Mars InSight

Assembly, Test and Launch

Vehicles

Surface Operations

Status & Highlights

Reference Information
The InSight Mars Lander (left) is similar in design to the Phoenix Mars Lander (below) used successfully in 2007 to study the surface near the Martian north pole.

- The reuse of the technology, developed and built by Lockheed Martin Space Systems in Denver, CO, provided a low-risk path to Mars without the added cost of designing and testing a new system.

The Phoenix Mars Lander is shown partway through assembly and testing at Lockheed Martin Space Systems in Denver, CO in September 2006.

- It was launched on August 4, 2007 from Florida and landed May 25, 2008.
- Phoenix verified the presence of water-ice in the Martian subsurface.
- The lander ended communications in November 2008, about six months after landing, when its solar panels ceased operating in the dark Martian winter.
The InSight spacecraft backshell is being lowered onto the lander, which is folded into its stowed configuration.

- The back shell and a heat shield (not shown) form the aeroshell which will protect the lander as the spacecraft plunges into the Martian upper atmosphere.
- The photo was taken on April 29, 2015 in a spacecraft assembly clean room at Lockheed Martin Space Systems in Denver, CO.
The Mars InSight lander is stowed inside the inverted back shell of the spacecraft’s protective aeroshell.

- The three lander stowed legs are attached to the bottom of the structure.
- The photo was taken on July 13, 2015 in a spacecraft assembly clean room at Lockheed Martin Space Systems in Denver, CO during preparation for vibration testing of the spacecraft.
The heat shield is suspended above the rest of the InSight spacecraft, in this image taken July 13, 2015, in a spacecraft assembly clean room at Lockheed Martin Space Systems in Denver, CO.

- The gray cone is the back shell which together with the heat shield forms a protective aeroshell around the stowed Mars lander.
- The photo was taken during preparation for vibration testing of the spacecraft.
On April 6, 2018, the Mars InSight spacecraft undergoes final preparations for launch at Vandenberg Air Force Base, CA.

- The spacecraft, without the heat shield, is shown mounted to an Atlas V launch vehicle adapter in a clean room.
On May 3, 2018, the Mobile Service Tower rolled back from the United Launch Alliance (ULA) Atlas V rocket carrying the Mars InSight inside it’s payload fairing.

- The Atlas V payload fairing along with Vandenberg Air Force Base, CA is shown atop Space Launch Complex-3 East.
Mars InSight Awaits Launch

The Mars InSight Lander is waiting for liftoff from its launch pad at Space Launch Complex-3 East, Vandenberg Air Force Base, CA.

- The United Launch Alliance Atlas V 401 rocket was launched early in the morning on May 5, 2018.
- This was the first interplanetary launch from the West Coast.
- Vandenberg was chosen because it had more availability during Insight’s five-week launch period than Florida.
- Mars InSight is the first Mars mission dedicated to studying the planet’s deep interior.
- Information about the layers of Mars today will advance understanding about the formation and early evolution of all rocky planets, including Earth.
1. During the InSight spacecraft cruise phase, the vehicle was propelled from Earth to final approach to Mars. The spacecraft includes a cruise stage with two fixed-wing solar panels and a cylindrical core attached to the aeroshell. The lander is inside the aeroshell. Along the way to Mars, the cruise stage performed several trajectory correction maneuvers to adjust the spacecraft’s path toward its final, precise landing site on Mars.

2. The mission’s approach phase began about 60 days before landing with a series of checkouts. It lasted until the spacecraft entered the atmosphere. The cruise stage was jettisoned before atmospheric entry.

3. The mission’s entry, descent and landing (EDL) phases began when the spacecraft, with a velocity of about 12,300 miles per hour, reached the top of the Martian atmosphere about 80 miles above the surface. The friction with the Martian atmosphere slowed the spacecraft’s descent and heated the heat shield. This friction with the atmosphere, before the opening of the spacecraft’s parachute, removed nearly 99.5 percent of the entry vehicle’s kinetic energy. During the entry phase, the spacecraft was controlled by thrusters.
4. InSight continued to descend until the proper velocity and deceleration trigger conditions were met to deploy the 39 ft diameter parachute from the back shell. This was expected at about 6.9 miles above the surface at a velocity of about 861 miles per hour (mph). The spacecraft descended on the parachute for about two minutes. During the first 25 seconds of parachute descent, InSight jettisoned its heat shield and extended its three landing legs. About two minutes after the parachute opened and one minute before landing, the spacecraft started using its radar to sense velocity and the distance to the surface.

5. Descent speed slowed to about 134 mph by the time the lander separated from the back shell and parachute, about two-thirds of a mile above the surface and about 45 seconds before touchdown. The separation was triggered by radar sensing of altitude and velocity. One second after lander separation, the 12 lander descent engines began firing. The spacecraft rotated to land in the desired orientation with the solar arrays extending east and west from the deck and the robotic arm’s work area on the south side of the lander. InSight was still traveling at about 17 mph, 164 ft above the surface when it transitioned to a constant velocity mode in preparation for soft touchdown. Approximately 15 seconds later, the vehicle landed with a velocity of 5 mph.

Select to view Insight EDL video: https://www.youtube.com/watch?v=PDSbUpmRksI&t=0s&index=12&list=PLTiv_XWHnOZpoZ2QD4-3PAtF3Xk-8uA
This artist’s concept depicts the InSight lander after landing and has deployed its instruments (SEIS and HP³) on the Martian surface in the Elysium Planitia region of Mars about 340 miles from the Curiosity rover’s landing site.

- The vehicle’s landing weight and size determined on Earth was 789 lbs and 19.7 ft x 5.1 ft X 3.3 ft.
- The primary mission duration is one Martian year plus 40 Martian days, nearly 2 Earth years until November 24, 2020.
- In this illustration of the InSight lander’s deployed configuration, south would be down toward the tethered instruments on the surface at the Martian work site.
InSight Lander Science Experiments

This artist’s illustration depicts the InSight stationary lander at work studying the interior of Mars.

- The lander is equipped with three principal instruments designed to probe the interior of Mars: SEIS, HP³ and RISE.
- In addition to its principal instruments, the lander will carry:
  - Auxiliary Payload Sensor Suite (APSS) to monitor atmospheric conditions at the landing site.
  -- APSS also includes the magnetometer and TWINS.
  - LaRRI, a corner cube retroreflector enabling passive laser range finding by orbiting spacecraft.
- The IDC & ICC cameras will be used primarily to aid in the deployment of the science instruments SEIS and HP³.
- No experiments will take pictures, analyze minerals, or dig up soil samples as other Mars landing missions have done.
The InSight mission uses NASA’s Deep Space Network (DSN), an international network of antennas (left) that provides communication links between planetary exploration spacecrafts and their mission teams on Earth.

- As with previous Mars landers and rovers, the InSight mission relies on the Mars orbiting spacecraft to relay data from the spacecraft to the DSN antennas.
- The Mars Reconnaissance Orbiter and 2001 Mars Odyssey orbiter have the primary responsibility to relay data to the DSN where it is sent to the Jet Propulsion Laboratory (JPL) in Pasadena, CA.

Just as InSight descended through the Martian atmosphere to land, two mini-spacecrafts, called Mars Cube One or MarCO, flew on their own path behind InSight to quickly relay data to Earth (right) about its entry, descent and landing.

- The JPL built MarCO satellites, each weighing 30 lbs, were launched on the same vehicle as Insight as a separate NASA technology experiment.
- Each of the two spacecrafts has a stowed size of about 14.4 inches x 9.5 inches x 4.6 inches.
November 26, 2018 - MarCO-B, one of the experimental Mars Cube One (MarCO) took this image of Mars from about 4,700 miles away during its flyby of the planet.

- MarCO-B was flying by Mars with its twin, MarCO-A, to serve as communications relays for the InSight spacecraft as it landed on Mars.
- This image was taken while MarCO-B was flying away from the planet after InSight landed.
- MarCO-B’s solar array is seen on the right in the image.
The site needed to be near the equator of Mars to provide sufficient sunlight for the solar panels year round; have a low elevation to allow for sufficient atmospheric braking during entry, descent and landing; reduce the probability of complications during landing by being flat and relatively rock-free; and have soft enough terrain to allow the heat flow probe to penetrate well into the ground.

The landing site is a smooth expanse of lava plains called Elysium Planitia.

The color coding on the map indicates elevation relative to a reference datum, since Mars has no “sea level.”

- The lowest elevations are presented as dark blue; the highest as white; the difference between green and orange in the color coding is about 2.5 miles, vertically.

The topographic map uses data from the Mars Orbiter Laser Altimeter on NASA’s Mars Global Surveyor spacecraft.

Since InSight’s science goals were not related to any particular Martian surface feature, potential landing sites were chosen on the basis of practicality.
November 26, 2018 - The Instrument Deployment Camera, located on the stowed robotic arm of the InSight lander, took this picture of the Martian surface on the same day the spacecraft landed on Mars.

- The camera’s transparent dust cover was still on in this image, to prevent particulates kicked up during landing from settling on the camera’s lens.
- The image was relayed from InSight to Earth via NASA’s Odyssey spacecraft, currently orbiting Mars.
December 4, 2018 - This image from InSight’s robotic-arm mounted Instrument Deployment Camera shows the end of the arm, instruments on the spacecraft’s deck and the Martian surface of Elysium Planitia in the background.

- The camera’s transparent dust cover was still on in this image, to prevent particulates kicked up during landing from settling on the camera’s lens.
- To the right can be seen a small portion of one of the two solar panels that help power InSight and part of the UHF communication antenna.
December 6, 2018 (sol 10 or the 10th Martian day since the landing) - This is the InSight lander’s first self-portrait on Mars.

- It displays the lander’s solar panels and deck.
- On top of the deck are its science instruments, weather sensor booms and UHF antenna.
- The self-portrait is made up of 11 images which were taken by its Instrument Deployment Camera, located on the elbow of its robotic arm.
- The images were then stitched together into a mosaic.
December 18, 2018 - Engineers at the Jet Propulsion Laboratory in Pasadena, CA sculpt a gravel-like material to mimic the terrain in front of the lander on Mars.

- Recreating the exact conditions, using lander camera images, allowed them to practice setting down the lander’s instruments on Earth before it was done on the Martian surface.
- A full-scale working lander model, aptly named “ForeSight,” let the team test all operations before they occurred on the Martian surface.

- The engineers confirmed the science team’s preferred seismometer placement of about 5.4 ft directly in front of the lander; the heat flow probe will be placed roughly the same distance from the lander, but about 4 ft to the left of the seismometer.
December 19, 2018 - The lander places its first instrument, called the Seismic Explorations for Interior Structure (SEIS), onto the surface of Mars.

- SEIS measures seismic waves caused by “marsquakes,” meteorite strikes and other phenomena.
- This was the first seismometer ever placed onto the surface of a planet other than Earth.
- The white robotic arm is shown supporting the black, hand-like, grapple at the end.
- The grapple is holding onto the copper-colored seismometer.
- The color-calibrated image was taken around Martian dusk by the Instrument Deployment Camera on the robotic arm.
December 13, 2018 - The annotations added after InSight landed on November 26, 2018 display the locations of InSight’s lander, heat shield, backshell and parachute.

- The image of the surface of Mars was taken by the Mars Reconnaissance Orbiter’s High Resolution Imaging Science Experiment camera on May 30, 2014.
InSight Status (as of January 7, 2019)

- On Nov. 26, 2018, the lander sent signals to Earth indicating that its solar panels were open and recharging the batteries on the Martian surface.
  - This was the first ever recording of Martian wind.
- The mission team deployed the lander’s robotic arm from the stowed configuration and used the attached camera to snap photos including the surrounding surface.
  - Engineers used the photos to decide where to place the spacecraft’s scientific instruments, SEIS and HP³.
- On Dec. 19, 2018, the lander deployed SEIS onto the surface of Mars.
  - RISE has already begun using the lander’s radio connection with Earth to collect preliminary data on the planet’s core.
  - Not enough time has elapsed for scientists to deduce what they want to know; scientists estimate they might have some results starting in about a year.
InSight Highlights (as of January 7, 2019)

May 5, 2018 - InSight was launched from Vandenberg Air Force Base, CA.
- The United Launch Alliance Atlas V 401 rocket was launched early in the morning.

Nov. 26, 2018 - InSight lands in Elysium Planitia, a broad plain that straddles the Martian equator.
- The lander touched down within the targeted landing area.
- InSight is NASA’s eighth lander or rover to successfully land on Mars.
- Mars Polar Lander is the only NASA spacecraft that failed to land in December 1999.
Reference Information

Images:
Courtesy of NASA, Lockheed Martin, and United Launch Alliance

Text:
https://upload.wikimedia.org/
https://www.lockheedmartin.com/
https://www.nasa.gov/
https://www.jpl.nasa.gov/
https://photojournal.jpl.nasa.gov/
https://mars.nasa.gov/
https://www.flickr.com/
https://www.nasaspaceflight.com/
https://en.wikipedia.org/
https://directory.eoportal.org/

InSight Spacecraft Nails Mars Landing, Irene Klotz, Aviation Week and Space Technology; December 10-23, 2018; Volume 180, Number 24, page 39 - Includes the number of NASA landing missions to Mars
http://phoenix.lpl.arizona.edu/
https://www.seis-insight.eu/

Video:
Insight Entry, Descent and Landing
https://www.youtube.com/watch?v=PDSbUpmRksI&t=0s&index=12&list=PLTiv_XWHnOZpoZ2QD4-3PATEFxAXK-8uA
InSight Atlas V Launch Vehicle

The United Launch Alliance Atlas V-401 vehicle was selected for the InSight mission because it had the right liftoff capability for the heavy weight requirements. It is one of the biggest rockets available for interplanetary flight.

- The rocket stands 188 ft tall, or about as tall as a 19-story building. Fully stacked, with the spacecraft, the Atlas V-401 weighs about 730,000 lbs.
- Atlas V-401 rockets are expendable launch vehicles meaning they are only used once.
  - The numbers in the 401 designation signify a payload fairing that is approximately four meters (13 ft) in diameter; zero solid-rocket boosters fastened alongside the central common core booster; and a one-engine Centaur upper stage.
- The Atlas V-401 rocket is provided by United Alliance, Centennial, CO, a joint venture of the Boeing Company and Lockheed Martin Corporation.
The Lander Spacecraft is comprised of subsystems that include:

### Structure Subsystem:

- **Science Deck and Enclosure** - builds on the proven design of NASA’s Mars Phoenix lander.
  - Components on the upper deck include the robotic arm and grapple, two dedicated science instruments and their accessories, a laser retroreflector, a UHF antenna and two Rotation Interior Structure Experiment X-Band antenna.

### Mechanisms Subsystem:

- **Landing Legs** - the three landing legs deploy after the heat shield separates and they absorb the shock during landing.

- **Instrument Deployment System (IDS)** - a robotic arm to deploy the instruments to the surface, and two cameras to support a variety of operations.
  - Instrument Deployment Arm (IDA) - the 15.1 ft robotic arm deploys the Seismic Experiment for Interior Structure and Heat Flow (SEIS) and Physical Properties Package (HP³) instruments to the Martian surface.
    - The IDA has a grapple to grasp the components that it will handle; it is launched and stored on the upper deck.
    - The scoop or bucket on the end of IDA prepares the ground before setting the instruments on the surface.
  - Instrument Deployment Camera (IDC) - mounted on the upper arm of IDA, it images the instruments on the lander’s deck and provides stereoscopic views of the terrain surrounding the landing site.
  - Instrument Context Camera (ICC) - a color camera mounted below the lander’s deck provides a complementary view of the instrument deployment area.
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- **Electrical Power Subsystem:**
  - **Solar Panels** - The lander’s two 7.1 ft diameter solar arrays on the surface extend east and west from the deck with a total length of 19.7 ft.
    -- The arrays are deployed by opening like a folding fan.
    - The panels provide 600 to 700 watts on a clear day, enough to power a household blender and plenty to keep its instruments conducting science.
    -- Even when dust covers the panels, what is likely to be a common occurrence on Mars, they should be able to provide at least 200 to 300 watts.
    - Additional solar panels are also mounted to the top deck.
  - **Batteries** - A pair of rechargeable, 25 amp-hour lithium-ion batteries provides energy storage.

- **Telecommunications Subsystem:**
  - The telecommunications subsystem ensures the flow of data to and from Earth.
    -- The primary method for sending data to Earth from the landing site is via UHF relay to an orbiter, through the lander’s helical antenna.
    --- Orbiters receive transmissions from InSight via UHF and relay the InSight data to Earth via X-band.
    -- The lander’s own X-band communications use a pair of medium-gain horn antennas on the deck, communicating directly with Deep Space Network antennas on Earth.
    --- The main uses for InSight’s X-band radio are the Rotation and Interior Structure Experiment.
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- **Propulsion Subsystem:**

  - The initial propulsion for pushing InSight from Earth to Mars comes from the launch vehicle rather than the spacecraft.
  
  - The lander carries 20 thrusters to control its orientation in space, to adjust trajectory as it coasts from Earth to Mars and to slow its final descent to the surface of Mars.
  
  -- The 20 thrusters are of three different sizes: four reaction control system (RCS) thrusters, each providing 1 lb of force; four trajectory correction maneuver (TCM) thrusters, each providing 5 lbs of force; and 12 descent engines, each providing 68 lbs of force.
  
  --- The eight used while the lander is encapsulated inside the aeroshell extend out through cutouts in the back shell.
  
  --- One “rocket engine module” with one RCS thruster and one TCM thruster is at each of four cutouts around the back shell to allow maneuvers in any direction.
  
  --- The descent engines are on the underside of the lander, used for control of the lander’s descent during the last minute before touchdown.
  
  --- All of the thrusters use hydrazine, a propellant that does not require an oxygen source.

- **Thermal Control Subsystem**

  - The lander’s thermal control subsystem is a passive design supplemented with heaters.
  
  -- It uses multilayer insulation blanketing, other insulation, painted radiator surfaces, temperature sensors, heat pipes and redundant heaters controlled by thermostats.
  
  -- An enclosure for key electronics is designed to maintain component temperatures between 5°F and 104°F.
  
  -- Science-payload components are thermally isolated from the lander and provide their own thermal control.
Guidance, Navigation and Control Subsystem:
- InSight will remain oriented as it travels to Mars by using redundant pairs of star trackers and Sun sensors mounted on the cruise stage.
-- A star tracker takes pictures of the sky and performs internal processing to compare the images with a catalog of star positions and recognize which part of the sky it is facing.
- During descent through Mars’ atmosphere, the spacecraft’s knowledge of its movement and position will come from an inertial measurement unit, which senses changes in velocity and direction, and a downward-pointing radar to assess the distance and velocity relative to the Martian surface.
-- The inertial measurement unit includes accelerometers to measure changes in the spacecraft’s velocity in any direction and ring-laser gyroscopes to measure how fast the spacecraft’s orientation is changing.

Command and Data Handling Subsystem:
- The Command and Data Handling Subsystem controls the spacecraft’s computer processing.
-- The system has two redundant computers, one active at all times and the other available as a backup.
- A payload interface card handles the processor’s interaction with InSight’s various science instruments and robotic arm.
- Flight software monitors the status and health of the spacecraft during all phases of the mission, checks for the presence of commands to execute, performs communication functions and controls spacecraft activities.
-- It protects the spacecraft by checking commands for faults and being ready to take corrective steps when it detects irregularities in commanding or spacecraft health.
InSight will be using its science experiments to take the “vital signs” of Mars: its pulse (seismology), temperature (heat flow) and its reflexes (radio science). The science experiments include:

- **Seismic Experiment for Interior Structure (SEIS)** - a seismometer that measures ground motions in a range of frequencies features six sensors of two different types.
  - The sensors are mounted on a three-legged precision leveling structure inside a remote warm enclosure box.
  - That combination will be set directly onto the ground and connected to the lander by a flexible tether containing power and data lines.
  - The Wind and Thermal Shield is an additional protective cover that is placed over SEIS.
  - The SEIS electronics box remains on the lander.
  - France’s national space agency (Centre National d’Études Spatiales, or CNES), Paris, leads the consortium that provides SEIS.

- **Heat Flow and Physical Properties Probe (HP³)** - pronounced “H-P cubed,” provides the first precise determination of the amount of heat escaping from the planet’s interior.
  - InSight’s robotic arm will place the instrument on the ground where a self-hammering mechanical mole burrows to a depth of 10 to 16 ft over the course of about 30 days.
  - The heat probe will penetrate more than 15-times deeper beneath the surface than any previous hardware on Mars.
  - A science tether with temperature sensors connects the upper end of the mole to the HP³ support structure, which is on the Martian surface.
  - An engineering tether connects HP³ support structure to the instrument’s back-end electronics box on the lander.
Heat Flow and Physical Properties Probe (Continued)
- The HP³ investigation also includes a radiometer to measure ground-surface temperature near the lander based on its infrared brightness.
- The German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, or DLR), headquartered in Cologne, provided the HP³.

Rotation and Interior Structure Experiment (RISE) - does not have its own dedicated science instrument because it uses InSight’s direct radio connection with Earth to assess perturbations of Mars’ rotation axis which can provide information about the planet’s core.
- The tools for RISE are the X-band radio on the lander and the large dish antennas of NASA's Deep Space Network.
- The lander’s radio link to Earth will provide precise tracking of the location of one site on the surface as the planet rotates, throughout the course of a full Mars year.

Auxiliary Payload Sensor Subsystem (APSS) - a suite of environmental-monitoring instruments measuring the local magnetic field, wind, and atmospheric temperature and pressure, attached to the lander deck.
- The primary reason for including these instruments in the mission’s payload is to aid interpretation of seismometer data by tracking changes in the magnetic field or atmosphere that could cause ground movement otherwise mistaken for a seismic event.
-- However, the APSS sensors can also serve on their own for other Mars science investigations.
- The University of California, Los Angeles, CA; Spain’s Center for Astrobiology (Centro de Astrobiología, or CAB), Madrid; and the Jet Propulsion Laboratory, Pasadena, CA contributed the key parts of APSS.
Auxiliary Payload Sensor Subsystem (Continued)

- **Magnetometer** - the first ever used on the surface of Mars.
  -- Researchers will use it to investigate variations in the magnetic field which may be induced at the surface by the variations resulting from interaction of the solar wind with Mars’ ionosphere.
  -- The instrument can determine both the magnitude and direction of the local magnetic field.
  -- Effects of the planet’s metallic core on the induced magnetic field at the surface could provide information about the size of the core.
  -- The University of California, Los Angeles, provided InSight’s fluxgate magnetometer.
  --- UCLA has previously provided magnetometers for other NASA missions, including the Galileo mission to Jupiter and the Space Technology 5 mission.

- **Temperature and Wind for InSight (TWINS)** - two finger-size booms mounted on short vertical supports on InSight’s deck monitor atmospheric temperature and the direction and velocity of the wind.
  -- Together the booms make up the TWINS instrument.
  --- The booms face outward in roughly opposite sides of the lander so that wind from any direction reaches at least one of them before the lander itself perturbs the wind much.
  --- Each of the booms holds sensors for recording air temperature and detecting air movement in three dimensions.
  -- Spain’s Center for Astrobiology (Centro de Astrobiología, or CAB), Madrid, provided TWINS.
  --- The instrument’s booms are refurbished flight spares from the CAB-provided weather station on NASA’s Curiosity Mars rover, called the Rover Environmental Monitoring Station.
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- **Laser Retroreflector for InSight (LaRRI)** - a dome-shaped device about 2 inches in diameter and 0.8 inch high, affixed to the top of the lander’s deck, holds an array of eight special reflectors.

- LaRRI is not part of the InSight mission’s own science investigations but may passively provide science value for many years to come.

- The national space agency of Italy (Agenzia Spaziale Italiana, or ASI) provided LaRRI to be used by a possible future Mars orbiter mission with a laser altimeter making extremely precise measurements of the lander’s location.

- Each of the eight reflectors uses three mutually perpendicular mirrors, joining at one point like an inner corner of a box.

-- This gives it the property of returning any incoming light directly toward its source.

- Apollo astronauts on the Moon placed larger arrays of similar “corner cube reflectors” at several lunar landing sites more than 45 years ago.

-- These have served ever since in experiments that use precisely timed laser pulses, sent from Earth and reflected back, for purposes such as determining the rate of change in the Moon’s distance from Earth and testing Einstein’s general theory of relativity.

- Scientists plan to use LaRRI, plus similar retroreflectors, on future missions that land on Mars for experiments that use reflection of laser pulses emitted by orbiters.

- Besides providing precise location information for experiments about gravity and planetary motion, such studies could include investigations of the Martian atmosphere and advances in using lasers as an alternative to radio for communications.