlais et al., 2004; Morschhauser et al., 2014). Induced magnetic fields, if observed and characterized, can constrain interior electrical conductivity (Verhoeven et al., 2005). Data from Mars Global Surveyor (MGS) and MAVEN characterize the external magnetic field above and within the ionosphere. At MGS mapping orbit altitudes, above the ionosphere, the power spectrum falls off as 1/f for periods of 1 to 300 seconds (Mittelholz et al., 2014). It is uncertain whether this variability propagates to the ground. For example, aerobraking orbits on Venus Express and on MGS all show weaker magnetic field variations below the ionosphere than within the ionosphere. The science objectives can leverage and are complementary to MAVEN science.

HP3 (Heat Flow and Physical Properties Probe)

The purpose of the HP3 instrument is to determine geothermal heat flow at the landing site (Spohn et al., 2014), which is interpreted in terms of the global heat budget (Grott and Breuer, 2010, Dehant et al., 2012, Plesa et al., 2015). This measurement is augmented by a determination of the surface brightness temperature using the HP3 radiometer (RAD) to determine the forcing function for the subsurface temperatures. To measure heat flow, a self-hammering mole will emplace a suite of temperature sensors and heaters (the TEM sensor suite) into the subsurface. The progress of the mole is monitored by the tether length monitor (TLM), which measures the length of tether being paid out, and the static tilt meter (STATIL), which determines the inclination of the mole with respect to vertical.

The instrument consists of the following functional subunits:

* Back End Electronics (BEE), located in the lander warm electronics box
* Engineering Tether, electrical connection between the Support System and the BEE
* Support System (including TLM, the science tether, and the mole), which will be deployed onto the surface
* Science Tether (TEM-P), which will be emplaced into the ground by the mole
* Mole (including TEM-A and STATIL)
* Radiometer (RAD), which is mounted under the lander deck

*Heat Flow Determination*

The level 1 science objective of the HP3 experiment is a determination of the surface heat flow F at the landing site with an uncertainty of better than ±5 mW m-2 (see Grott et al., 2015). Heat flow, or to be more precise the heat flux density, is generally assumed to be one-dimensional from a planet as first approximation, and is given by the 1-D form of Fourier’s Law (e.g. Grott et al., 2007, Kömle et al., 2011) where the negative sign is commonly omitted for convenience:

Here, k is the regolith thermal conductivity, T is temperature, and z is depth. HP3 measures temperature T using the TEM-P PT100 resistance temperature detectors (100 Ω at 0°C platinum resistance temperature sensors), depth z using the inclinations determined by STATIL and length determined by TLM, and thermal conductivity k using a the TEM-A temperature sensors and heaters (e.g., Kömle et al., 2011).

IDS (Instrument Deployment System)

The function of the IDS is to place the instruments safely on the surface of Mars. The IDS consists of four main components. The Instrument Deployment Arm (IDA) is responsible for placing the instrument packages on the surface and provides pointing for the Instrument Deployment Camera (IDC). The IDC is mounted on the arm and is used to image the work area in stereo for deployment planning and secondary geologic science of the area surrounding the Lander. The Instrument Context Camera (ICC) provides a wide-angle view of the entire workspace and provides a degraded functional back up to the IDC. The ICC is mounted at the bottom of the Lander’s deck, right underneath the base of the IDA. The last component is the IDS control software.

RISE (Rotation and Interior Structure Experiment)

InSight’s Rotation and Interior Structure Experiment (RISE) uses the Lander’s X-band radio system in combination with tracking stations of the NASA Deep Space Network to estimate the precession and nutation of Mars in order to provide constraints on the Martian interior structure. The Martian axis of rotation precesses and nutates due to external torques, primarily due to the Sun. The precession rate is a key indicator of the density of the Martian core, while the nutation is sensitive to the state of the core; a fluid core results in a larger nutation amplitude. The Martian precession rate has been estimated earlier from Doppler data taken from the Viking and Mars Pathfinder landers (Folkner et al. 1997a) and from the Mars Exploration Rover (Kuchynka et al. 2014). InSight will provide an improved precession rate and the first detection of the nutation amplitudes by providing observations over one Martian year.

The RISE measurements are the two-way Doppler shift measured at the DSN stations of a radio signal sent by the DSN to InSight where the signal is detected and a coherent signal re-transmitted back to the DSN. Nominally, measurements will be made during one 1-hour tracking pass per week during the Instrument Deployment Phase and four 1-hour tracking passes per week during the Science Monitoring Phase.

The RISE objective are to determine the Martian rate of precession, which is proportional to the polar moment of inertia of Mars, and the amplitude of the semi-annual nutation, which is a function of the polar moment of inertia of the core and the free-core nutation (FCN) rate (Folkner et al. 1997b; Le Maistre et al. 2012). The total and core polar moments of inertia in turn provide constraints on the density, state, and size of the core (Rivoldini et al. 2011).

The RISE measurements are also sensitive to changes in the Martian spin rate, that are driven primarily by seasonal redistribution of CO2 between the atmosphere and the ice caps. These seasonal changes have been detected previously and compared with models (e.g. Konopliv et al. 2011). InSight will be more sensitive to these effects than previous missions. The changes in rotation rate will be determined during the planned data analysis to determine precession and nutation, but are not specific science objectives for InSight.

Mission Phases

The following sections describe the phases of the InSight mission, from launch through the end of surface operations. The timeline and primary activities are summarized for each phase.  
  
Launch

The current baseline launch window for InSight extends from March 4 to March 26, 2016. For a launch on any date during this window, Entry, Descent, and Landing (EDL) will occur September 28, 2016.

Update: The actual launch date was May 5, 2018.

Mission Phase Start Time: 2018-05-05  
Mission Phase Stop Time: 2018-05-05  
   
Cruise

Cruise operations concentrate on monitoring the health and performance of the flight systems and navigating the spacecraft to Mars. Spacecraft engineering subsystems checkouts, calibration activities, and instrument payload aliveness checkouts are performed early during cruise operations. Other than the checkouts/calibrations 24 days post-launch, all payloads are off during this phase. During the cruise to Mars, the spacecraft will perform Trajectory Correction Maneuvers (TCMs).   
  
Mission Phase Start Time: 2018-05-05  
Mission Phase Stop Time: 2018-11-26

Approach

The last 60 days before landing compromise the approach phase, involving additional trajectory correction maneuvers.  
  
Mission Phase Start Time: 2018-09-27  
Mission Phase Stop Time: 2018-11-26

Entry, Descent, and Landing

Entry, descent, and landing activities occur within ~10 minutes prior to landing on Mars. InSight uses a heatshield, parachute, and thruster-controlled lander descent stage to reach the surface. Immediately after touchdown, the lander configures itself for landed operations including deploying both solar arrays and taking an image using the ICC.

Target Name: Mars  
Mission Phase Start Time: 2018-11-26  
Mission Phase Stop Time: 2018-11-26

Deployment

Instrument deployment begins when the solar arrays are deployed and the lander is in a safe and communicative state. Instrument deployment operations take approximately 42 to 60 sols and cover assessment of the landed workspace, determination of instrument deployment sites, deployment of the instruments (HP3 and SEIS, including the WTS), and the release of the HP3 mole. During this phase, the lander, its surrounding environment, and the workspace are characterized, the payload elements are checked out, weekly RISE measurements are acquired, and the critical data collected on Sol 0—the landing sol—are relayed to Earth. After the Science Team has selected suitable deployment sites within the workspace, the IDA places the SEIS (and covering WTS) and HP3 instruments on the surface of Mars. At that point instrument calibration and science data collection commences and the HP3 mole is released for penetration activity.

The selection of the instrument deployment sites will be governed by the Instrument Site Selection Working Group (ISSWG) and consist of four main phases:

1) Initial qualitative assessment of the workspace

2) Systematic mapping of the workspace

3) Quantitative assessment of four prospective sites

4) Certification of two prospective sites

Analysis data products utilized in this assessment include: 4 mm Digital Elevation Maps (DEMs), maps of the slope, roughness, surface normal, and tilt, terrain and soil maps with soil physical properties assessment, rock map with size-frequency distribution and shadow map, SEIS noise map, HP3 thermal map, instrument tether routing, and mole penetrability assessment.

Due to the nature of the deployment timeframe, a rapid analysis of lander and payload telemetry is performed to assess the health and safety of the engineering subsystems and the status of instrument deployment activities. During this phase, InSight personnel will be co-located at JPL and work on a modified Earth-time schedule in which the start of the shift on Earth will track Mars time, sliding forward from 6 AM until it reaches 1 PM. After this point, the downlink from Mars arrives too late in the day on Earth to allow commands to be generated before a reasonable end of shift (a 10-hour shift is planned for deployment). Operations will be nominally planned daily with two floating days off per week. Due to the intensive and highly scripted nature of the deployment phase, limited, if any, time is expected to be available for ancillary science to be added during this phase. Operational support for the IDA is only planned for the deployment timeframe. Any IDA operation after the deployment phase is on a best efforts basis.

Target Name: Mars  
Mission Phase Start Time: 2018-11-26  
Mission Phase Stop Time: 2019-02-25

Science Monitoring

The science monitoring operations begin after the instruments have been placed on the surface. During this phase, SEIS monitoring starts and the HP3 mole penetrates to its final depth. During the science monitoring operations, SEIS and HP3 are in nominal data collection mode and gather science data autonomously and continuously and store this data in the instruments’ nonvolatile memory. The lander nominally provides continuous power to SEIS and HP3 throughout this phase, collects data from the instruments during every full wake up, and relays the data to Earth, usually twice per sol. The lander powers on the RISE X-band communications system for one-hour an average of four times per week during which Doppler-tone monitoring sessions with the DSN are performed. The radiometer (part of HP3) is commanded to take four 1-hour measurements during each sol for five minutes duration each, and every L s ~ 15 o , an hourly radiometer measurement campaign is undertaken lasting one entire sol with one measurement per hour for five minutes duration in each instance. The active TWINS’ boom is swapped several times per sol to account for changing wind direction.

Since the lander is solar powered, the life of the lander is driven by Mars’ diurnal cycle. Lander communications are determined by when orbiter overflights allow for UHF relay, typically twice per day at 3 AM and 6 PM LMST. The lander spends the majority of the science monitoring operations asleep. On a typical sol, the lander wakes up every three hours to check the battery state of charge, to run FSW diagnostics and fault-protection checks, and to collect housekeeping data. During two of the daily wake cycles the lander stays awake for an additional time to process science data and relay the data to an orbiter asset. Although science data are relayed back to Earth twice per sol, commands are relayed to the lander only once per week.

Science monitoring operations are simple and routine. No ground-in-the-loop is required under nominal conditions. The flight team works on Earth time, and only during the nominal 8-hr prime shift. All operations teams reside at their respective institutions, and the SEIS and HP3 IOTs work standard shifts for the time zone of their institutions. Operations are performed using a strategic process/timeline with sequences for the lander uplinked a week at a time. The rapid turnaround process supported during instrument deployment will no longer be used, although anomaly resolution will continue to be supported in that manner. Seismic and APSS event data selection by the instrument and science teams will be performed. Operations processes and interfaces will accommodate time differences for nominal operations between the different institutions supporting Science Monitoring operations.

Target Name: Mars  
Mission Phase Start Time: 2019-02-25  
Mission Phase Stop Time: 2022-12-15

Mission Objectives

The overall goal of the InSight mission is to improve our understanding of terrestrial planet formation and evolution by understanding the origin and evolution of Mars. InSight investigates Mars’ interior structure, thermal and chemical evolution, and geologic processes. It also determines Mars’ present level of geologic activity and impact flux. InSight reveals the processes of formation and differentiation of the Martian core and crust, and illuminates the evolution of its interior by constraining the following parameters:

* Determine the depth of the crustal-mantle boundary to within ±10 km
* Detect any regional-scale crustal layering with velocity contrast ≥0.5 km/s over a depth interval ≥5 km
* Determine the seismic velocities in the upper 600 km of mantle to within ±0.25 km/s
* Determine whether the outer core is liquid or solid to a 90% confidence level
* Determine the core radius to within ±200 km
* Determine the core density to within ±450 kg/m3
* Determine the heat flux at the landing site to within ±5 mW/m2
* Determine the rate of seismic activity to within a factor of 2 for rates greater than 2x10 18 Nm/yr
* Determine epicenter distance to ±25% and epicenter azimuth to ±20°
* Determine the rate of meteorite impacts to within a factor of 2

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