

National Aeronautics and  
Space Administration



# INGENUITY

## MARS HELICOPTER

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LANDING PRESS KIT



January 2021

[www.nasa.gov](http://www.nasa.gov)

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# Introduction



NASA's Ingenuity Mars Helicopter is the first aircraft humanity has sent to another planet to attempt powered, controlled flight. If its experimental flight test program succeeds, the data returned could benefit future explorations of the Red Planet – including those by astronauts – by adding the aerial dimension, which is not available today.

While Ingenuity is a technology experiment that is separate from the rover's science mission, the helicopter launched to Mars on July 30, 2020, attached to the belly of NASA's Mars 2020 Perseverance rover. They will land together in Jezero Crater on Feb. 18, 2021.

For more on the Perseverance rover, visit [go.nasa.gov/perseverance-landing-press-kit](https://go.nasa.gov/perseverance-landing-press-kit)

## 7 Things to Know About Ingenuity

NASA's Ingenuity Mars Helicopter is small but mighty. In a mere six years, it went from being an implausible prospect to a 4-pound (1.8-kg), space-certified companion to Mars aboard the Perseverance rover. And when Ingenuity arrives at Mars, it will aim to push the limits of flight. Here are seven things you should know about Ingenuity:

### 1. Ingenuity is an experimental flight test.



*Image credit: NASA/JPL-Caltech*

Ingenuity is what is known as a technology demonstration – a project that seeks to test a new capability for the first time, with limited scope. Previous groundbreaking technology demonstrations include the [Mars Pathfinder](#) rover, Sojourner, and the [Mars Cube One](#) (MarCO) CubeSats that flew by Mars in 2018.

The helicopter does not carry science instruments and is a ride-along on the Mars 2020 Perseverance mission. Ingenuity's objective is an engineering one: to demonstrate rotorcraft flight in the extremely thin atmosphere of Mars.

## 2. Ingenuity will attempt the first powered, controlled flight on another planet – a feat with a high degree of difficulty.



Image credit: NASA/JPL-Caltech

Mars has beyond bone-chilling temperatures, with nights as cold as minus 130 degrees Fahrenheit (minus 90 degrees Celsius) at Jezero Crater. These temperatures will push the original design limits of the off-the-shelf parts used in Ingenuity. Tests on Earth at the predicted temperatures indicate they should work as designed, but the team is looking forward to the real test at Mars. One of Ingenuity's first objectives when it gets to the Red Planet is just to survive the frigid Martian night for the first time.

Mars has a rarefied atmosphere – just about 1% of the density of our atmosphere on Earth. Because the Mars atmosphere is so much less dense, Ingenuity is designed to be light, with rotor blades that are much larger and spin much faster than what would be required for a helicopter of Ingenuity's mass on Earth. Mars does give the helicopter a little help: The gravity there is only about one-third that of Earth's. That means slightly more mass can be lifted at a given spin rate.

Ingenuity will attempt up to five test flights within a 30-Martian-day (31-Earth-day) demonstration window.

Its pioneering aspirations are similar to those of the Wright brothers' Flyer, which achieved the first powered, controlled flight on Earth.

## 3. Ingenuity relies upon the Mars 2020 Perseverance spacecraft for safe passage to Mars and for operations on the Red Planet's surface.



Image credit: NASA/JPL-Caltech

Ingenuity is nestled up sideways under the belly of the Perseverance rover, with a cover to protect it from the debris kicked up during landing. Both the rover and the helicopter are safely ensconced inside a clamshell-like entry capsule during the 293-million-mile (471-million-kilometer) journey to Mars. The power system on the Mars 2020 spacecraft periodically charges Ingenuity's batteries on the way there.

To reach the Martian surface, Ingenuity rides along on Perseverance's entry, descent, and landing system, which features a supersonic parachute, new "brains" for [avoiding hazards autonomously](#), and components for the maneuver known as the [sky crane](#). Only about 50% of the attempts to land on Mars, by any space agency, have been successful.

Once a suitable site to deploy the helicopter is found, the rover's Mars Helicopter Delivery System will shed the landing cover, rotate the helicopter to a legs-down configuration, and [gently drop Ingenuity](#) on the surface in the first few months after landing. Throughout the helicopter's commissioning and flight test campaign, the rover will assist in communications back and forth from Earth. The rover team also plans to collect some images of Ingenuity.

#### 4. Ingenuity is smart for a small robot.

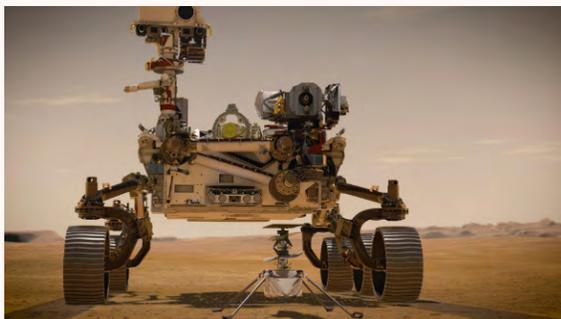


Image credit: NASA/JPL-Caltech

Delays are an inherent part of communicating with spacecraft across interplanetary distances, which means the helicopter's flight controllers at JPL won't be able to control the helicopter with a joystick or to look at engineering data or images from each flight until well after the flight takes place.

Therefore, Ingenuity will make some of its own decisions, based on parameters set by its engineers on Earth. Ingenuity has a kind of programmable thermostat, for instance, that will keep it warm on Mars. During flight, Ingenuity will analyze sensor data and images of the terrain to ensure it stays on the flight path programmed by project engineers.

#### 5. Ingenuity has already demonstrated feats of engineering.



Image credit: NASA/JPL-Caltech

It took humankind centuries and a lot of trial and error to figure out how to fly planes and helicopters on Earth. In careful steps over six years, engineers on the Ingenuity team were able to demonstrate that it was possible to build something ultra-lightweight that could generate enough lift in Mars' thin atmosphere to take off from the ground, and that could operate and survive autonomously in the challenging Martian environment. These accomplishments have already pushed the boundaries of flight.

Ingenuity has now survived the dynamic environment around launch and proved it can charge its off-the-shelf batteries in space. Flying over the surface of Mars will confirm results from flight tests performed in special space simulation chambers and provide insights into operating a helicopter on Mars.

## 6. The Ingenuity team counts success one step at a time.

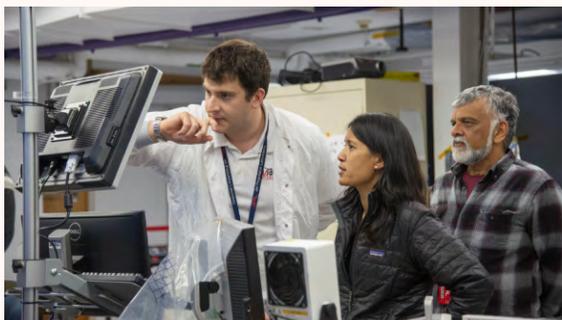


Image credit: NASA/JPL-Caltech

Given Ingenuity's experimental nature, the team has a long list of milestones the helicopter must pass before it can take off and land in the spring of 2021. The team will celebrate each milestone:

- Surviving the cruise to Mars and landing on the Red Planet
- Safely deploying to the surface from the belly of the Perseverance rover
- Autonomously keeping warm through the intensely cold Martian nights
- Autonomously charging itself with its solar panel
- Successfully communicating to and from the helicopter via a subsystem known as the Mars Helicopter Base Station on the rover

If the first experimental flight test on another planet is successful, the Ingenuity team will attempt more test flights.

## 7. If Ingenuity succeeds, future Mars exploration could include an ambitious aerial dimension.



Image credit: NASA

Ingenuity is intended to demonstrate technologies needed for flying in the Martian atmosphere. If successful, these technologies could enable other advanced robotic flying vehicles that might be part of future robotic and human missions to Mars. Possible uses of a future helicopter on Mars include offering a unique viewpoint not provided by current orbiters high overhead, or by rovers and landers on the ground; high-definition images and reconnaissance for robots or humans; and access to terrain that is difficult for rovers to reach. A future helicopter could even help carry light but vital payloads from one site to another.



# Media Services

## Media Contacts

### **Policy/Program Management**

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# Products and Events

## News Releases, Features, and Status Reports

News, updates, and other information about the Ingenuity Mars Helicopter will be available at [nasa.gov/mars](https://nasa.gov/mars) and the [Ingenuity website](#).

The latest information about landing activities can be found on the Perseverance rover's [landing page](#).

## Video and Images

Two Ingenuity Mars Helicopter media reels are available in the NASA Image and Video Library: [animations](#) and [b-roll](#).

Ingenuity image and video galleries are available at [NASA's Mars site](#) and [Planetary Photojournal](#).

A collection of Perseverance rover and Ingenuity Mars Helicopter videos is also available at <https://vimeo.com/showcase/7377243>.

The NASA image use policy is available [here](#).

The JPL image use policy is available [here](#).

## Media Events

The most current information about upcoming Mars 2020 Perseverance rover and Ingenuity Mars Helicopter media events and where they may be viewed can be found in the [Perseverance landing toolkit](#). More information on NASA TV and streaming channels can be found below in the [Watch Online](#) section.

### Briefings and Availabilities

A virtual news conference previewing the Mars landing will take place on **Jan. 27, 2021, at 4:30 p.m. EST (1:30 p.m. PST)**. Members of the media may dial into a telecon line to ask questions by contacting Rexana Vizza, [rexana.v.vizza@jpl.nasa.gov](mailto:rexana.v.vizza@jpl.nasa.gov). Members of the public can submit questions via social media with the tag **#CountdownToMars**.

A pre-landing news conference including the helicopter is scheduled for **Feb. 16, 2021, 1 p.m. EST (10 a.m. PST)**, originating from NASA's Jet Propulsion Laboratory in Southern California. Because of the ongoing coronavirus pandemic, media participation in these briefings will be virtual. Members of the media interested in asking questions during the briefing should contact Rexana Vizza, [rexana.v.vizza@jpl.nasa.gov](mailto:rexana.v.vizza@jpl.nasa.gov).

A post-landing news conference at JPL is expected to begin approximately one and a half hours after landing.

Additional news conferences after landing will be scheduled as events warrant.

All news briefings will be broadcast and livestreamed.

Interviews with mission team members may be arranged by calling the JPL newsroom at 818-354-5011 or filling out the form at <https://bit.ly/mars-landing-media>.

## Live Landing Feed

A live video feed of key landing activities and commentary from the mission control areas at JPL will be broadcast. This live commentary show is expected to begin at 2:15 p.m. EST (11:15 a.m. PST) and last for about two hours.

A Spanish-language simulcast will also be available on the [NASA en Español YouTube](#) channel and the @NASA\_es social media accounts

## On-Site Media Logistics

News media representatives who would like to cover the Mars 2020 Perseverance and Ingenuity Mars Helicopter landing in person at JPL must be accredited in advance. All accreditation requests should be submitted to Rexana Vizza, [rexana.v.vizza@jpl.nasa.gov](mailto:rexana.v.vizza@jpl.nasa.gov).

Due to the ongoing COVID-19 pandemic, JPL will be credentialing a limited number of media for on-site access. State and local restrictions, as well as federal guidelines, will determine the scope of and rules for in-person activities and are subject to change. Only U.S. citizens or green card holders representing U.S. media outlets and U.S.-based reporters for international outlets will be considered for credentials. Requests must have been submitted by **Jan. 14, 2021**, to Rexana Vizza, [rexana.v.vizza@jpl.nasa.gov](mailto:rexana.v.vizza@jpl.nasa.gov).

NASA will provide ample opportunities for members of the media to cover the landing remotely, including virtual participation in news briefings.

Members of the media interested in in-person interviews with mission team members (subject to coronavirus restrictions) may call the JPL newsroom at **818-354-5011**.

## How to Watch (Live and On Demand)

News briefings and landing commentary will be livestreamed on [NASA TV](#), [NASA.gov/live](#), and [YouTube.com/NASA](#). On-demand recordings will also be available after the live events have finished on YouTube. Any additional feeds or streams will be listed in the [Watch Online section](#) of the Mars 2020 Perseverance mission website.

NASA TV channels are digital C-band signals carried by QPSK/DVB-S modulation on satellite Galaxy-13, transponder 11, at 127 degrees west longitude, with a downlink frequency of 3920 MHz, vertical polarization, data rate of 38.80 MHz, symbol rate of 28.0681 Mbps and 3/4 FEC. A Digital Video Broadcast-compliant Integrated Receiver Decoder is needed for reception. For more information about NASA TV's programming schedule, visit <http://www.nasa.gov/ntv>.

A clean feed of mission activities will also be available on the NASA TV media channel and [YouTube.com/JPLRaw](#).

## Eyes on the Solar System

Follow the journey of the Mars 2020 Perseverance spacecraft with Ingenuity inside in real time through [NASA's Eyes on the Solar System](#).



## Additional Resources on the Web

Online and PDF versions of this press kit are available online at [go.nasa.gov/ingenuity-press-kit](https://go.nasa.gov/ingenuity-press-kit).

The Mars 2020 Perseverance press kit is available online at [go.nasa.gov/perseverance-landing-press-kit](https://go.nasa.gov/perseverance-landing-press-kit).

Additional information about the Ingenuity is available on the [Mars Helicopter page](#).

A 3D model of the helicopter is also [available](#).

## Social Media

Join the conversation and get mission updates about the Ingenuity Mars Helicopter, the Perseverance rover, JPL, and NASA via these accounts:

Twitter: [@NASAPersevere](#), [@NASAJPL](#), [@NASAMars](#), [@NASA](#)

Facebook: [/NASAPersevere](#), [/NASAJPL](#), [/NASAMars](#), [/NASA](#)

Instagram: [@NASAJPL](#), [@NASA](#)

# Quick Facts



## Helicopter Names



*Image credit: NASA/JPL-Caltech*

[Ingenuity](#) Mars Helicopter, submitted by Vaneeza Rupani of Tuscaloosa County High School in Northport, Alabama.

# Spacecraft

**Weight:** About 4.0 pounds (1.8 kilograms) on Earth, and about 1.5 pounds (0.68 kilograms) on Mars

**Height:** 1.6 feet (0.49 meters)

**Rotor system:** Four specially made carbon fiber blades arranged into two 4-foot-long (1.2-meter-long) counter-rotating rotors that spin at roughly 2,400 rpm

**Fuselage (body) dimensions:** 5.4 inches by 7.7 inches by 6.4 inches (13.6 centimeters by 19.5 centimeters by 16.3 centimeters); four carbon composite landing legs, each 1.26 feet (0.384 meters) long, giving the helicopter about 5 inches (13 centimeters) of clearance above the ground

**Power:** Solar array on top of the rotor system charges six lithium-ion batteries

## Cameras

**Two cameras on Ingenuity:** One color with a horizon-facing view for terrain images and one black-and-white for navigation.

# Launch

**Launch:** July 30, 2020, 7:50 a.m. EDT (4:50 a.m. PDT)

**Launch site:** Space Launch Complex 41, Cape Canaveral Air Force Station, Florida

**Launch vehicle:** United Launch Alliance (ULA) Atlas V 541

**Spacecraft's distance to travel from Earth to Mars (July 30 launch):** 293 million miles (471 million kilometers)

## Surface Mission



Image credit: NASA/JPL-Caltech

**Time of Mars landing:** Feb. 18, 2021, 3:55 p.m. EST (12:55 p.m. PST). The time of day at the landing site will be 3:53 p.m. local mean solar time.

**Landing site:** Jezero Crater, about 18 degrees latitude, 77 degrees longitude

**Ingenuity flight test program duration:** Up to 30 Martian days (about 31 Earth days)

## Mars

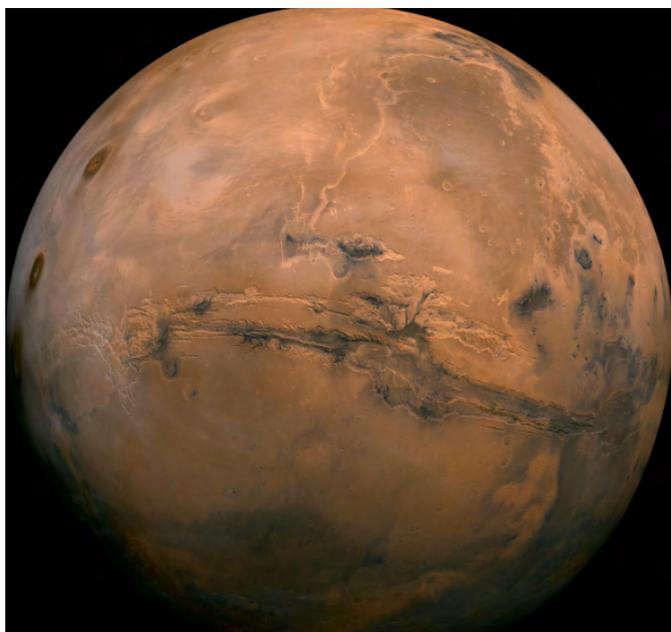


Image credit: NASA/JPL-Caltech

**Size:** Approximately half the diameter of Earth but twice the diameter of Earth's Moon. As a desert planet, Mars has roughly the same amount of surface area as the dry land on Earth.

**Mass:** About 10% of Earth's

**Gravity:** About 38% as strong as Earth's

**Orbit:** Elliptical and about 1.5 times farther from the Sun than Earth is (about 141.5 million miles or 227.7 million kilometers from the Sun, on average)

**Year:** One Mars year (one revolution around the Sun) takes 687 Earth days

**Day:** One Mars day, or sol (one rotation), is 24 hours, 39 minutes, 35 seconds long.

**Atmosphere:** About 1% the density of Earth's atmosphere at the surface

**Temperature:** Surface temperature averages minus 64 degrees Fahrenheit (minus 53 degrees Celsius); varies from minus 199 Fahrenheit (minus 128 Celsius) during a polar night to 80 Fahrenheit (27 Celsius) midday at the equator at closest point in orbit to Sun

**Distance from Earth on Feb. 18, 2021:** 127 million miles (205 million kilometers)

## Program

NASA has invested about \$85 million to build the Ingenuity Mars Helicopter, accommodate it on Perseverance, and operate the helicopter on Mars.



# Mission: Overview

The Ingenuity Mars Helicopter and the Mars 2020 Perseverance rover launched together from Cape Canaveral, Florida, on July 30, 2020. Both will arrive at the surface of Mars' Jezero Crater on Feb. 18, 2021. Once the Perseverance team has completed a detailed checkout of the rover's systems and subsystems and once both the rover and helicopter teams have agreed upon a good drop-off location, Ingenuity will be deployed and begin its flight test program. This is expected to take place in the first few months after landing. The Ingenuity Mars Helicopter flight test program will span no more than 30 sols (a sol is one Mars day, which is 24 hours, 39 minutes, and 35.244 seconds).

As soon as the Ingenuity technology demonstration is complete, the Mars 2020 rover will transition into its science operations phase. During a prime mission that will last at least one Mars year (about 687 Earth days), Perseverance's investigations in Jezero Crater will address high-priority science goals for Mars exploration – among them, searching for signs of ancient microbial life and collecting Martian rock and regolith (broken rock and dust) for future return to Earth. The results of Ingenuity's flight test program will have no bearing on the Mars 2020 Perseverance rover mission's science goals or success. Find more information about the mission in the [Perseverance rover press kit](#).

## Helicopter Objectives

**The helicopter team has a sequence of objectives for this high-risk, high-reward project. The team has already successfully completed the first major objective:**

**To demonstrate powered flight in the thin atmosphere of Mars is possible.**

- The Martian atmosphere is only about 1% as thick as Earth's, making it very difficult to generate the lift necessary to fly.
- The team has successfully designed, built, and flight-tested Ingenuity in a Mars-like atmospheric environment in a special chamber on Earth.

**After the testing on Earth, the team now aims:**

### **To actually fly the helicopter on Mars.**

- The flight tests at Mars will inform the team of the actual performance in the true environment of Mars compared to the models assumed for the environment and the flight tests that took place on Earth.
- The Ingenuity team will attempt up to five flight tests during its 30-sol experiment window. Each successful flight will allow the team to consider expanding the test envelope for the next flight. If data suggests the mission did not meet expectations, the team may elect to reproduce the previous flight profile.
- The helicopter will start each flight from a 33-by-33-foot (10-by-10-meter) airfield and end back in this airfield.
- The helicopter will fly at altitudes of 10-15 feet (3-5 meters) in altitude and travel as far as 160 feet (50 meters) downrange and back to the starting area.
- Engineers will fly the helicopter for no more than about 90 seconds on each flight.

**The helicopter experiment will also inform engineers about:**

### **Use of miniaturized flying technology in space.**

- To fit within the payload space on the Perseverance rover's belly while also maintaining the capability to fly in Mars' thin atmosphere, Ingenuity was designed to be as light and compact as possible (about 4 pounds, or 1.8 kilograms, on Earth).
- Its onboard computers, batteries, sensors, and heaters all fit within a fuselage that is about the size of a tissue box.
- In addition to having to be small and lightweight, the helicopter's components had to be stress-tested to be sure they could survive the cold temperatures and radiation in deep space and on Mars.

### **Autonomous operations of an aerial system at another planet or moon.**

- Like the rover, the helicopter is too far from Earth to be operated with a joystick. So engineers will learn to operate the aerial vehicle from many millions of miles away.
- The helicopter is designed to fly, land, communicate, manage its energy, and keep warm autonomously.
- Innovative mathematical algorithms will allow flight in the thin atmosphere, keep track of the helicopter's movements, and ensure it remains on the planned flight path.

## **Future Implications**

**The fundamental mathematical models, simulations, and design approach used for Ingenuity position NASA to consider incorporating small helicopters into mission plans for future robotic and human exploration at Mars.**

- Taking to the air would give scientists a new perspective of a region's geology and allow them to peer into areas too steep or slippery to send a rover.
- Future generations of Mars helicopters could provide a supporting role as robotic scouts, surveying terrain from above.
- These future helicopters could also collect samples or carry an instrument payload for in-situ scientific investigation. In addition, a future Mars helicopter could help carry light but vital payloads from one site to another.



*Image credit: NASA*

## Getting to Mars



*Image credit: NASA/Joel Kowsky*

The Mars Helicopter was designed to fly at the Red Planet, but it needs help to survive the space environment and the extreme temperatures of interplanetary cruise or entry, descent, and landing (EDL) on Mars. For these phases of the project (as well as early surface operations before the helicopter's deployment), Ingenuity will rely on the Mars 2020 Perseverance mission to provide power, a communications link to Earth, and shielding from both micrometeorites and entry heating.

The Perseverance rover, with Ingenuity attached to its belly and protected by a debris shield (that protects the helicopter from rocks kicked up during Perseverance’s landing), launched from Space Launch Complex 41 at Cape Canaveral Air Force Base on July 30, 2020, at 7:50 a.m. EDT (4:50 a.m. PDT) aboard a two-stage United Launch Alliance (ULA) Atlas V 541 rocket.

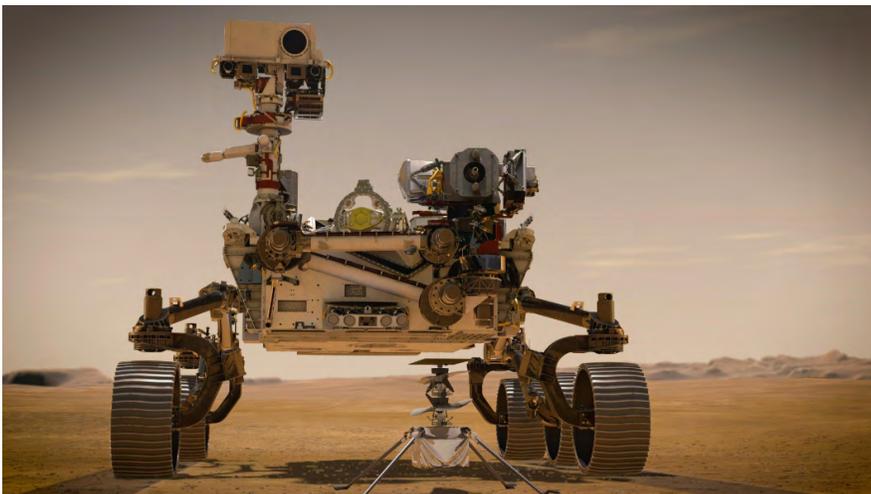
During cruise to Mars, the Perseverance rover, its descent stage, and the Ingenuity Mars Helicopter are encased inside a capsule known as an aeroshell; the aeroshell is attached to the disk-shaped, solar-powered cruise stage.

Among the numerous housekeeping tasks the mission team performs during cruise is a biweekly [recharge of Ingenuity’s batteries](#). The closely monitored one- to two-hour operation includes checking the rotorcraft’s six lithium-ion batteries as well as bringing the charge level of each back up to about 35% – the level of charge the Ingenuity team has determined is optimal for battery health during cruise.

To reach the Martian surface, Ingenuity remains attached to Perseverance’s chassis as the rover’s EDL system carries them to the surface in a fast-paced set of milestones that last about seven minutes. [Not only is the choreography of EDL complex](#), but the time delay involved in communicating with Earth means that the spacecraft has to accomplish this choreography all by itself. Many engineers refer to this complex sequence of events as the “[seven minutes of terror](#).”

Find more information about Perseverance’s interplanetary cruise and entry, descent, and landing in the [Perseverance rover press kit](#).

## Surface Phase



*Image credit: NASA/JPL-Caltech*

### Early Surface Operations

The rover should touch down in the Martian afternoon – about 3:53 p.m. local mean solar time. Soon after, the rover’s computer switches from entry, descent, and landing (EDL) mode to surface mode. This initiates autonomous activities for Sol 0, the first Martian day on the surface of the Red Planet.

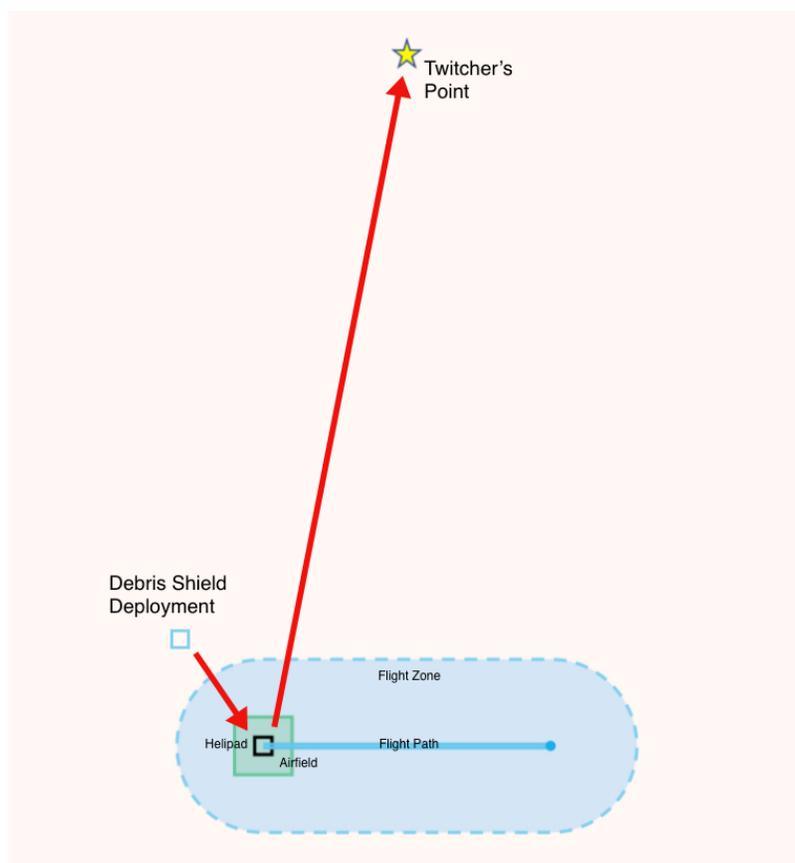
During Perseverance's Surface Operations Transition Phase, engineers begin the commissioning process, checking to confirm that all rover systems, subsystems, and instruments are ready to proceed with surface mission objectives. Still connected to the belly of the rover via the Mars Helicopter Delivery System, Ingenuity will receive its own checkout as well as a battery charging within a couple sols of landing.

For the first few months, including the time the helicopter is conducting test flights, the Perseverance and Ingenuity operations teams will work on Mars time, which means they will be setting their clocks to sync with the Martian day (about 40 minutes longer than an Earth day). This allows them to respond quickly to any issue the rover or helicopter might have and to prepare revised instructions for the next sol.

## Surveying Candidate Airfields

After commissioning is complete, the rover and helicopter teams will search for the best natural airfield in the vicinity. The airfield is a 33-by-33-foot (10-by-10-meter) region where the helicopter will always take off and return. It will fly within an area called the flight zone. The rover will visit the top candidate airfield, using its navigation cameras to provide detailed surface imaging and digital elevation maps.

The Mars 2020 mission has determined that wherever Perseverance lands within its 4.8-by-4.1-mile (7.7-by-6.6-kilometer) landing ellipse, there is a 75% probability of finding a good airfield for Mars Helicopter flight operations within 330 feet (100 meters). But a certifiable airfield could be more distant and take longer to identify and confirm.



*A schematic of the flight zone (blue oval) where Ingenuity will conduct its first flight activities. First, Perseverance will drop the debris shield covering Ingenuity, drive to the helipad (innermost box) to drop off the helicopter, and then move out to a safe distance at Twitcher's Point (the star). The helicopter would start its test program at the helipad, fly out a pre-programmed flight path, and return again to the helipad.*  
Image credit: NASA/JPL-Caltech

**Engineers looking for a desirable airfield will evaluate the following criteria:**

- **Helipad** (innermost box in graphic above): A 10-by-10-foot (3-by-3-meter) area where Perseverance will deploy the Ingenuity Mars Helicopter. Preferably, the box should be free of rocks more than 2 inches (5 centimeters) high and should be sloped no more than an average of around 5 degrees.
- **Airfield** (larger box): A 33-by-33-foot (10-by-10-meter) area surrounding the helipad. The surface should have as few rocks as possible exceeding 2 inches (5 centimeters) in height and have an average slope of no more than approximately 4 degrees.
- **Flight zone** (flattened oval): The area is defined by a boundary that extends horizontally 50 feet (15 meters) – in any direction – beyond the Mars Helicopter’s expected flight path during test flights. The terrain inside the zone must have sufficient visual features for the helicopter to track its movements using the onboard navigation camera.
- **Debris shield deployment box** (blue box above the oval): The location where the debris shield will be dropped (exposing the Mars Helicopter to the Martian environment for the first time). The box will be located 50 feet (15 meters) or more from the edge of the helipad. The optimal 10-by-10-foot (3-by-3-meter) box would have no more than a 10-degree slope and no obstructions (rock or surface bumps) that reduce rover ground clearance by over 2 inches (5 centimeters).
- **Twitcher’s point** (star): Perseverance’s parking spot during the Ingenuity flight tests. “Twitcher” is a British (and now Martian) term for those who travel long distances to see a rare bird. Located about 330 feet (100 meters) from the edge of the flight zone, the site should be relatively level. Twitcher’s Point also must allow direct line-of-site between the rover and the helicopter during all portions of potential flight tests for optimal radio communications and imaging.

## Helicopter Deployment Phase

This sequence of activities, which is expected to take 10 sols if all goes well, begins with the deployment of the debris shield and ends with the helicopter on the surface of Mars. Each step is accompanied by communications back to Earth (via the rover and orbiters and NASA’s Deep Space Network) along with periodic transmission of pictures taken by the rover’s cameras, including the WATSON imager that is part of the SHERLOC instrument located on the end of the rover’s robotic arm.

This period will include the rover’s drive to the center of the helipad, the release of the lock on the Mars Helicopter Delivery System and slow rotation of the helicopter down to the surface, deployment of the helicopter’s legs, the charging of the batteries to 100%, and then the gentle drop 6 inches (15 centimeters) to the surface on the last sol. After the drop, Perseverance drives away to expose Ingenuity to the Sun so the helicopter can recharge its batteries.

## Milestones

Once Ingenuity is deployed to the surface, it has 30 sols (31 Earth Days) to complete its activities. The first phase is a commissioning process that is expected to take about a week; then the first flight tests begin.



*Image credit: NASA/JPL-Caltech*

**At the beginning of Ingenuity’s surface operations, the helicopter will aim to hit the following milestones:**

- Autonomously keeping warm through the intensely cold Martian nights (as frigid as minus 130 degrees Fahrenheit, or minus 90 degrees Celsius).
- Autonomously charging with its solar panel.
- Confirming the communications link: between the helicopter and its base station; between the base station and the rover’s communication system; and then between the rover and Earth, all the way back to the helicopter flight operators.
- Unlocking its rotor blades, confirming blades can change their angle, or pitch, and then performing both low-speed (50 rpm) and high-speed (2,400 rpm) spin tests while still standing on the surface.

**Once Ingenuity is certified for its test flights, it will attempt:**

- Lifting off for the first time in the thin Martian atmosphere
- Flying autonomously
- Landing successfully

If all those steps are successful, Ingenuity will attempt up to four additional test flights.

## First Experimental Flight Test on Another World

**Mars Flight Test No. 1** is scheduled to launch at about 11 a.m. local time on Mars, when winds in the area are expected to be lightest and the battery will be at an adequate state of charge. In addition to using existing wind models, the teams will also be regularly checking data from the rover's [Mars Environmental Dynamics Analyzer](#) (MEDA) instrument, which will provide data on the winds in the vicinity.

By the time of liftoff, the helicopter's flight computer will have autonomously run through a series of preflight checks and run the rotor system to around 2,400 rpm. If everything remains go, the computer will command the rotor blades to change their angle, or pitch, taking a deeper bite into the tenuous Martian atmosphere. The first attempt at powered, controlled flight from Mars will begin a fraction of a second later.

The goals of Flight Test No. 1: lift off, climb, hover, and land. Ingenuity will be tasked with climbing at about 3 feet per second (1 meter per second) to an altitude of about 10 feet (3 meters). Then it is expected to hover for about 20 seconds and descend at about 3 feet per second (1 meter per second) until touchdown.

Flight tests will be divided into three-sol blocks. In addition to flying the helicopter, engineers use the first sol of each block for activities, including finalizing and transmitting the command sequences and acquiring preliminary data after the flight test's completion. As soon as these first glimpses (including two low-resolution images taken in-flight) are downlinked, the Ingenuity team will begin reconstructing the vehicle's performance and planning the next sortie. The second day's communication from the helicopter will include all the engineering data acquired during the test. The images taken during the flight (up to four black-and-white navigation and three color) will be received on Day 3, providing the helicopter team an even clearer "picture" of what took place in the air millions of miles away. Later that evening, the team will meet to decide whether to begin a new test block the following day and, if so, what kind of flight profile to attempt.

### Flight Test No. 2 and Beyond

If the team declares the first test flight a success, the goals of **Flight Test No. 2** could be expanded to include climbing to 16 feet (5 meters) and then flying horizontally for a few feet (meters), flying horizontally back to descend, and landing within the airfield. Total flight time could be up to 90 seconds. Images from the helicopter's navigation camera will later be used by project team members on Earth to evaluate the helicopter's navigation performance.

If the second experimental test flight is a success, the goals of **Flight Test No. 3** could be expanded to test the helicopter's ability to fly farther and faster – up to 160 feet (50 meters) from the airfield and then return. Total flight time could be up to 90 seconds.

If the project timeline allows for **Flight Tests No. 4 and 5**, the goals and flight plans will be based on data returned from the first three tests. The flights could further explore Ingenuity's aerial capabilities, including flying at a time of day where higher winds are expected and traveling farther downrange with more changes in altitude, heading, and airspeed.

## Perseverance's Role

Based 330 feet (100 meters) from the center of Ingenuity's airfield, Perseverance will have an unencumbered view of the helicopter, whether on the surface or in flight. The rover will act as a communications relay between Ingenuity, [Mars orbiters](#), and mission controllers on Earth. Perseverance's [MEDA](#) instrument is expected to provide meteorological information (including data on airborne dust), while its [Mastcam-Z](#) and [navigation cameras](#) will collect still images of Ingenuity – and possibly a video or two. The rover's two microphones (one located on the SuperCam instrument; the other, on its chassis) will attempt to pick up the sounds of the flight operations.

At the conclusion of the Ingenuity Mars Helicopter flight test program, Perseverance will begin to carry out its ambitious science mission: searching for signs of ancient microbial life, characterizing the climate and geology of Mars, and collecting carefully selected samples for future return to Earth. Find more on Perseverance's science objectives in the Science section of the Perseverance rover press kit.

# Mission: Spacecraft

Weighing just about 4 pounds (1.8 kilograms) on Earth but only 1.5 pounds (0.68 kilograms) on Mars, NASA's Ingenuity Mars Helicopter is a small, autonomous rotorcraft designed to test – for the first time – powered, controlled flight in the thin Martian atmosphere. Ingenuity's mission is a purely experimental flight test. If even only one test flight is achieved, it will provide NASA with a wealth of data and operational experience that can be applied to future aircraft designs for other worlds.

Because Ingenuity is a technology demonstration, there is no requirement to collect science data and there are no science instruments onboard. Instead, the helicopter carries a combination of custom-made and off-the-shelf components – many from the world of cell phone technology – including two cameras. These components are optimized for flight testing along with relaying engineering data and some imagery back to Earth.

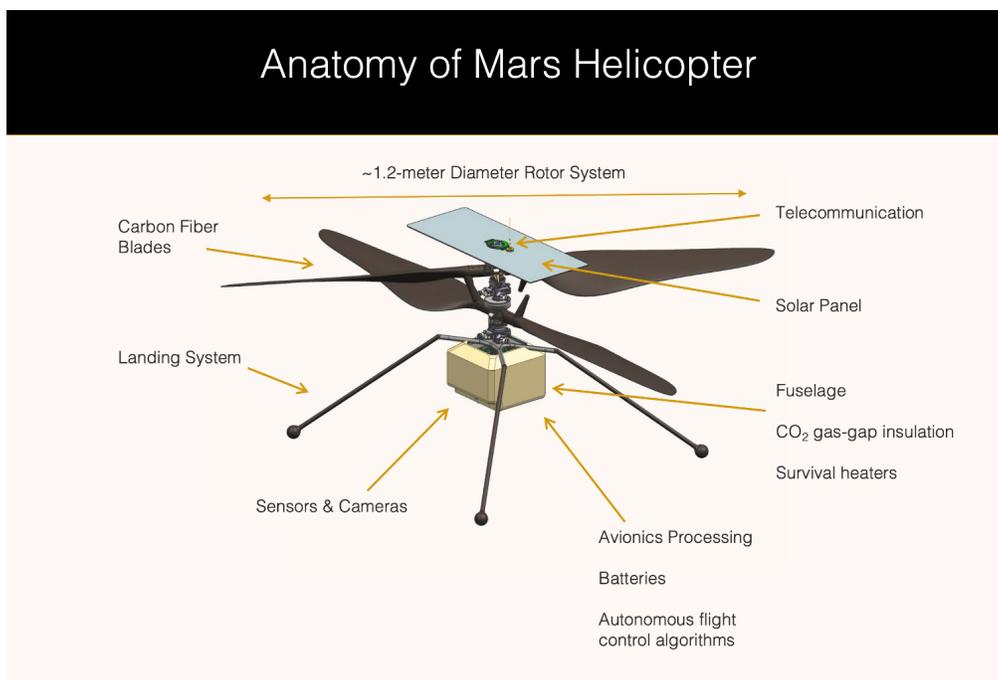


Image credit: NASA/JPL-Caltech

NASA's Jet Propulsion Laboratory in Southern California oversaw the system architecture, design, and development. JPL also built the fuselage and integrated the full vehicle. AeroVironment of Simi Valley, California, built the rotor system, landing gear, and solar panel substrate. SolAero Technologies of Albuquerque, New Mexico, integrated the solar panel.

NASA Ames Research Center in California's Silicon Valley and NASA's Langley Research Center in Hampton, Virginia, provided rotorcraft expertise, computational fluid dynamics analysis, and optimization of the blade design.

## Rotor System

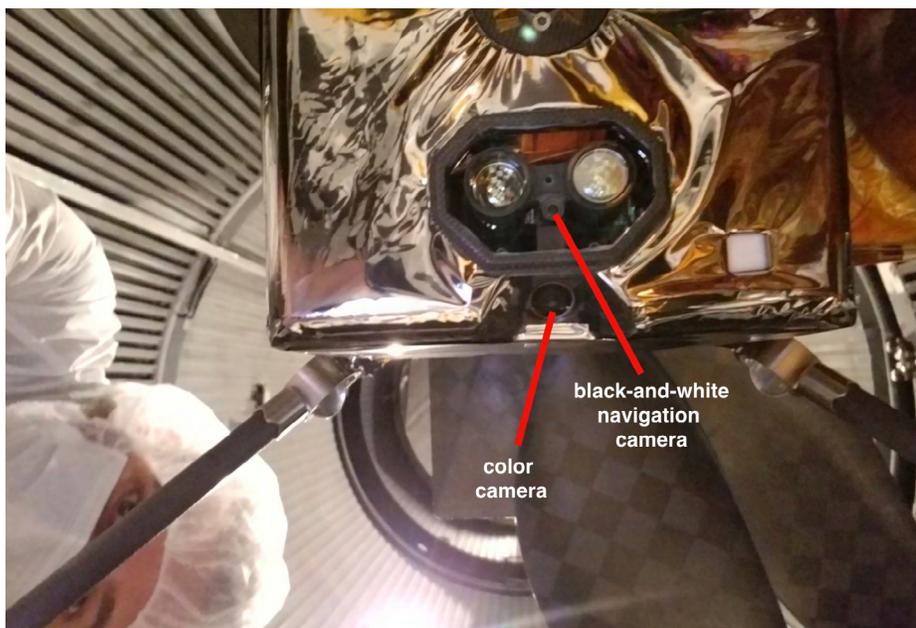
Ingenuity's rotor system features four carbon-fiber blades arranged into two 4-foot (1.2-meter) counter-rotating rotors that spin at about 2,400 rpm.

## Fuselage

Ingenuity's fuselage is just 5.4 inches by 7.7 inches by 6.4 inches (13.6 centimeters by 19.5 centimeters by 16.3 centimeters) – about the size of a tissue box. Engineers have packed this tiny space with computers, batteries, sensors, heaters, and telecommunications hardware.

Four carbon composite landing legs, each about 1.26 feet (0.384 meters) long, give the helicopter 5.1 inches (0.13 meters) of clearance above a level surface.

## Cameras



*Image credit: NASA/JPL-Caltech*

- One black-and-white 0.5 megapixel downward-facing navigation camera on the bottom of the fuselage.
- One color 13 megapixel horizon-facing terrain camera on one of the bottom edges of the fuselage.

## Flight Performance

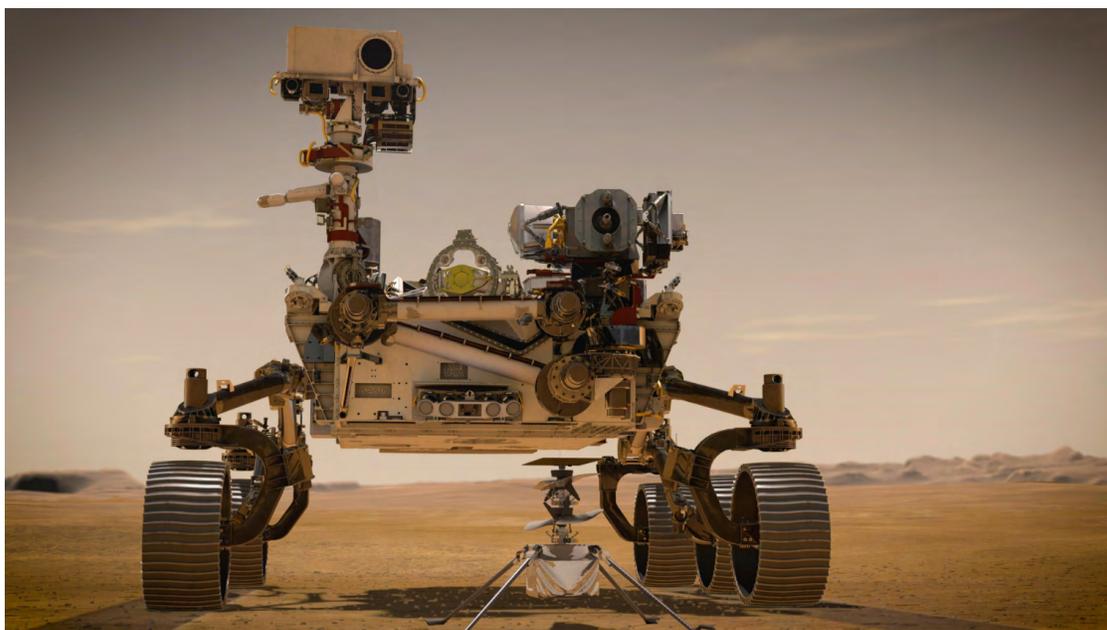
- Maximum anticipated altitude of Ingenuity during its flight tests is about 16 feet (5 meters).
- Maximum time aloft during any flight test is expected to be no more than 90 seconds.
- The helicopter's downward-facing black-and-white camera will take images which are used for navigation (determining position and attitude) in real time during the flight. The horizon-facing color camera is expected to acquire a few color images during flight.

## Supporting Hardware

To touch down in Jezero Crater and perform successful flight operations there, Ingenuity will rely on the Perseverance rover and other major Mars 2020 spacecraft components.

### Perseverance Rover

The size of a small SUV, Perseverance will explore Jezero Crater, collecting and caching the first samples from another planet for future return to Earth. Ingenuity will remain attached to Perseverance's belly, encapsulated in a protective debris shield, until it is deployed for flight tests. During interplanetary cruise, landing, and early surface operations, Ingenuity will rely on the rover for electrical power and communications. Once Ingenuity is deployed on the surface, the rover will act as a communications relay between the helicopter and Earth, and also will document the flight tests with its onboard cameras.



*Image credit: NASA/JPL-Caltech*

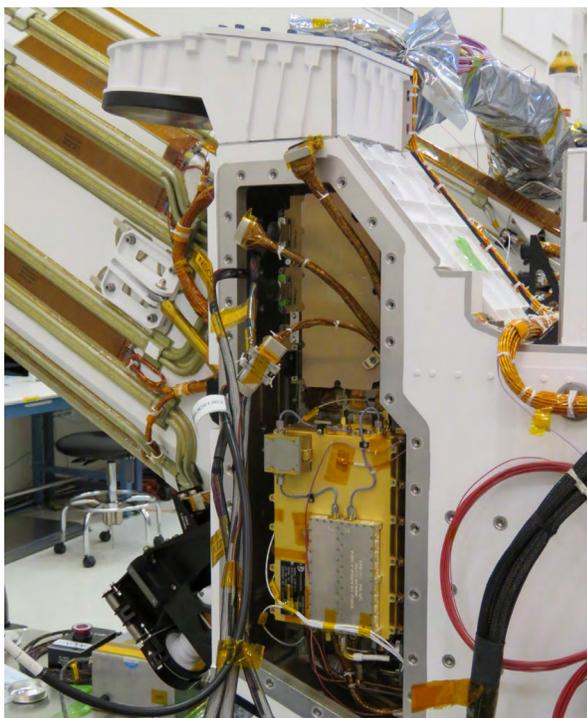
## Mars Helicopter Delivery System



*Image credit: NASA/JPL-Caltech*

Designed collaboratively by Lockheed Martin Space in Denver, and the Mars 2020 and Mars Helicopter teams at NASA's Jet Propulsion Laboratory, the Mars Helicopter Delivery System attaches Ingenuity to the belly of the rover during the journey to the Red Planet, landing, and early surface operation. A debris shield encapsulates and protects the helicopter and delivery system from rocks that could be kicked up during landing. The debris shield will remain in place until just days before Ingenuity is deployed to the surface. About 60 days after landing, the delivery system will deploy the helicopter, rotating and dropping it 5 inches (13 centimeters) or so (depending on surface variations) onto the Martian surface. After its job is complete (and Ingenuity is deployed), the delivery system will remain attached to the belly of Perseverance for the remainder of the rover's mission.

## Mars Helicopter Base Station



The Mars Helicopter Base Station, an electronics box installed in the Perseverance rover, carries the computers that monitor and regulate helicopter systems while it is attached to the rover and the communications gear that – after the helicopter's deployment to the surface – stores and routes communications between Ingenuity, Perseverance, and Earth.

*Image credit: NASA/JPL-Caltech*

## Mars 2020 Cruise Stage, Aeroshell, and Descent Stage



Image credit: NASA/JPL-Caltech/KSC

Both the Perseverance rover and the Mars Helicopter depend upon the mission's cruise stage, aeroshell, and descent stage to successfully navigate between Earth and Mars, and to safely land on the Red Planet.

## Power

Ingenuity is powered by a six lithium-ion battery system that is recharged daily by a solar array located atop its rotor system. Solar cells in the array are optimized for the solar spectrum encountered at Mars, and the stored energy is used to operate heaters for the cold Martian nights as well as power the helicopter during flight operations. Power expended by the helicopter during an up-to-90-second flight is about 350 watts.

## Telecommunications: How Ingenuity Talks to Earth

Communications between mission controllers back at JPL in Southern California and the Mars Helicopter are relayed by a string of assets. The antennas of NASA's Deep Space Network send commands and other data from Earth directly to the Perseverance rover or to [Mars orbiters](#) that then relay those transmissions to Perseverance. Perseverance's main computer relays the commands and data to the Helicopter Base Station on the rover, which then transmits them to the helicopter. Conversely, the base station collects transmissions from the helicopter, stores them, and routes the data through the rover's main computer on a similar path back to the orbiters or occasionally, straight back to Earth.

Ingenuity and the base station use a UHF telecom link (900 MHz) to communicate with each other. The system can relay data at up to 250 kilobytes per second over distances of up to 3,300 feet (1,000 meters). During flights, a one-way data stream will be sent in real time from the helicopter to the rover for storage and subsequent retransmission to Earth. After landing, the helicopter will re-transmit the inflight data stream and additional data from the flight.

For more information on how Perseverance communicates with Earth, read the [Telecommunications section](#) of the rover's press kit.

## Biological Cleanliness

The United States has obligations under the international [1967 Outer Space Treaty](#) to explore space in a manner that avoids the harmful contamination of celestial bodies and also any adverse effects to Earth's environment resulting from any return of extraterrestrial matter. To help meet these obligations, NASA's Planetary Protection Office draws up cleanliness standards known as planetary protection requirements. These requirements call for missions to take precautions to limit the amount of Earth-sourced biological material carried by NASA robotic spacecraft that travel to Mars. Flight hardware for the Mars 2020 Perseverance mission and the Ingenuity Mars Helicopter have been designed and built to meet NASA [planetary protection](#) requirements. NASA's primary strategy for limiting Earth-based contamination of Mars is to be sure that all hardware going to the planet is biologically clean.

To meet these cleanliness standards, engineers assembled the rover, the helicopter and other parts of the spacecraft in "clean rooms." This type of room has powerful air filters that limit dust particles, and its surfaces and floors are frequently treated with strong cleaning solutions to kill and remove living microbes. Mission hardware is cleaned using techniques that have proven effective on many previous missions and are designed not to damage the spacecraft.

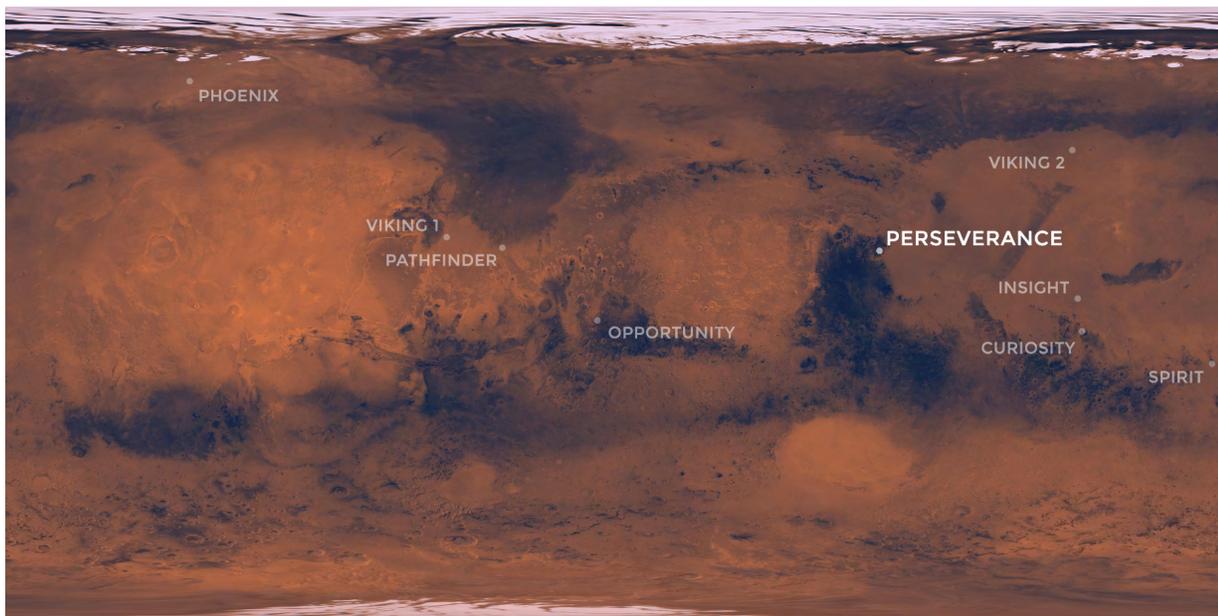
At launch, the entire payload going to Mars (the Perseverance rover, the Ingenuity Mars Helicopter, and the cruise stage, aeroshell, and descent stage) will carry fewer than 500,000 bacterial spores (dormant forms of bacteria). This is a tiny number as far as spores go and wouldn't even cover a typical smartphone camera lens. Of this number, the parts of the Mars 2020 spacecraft intended to land on Mars – including the rover, helicopter, the parachute, and the descent stage – were mandated to have no more than 300,000 spores in total. The helicopter was allotted 33,000 spores and ended up with a count of 21,900.

Find more information in the [Biological Cleanliness section](#) of the Perseverance rover press kit.



# Mission: Jezero Crater

## Jezero Crater



*Location where Perseverance will land, with the locations of other successful NASA Mars landings.*

*Image credit: NASA/JPL-Caltech*

Perseverance and Ingenuity, which is attached to the rover's belly, will land in Jezero Crater, located on the western edge of Isidis Planitia, a giant impact basin just north of the Martian equator at about 18 degrees latitude, 77 degrees longitude. Western Isidis presents some of the oldest and most scientifically interesting landscapes Mars has to offer. Scientists believe the 28-mile-wide (45-kilometer-wide) crater was home to a lake about 3.5 billion years ago – the word “Jezero” in several slavic languages means “lake” – as well as an ancient river delta. Together, they could have collected and [preserved ancient organic molecules](#) and other potential signs of microbial life from the water and sediments that flowed into the crater billions of years ago.

Find more on Jezero Crater in the Perseverance rover press kit's [Landing Site section](#).



# Management

## NASA Leadership

At NASA Headquarters in Washington, **Steve Jurczyk** is the agency's acting administrator. **Thomas Zurbuchen** is the associate administrator for the Science Mission Directorate. **Lori Glaze** is the director of the Planetary Science Division. **Eric Lanson** is the acting director of the Mars Exploration Program, and **Michael Meyer** is the chief Mars scientist at headquarters.

The Mars helicopter technology demonstration activity is supported by NASA's Science Mission Directorate, the NASA Aeronautics Research Mission Directorate, and the NASA Space Technology Mission Directorate.

## Ingenuity Mars Helicopter Technology Demonstration

At NASA Headquarters, **Dave Lavery** is the program executive for the Ingenuity Mars Helicopter. NASA's Jet Propulsion Laboratory, a division of Caltech in Pasadena, California, manages the helicopter technology demonstration for NASA. At JPL, **MiMi Aung** is the project manager and **J. (Bob) Balaram** is chief engineer.

# Gallery

## Images



### Ingenuity / NASA Images and Video Library

[go.nasa.gov/ingenuity-media-collection](https://www.nasa.gov/ingenuity-media-collection)



### Ingenuity / NASA Mars Website

[go.nasa.gov/mars-helicopter-images](https://www.nasa.gov/mars-helicopter-images)



### Ingenuity / Planetary Photojournal

[go.nasa.gov/ingenuity-photojournal](https://www.nasa.gov/ingenuity-photojournal)



### NASA HQ Photos / Flickr Gallery

<https://www.flickr.com/photos/nasahqphoto/>

## Web Videos



**Ingenuity Overview**  
<https://bit.ly/ingenuity-overview>



**Mars Helicopter UHD Trailer**  
<https://bit.ly/ingenuity-trailer>



**Mars Helicopter Deployment System**  
<http://bit.ly/helicopter-deployment-video>



**Naming Ingenuity**  
<http://bit.ly/naming-ingenuity-video>



**Ingenuity and Perseverance Video Collection**  
<https://vimeo.com/showcase/7377243>

## Animations and Raw Video



**Ingenuity Mars Helicopter B-Roll Media Reel**  
<https://go.nasa.gov/mars-helicopter-b-roll>



**Ingenuity Mars Helicopter Animations Media Reel**  
<https://go.nasa.gov/mars-helicopter-animations>



**Ingenuity Team Meetings Media Reel**  
<http://go.nasa.gov/ingenuity-team-meetings>