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An artist's rendition of NASA's InSight lander moments before its successful touchdown on the Martian surface.

JPL-CALTECH AND NASA

NASA's InSight Mission

After enduring a high-tension descent from orbit, the spacecraft will now begin its quest to peel back the profound mysteries of the Red Planet's interior

By Ian O'Neill

A new space robot now calls Mars “home.”

NASA’s InSight lander completed its seven-month interplanetary journey of nearly 500 million kilometers in dramatic style on November 26, 2018 slamming into the Martian atmosphere at a speed of nearly 20,000 kilometers per hour. Only six-and-a-half harrowing minutes later, after ejecting its heatshield, deploying a supersonic parachute and firing retrorockets, its speed had dramatically slowed to a jogging pace after traversing the 130 kilometers between Mars’s upper atmosphere and the planet’s arid surface.

According to mission controllers at NASA’s Jet Propulsion Laboratory (JPL) in Pasadena, California, InSight’s entry, descent and landing (EDL) phase was completed without a hitch and the $850 million lander touched down shortly after 2:50 P.M., Eastern time. The mission’s twin relay CubeSat companions, Mars Cube One (MarCO), which have been flying alongside InSight during its interplanetary cruise phase, also successfully fulfilled their mission, transmitting signals from Mars during InSight’s EDL back to Earth in near real-time. Minutes after landing, InSight transmitted its first color image from Mars, via the MarCO relay, showing a bleak landscape through a veneer of dust that had accumulated on its camera’s protective cover. Now that the dust has settled, NASA can focus on the lander’s future as a scientific gold mine that will give Mars an unprecedented internal examination to better understand heretofore hidden details of the world’s origins and history.

The lander safely touched down on its dusty landing site of Elysium Planitia, near the Red Planet’s equator, a region scientists refer to as “vanilla”—not because it is boring per se but because it is flat and free of rocky obstacles that could damage the lander. And besides, InSight cares little for the superficialities on the surface; its interest lies far deeper.

InSight, which stands for “Interior Exploration using Seismic Investigations, Geodesy and Heat Transport,” is a stationary science platform with a suite of instrumentation that will work in concert to give the planet an “ultrasound.” Unlike its more mobile brethren, such as NASA’s Curiosity and Opportunity rovers, it will do all of its investigations where it landed, in situ. Its ultra-sensitive seismometer (Seismic Experiment for Interior Structure, or SEIS, experiment) will detect seismic waves rippling through Mars and, by measuring their propagation through the subsurface, will assemble a detailed picture of Mars’s interior for the first time. Using its robotic arm, InSight will pluck SEIS from the lander’s top deck to place it carefully on the dusty surface. Another instrument (the Heat Flow and Physical Properties Package, or HP3, experiment) will also be placed on the surface, deploying a thermal probe that will drill itself several meters into the surface to measure heat percolating through the planet. InSight also has an experiment (Rotation and Interior Structure Experiment, or RISE) that will precisely measure the planet’s “wobble” to reveal the size and density of the Martian core.

Until now, all Mars missions have focused on the planet’s surface and atmosphere. Although InSight will also have an onboard weather station and suite of cameras, the mission’s focus is on peeling back the profound mysteries of the Martian interior.

“The main goal of InSight is to understand what the fundamental makeup is of Mars, as in how large the core is, how large the mantle is and how large the crust is,” says Tom Hoffman, project manager for InSight at JPL. “We’re doing that largely with a seismometer detecting ‘marsquakes.’”

Quakes are a familiar feature of our tectonically active Earth. Continental plates shift as they float atop a hot and viscous mantle, rubbing and pushing against one another, producing earthquakes and volcanoes. Mars, however, is very different. It is not currently tectonically active, and its volcanoes have been dormant for hundreds of millions of years. Unlike earthquakes, marsquakes are a consequence of a cooling and shrinking world, says Hoffman, and hopes are high that there will be many marsquakes for InSight to detect. The seismic waves marsquakes produce will be used by InSight to create a 3-D picture of Mars’s interior—but they can also be used to study meteorites thudding into the surface.

“Depending on how large the meteorite impacts are and how far away they are from the lander, it determines how well we can detect them or not," adds Hoffman. "We also have orbital assets [such as NASA's Mars Reconnaissance Orbiter] that can then show us exactly where that impact was, because we are constantly mapping the surface."

Interestingly, meteorite impacts also had an important part to play in the selection of Elysium Planitia as InSight's landing zone, says Suzanne Smrekar, InSight deputy principal investigator, who is also at JPL. Once deployed on the surface, the HP3 self-penetrating heat flow probe—aptly nicknamed "the mole"—will pound the ground tens of thousands of times to eventually burrow as much as 5 meters below the surface. But it can only do so if there is no hard bedrock in its way. How, though, could scientists know whether or not there are mission-scuttling rocks hidden just below Elysium Planitia's dirt?

"An impact crater can act like a probe of the subsurface," Smrekar explains. While surveying the landing site during the planning phase of InSight's mission, scientists studied the ejecta from small impact craters scattered across Elysium Planitia. As a rule, meteors will gouge a hole approximately a tenth as deep as the crater's diameter. They found that, for this region, craters as wide as 100 meters didn't appear to throw up any large rocks, meaning the upper 10 meters of this region is composed mainly of fine material, such as small stones, sandy material and dust, that would pose no insurmountable barriers for InSight's "mole."

Assuming the heat flow probe deploys successfully, the measurements it makes could transform our understanding not only of how Mars evolved, but also how other rocky planets, like Earth, came to be.

After formation, planets contain a lot of heat that slowly leaks to the surface over billions of years. Directly measuring the flow of this heat in modern Mars will help alleviate some huge uncertainties in planetary formation models. For example, planets form by slowly accreting asteroids, but the type of asteroid that clumps together greatly affects a planet's composition and therefore its heat flow. Many indirect measurements of Mars's heat flow have been made, but they often contradict theoretical models.

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—Bruce Banerdt

"Some heat flow estimates are consistent with the idea that Mars, and all the rocky planets in fact, formed from a certain class of asteroids—chondritic asteroids—that have a certain amount of radiogenic material [which generates heat]," explains Smrekar. "But some of those measurements don't agree with that; they indicate that Mars is composed of less chondritic material and its interior should be a lot colder than our models predict."

Once InSight measures the heat flow number just below its landing site, it can be extrapolated globally, adds Smrekar. "This one crazy number will tell us so much about the history of Mars as well as the present day—that's what I'm most excited to get."

Beyond developing planetary evolution models, the heat flow measurements will also have implications for understanding if Mars has ever been habitable enough to support life. Some hypotheses suggest that there may be reservoirs of water just below the Martian surface, and the value of the heat flow number could help us understand whether these reservoirs are in a life-giving liquid state or are a not-so-life-giving solid ice.

InSight has another trick to decipher what's inside Mars, but it needs a little help from the Deep Space Network (DSN)—radio antennae on Earth that maintain contact with robotic space missions throughout the solar system. By analyzing subtle frequency shifts in radio transmissions between InSight and the DSN, scientists will be able to measure just how fast the lander is moving relative to Earth. Over the two years of InSight's primary mission, the experiment will build a picture of how much Mars wobbles as it rotates, using the lander as a fixed point on the planet's surface.

"We'll be able to track the location of InSight to an accuracy of about 10 inches," says Bruce Banerdt, InSight principal investigator. "That's phenomenal—it's as close as you can get to magic and still be science."

Mars's wobble can provide us with information about the core of the planet, says Banerdt. "If Mars's core is liquid, it's actually kinda sloshing around inside, and the size and speed of that wobble is related to the size of the core and the density of the core. The heavier the core, the more sloshing, the greater the effect on the wobble."

InSight will be very different from the Mars missions that have come before it, but it's going to fill a crucial role in humanity's quest to understand how Mars formed and whether it has ever played host to life. Ultimately, by giving Mars an internal examination we'll be able to compare the Red Planet's composition with Earth's, greatly improving our understanding of how planets in our solar system—and even exoplanets orbiting other stars—actually form.