Case Study: Flying a Helicopter on Mars

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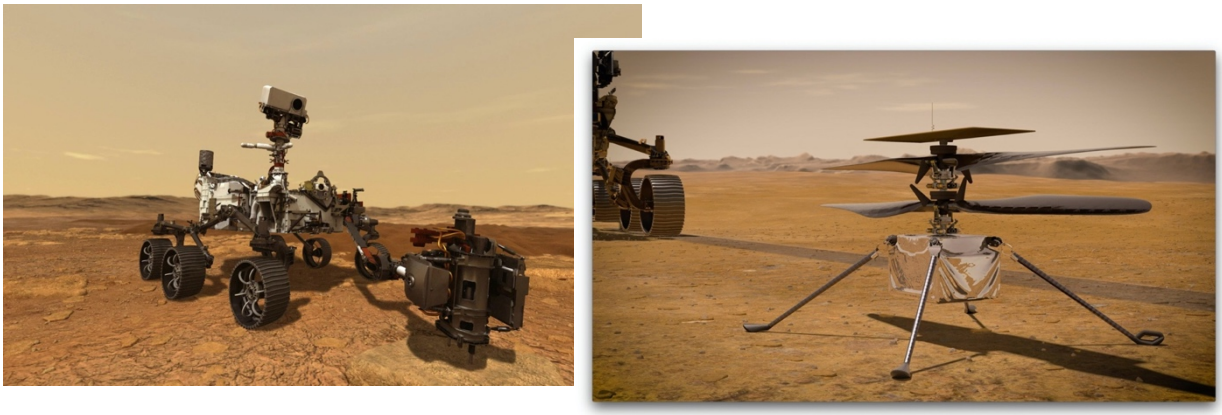
NASA's newest rover—*Perseverance*—is scheduled to land on Mars on Feb. 18, 2021. *Perseverance* will be looking for evidence of past microbial life, as well as studying Mars's geology. Onboard *Perseverance* is a helicopter—the Ingenuity Mars Helicopter will be the first powered aircraft on another planet!



Perseverance *is the fifth rover to land on Mars. The others are* Pathfinder, Spirit, Opportunity, *and* Curiosity. *Left: in this artist's illustration,* Perseverance *is collecting a core drill sample to be returned to Earth through a future mission. Credit: NASA/JPL-Caltech. Right: artist's illustration of the Ingenuity Mars Helicopter. Ingenuity is about 0.5 m high. Credit: NASA/JPL-Caltech*

The purpose of Ingenuity is to test the waters for future flight missions on Mars and other bodies in the solar system. Ingenuity doesn't have any science instruments, so it won't be doing any experiments. It does have two cameras, though: one black and white, and one colour.

Helicopters and other aircraft on Earth are designed, naturally, to work in Earth's gravity, atmosphere, and temperatures. None of these are similar to Mars's gravity, atmosphere, and temperatures.

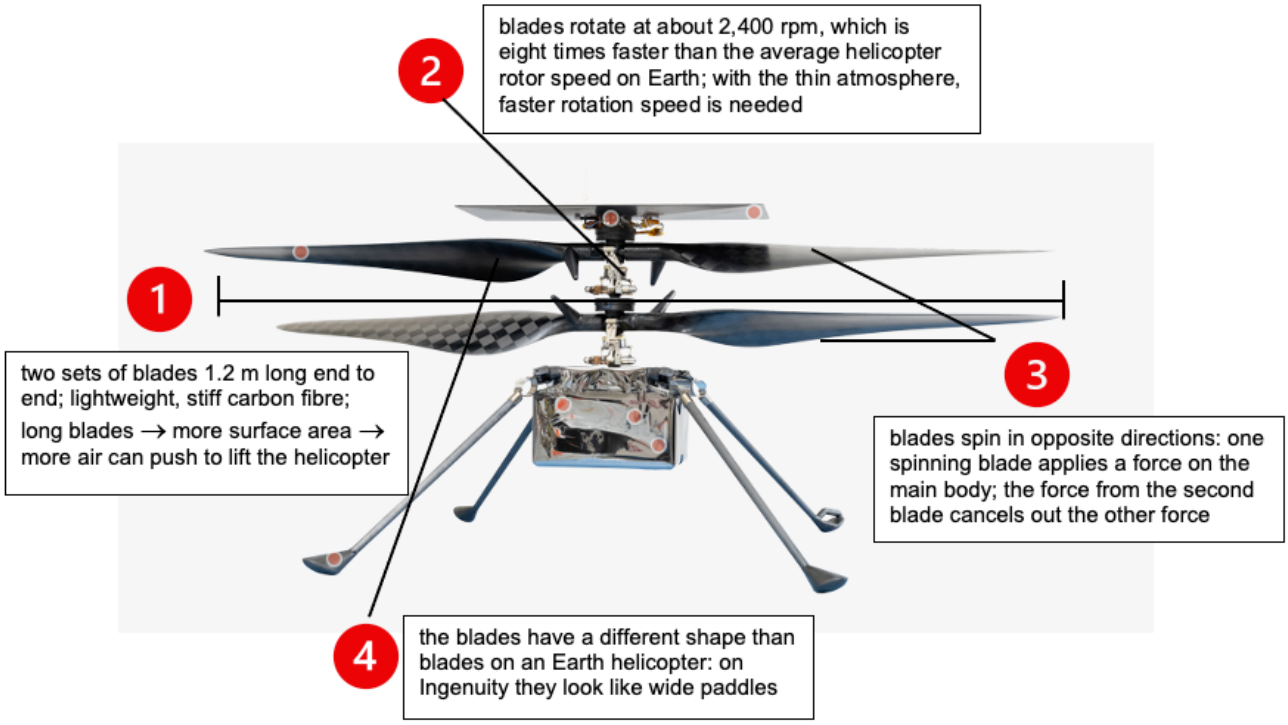
- The gravity on Mars is a little over one-third of Earth's gravity.
- Mars's atmosphere is about 1% the density of Earth's atmosphere (and with quite a different mixture of gases). Therefore, the atmospheric pressure on Mars is next to nothing.
- And it's cold on Mars. Much, much colder than on Earth. Nights can be as cold as –90° C at Jezero Crater, where *Perseverance* is to land. Fortunately, Ingenuity has a heater.

How Can a Helicopter Fly on Mars?

So how does an Earth-designed helicopter work in Mars conditions? For starters, Ingenuity has to operate on its own. It cannot be directly controlled from Earth like we control drones, for instance, because of the time it takes to get signals to and from Mars. Depending on where Mars and Earth are in their orbits, it takes between 3 minutes and 22 minutes for a one-way signal to reach Mars. Ingenuity will, however, get the initial command to start, and other commands, from Earth through *Perseverance*.

Rotor Blades

The design of Ingenuity's rotor blades is the key to flying on Mars, as shown in this graphic.



With such a thin atmosphere on Mars, the long, paddle-shaped blades and higher blade rotation speed are needed. Credit: image of Ingenuity: NASA/JPL-Caltech

Questions

1. Why does an aircraft need air to fly?

2. Why is designing a helicopter to fly on Mars different from designing a helicopter to fly on Earth?

3. (a) Why do you think Ingenuity's rotor blades are stiff?
   (b) Why do you think the engineers who designed Ingenuity's rotor blades made them paddle shaped? Keep in mind that Ingenuity is getting to Mars basically as *Perseverance*'s luggage.

4. What are two ways to modify a helicopter design so that it can fly on Mars? Explain.

5. (a) Which is denser, hot air or cold air?
   (b) Do you think the density of air affects lift? Explain.
   (c) How would the temperature of air on Mars affect flight?
   (d) Do you think the cold temperature on Mars can affect Ingenuity's electronics?

6. If Ingenuity is successful, what do you think that could mean for future exploration of Mars and other objects in the solar system?

Research

7. Research to learn how NASA engineers can test their helicopter design to see if it could fly on Mars. Give a brief description of your findings.

References

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Sample Answers

1. An aircraft needs air to fly because the air pushes up on the wings or blades to lift the aircraft.

2. Mars is different from Earth in many ways, but in terms of flight the main differences are in gravity and atmosphere. The gravity on Mars is quite a bit less than Earth's gravity, but this is good because it's easier to lift something in a lower gravity environment. The atmosphere on Mars is really thin, so that makes it difficult for an aircraft to get off the ground.

3. (a) If the blades were not stiff, they would not be able to stay rigid because the atmosphere pushing against them is so thin. If the blades are not rigid, the helicopter won't be able to fly.
   (b) The paddle shape of Ingenuity's rotor blades gives more surface area. More surface area allows more Martian air to push on the blades, to help Ingenuity fly. Room onboard *Perseverance* is limited, so instead of making the blades longer, the engineers made them wider to make sure Ingenuity fit in the storage space.

4. Two ways to modify the design of a helicopter to fly on Mars are to make the helicopter's blades longer and rotate them faster. These changes are necessary because of the super thin atmosphere on Mars. In thin air, the helicopter needs to go faster to be able to fly, so it needs the faster rotation speed.

5. (a) Cold air is denser than hot air.
   (b) If the air is denser, it is easier for an aircraft to get off the ground because there's more air per cubic volume. So, yes, air density affects lift.
   (c) Mars is super cold, so whatever air there is must be denser, which helps flight.
   (d) Super cold temperatures can affect the electronics of any device.

6. If flying on Mars, another planet, or other object in the solar system is doable, then that means we could learn even more about the planet or object than a rover could. For instance, a helicopter could fly to areas where rovers may not be able to get to, such as the poles and steep mountains.

7. The engineers have a lab where they can change the type of gases in the air, the amount of air, and the amount of air pressure to simulate Mars conditions. It's called the JPL Space Simulator. (JPL is the Jet Propulsion Laboratory, where Ingenuity was designed and built.) It's difficult to simulate Mars gravity, though. To do this, they use a "gravity offload" system. This is basically a motorized rope or tie attached to the top of Ingenuity—the motor steadily pulls on the rope to simulate the gravity on Mars.