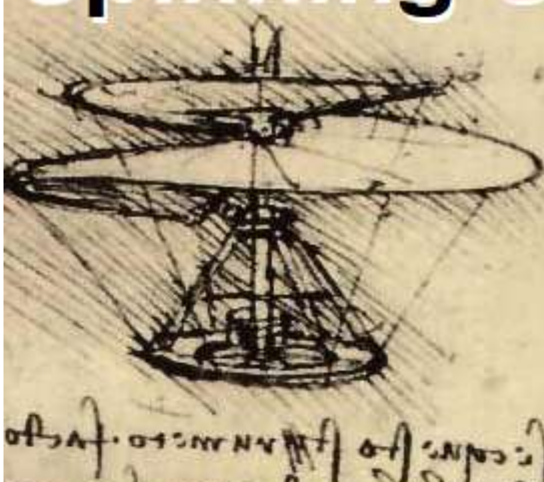
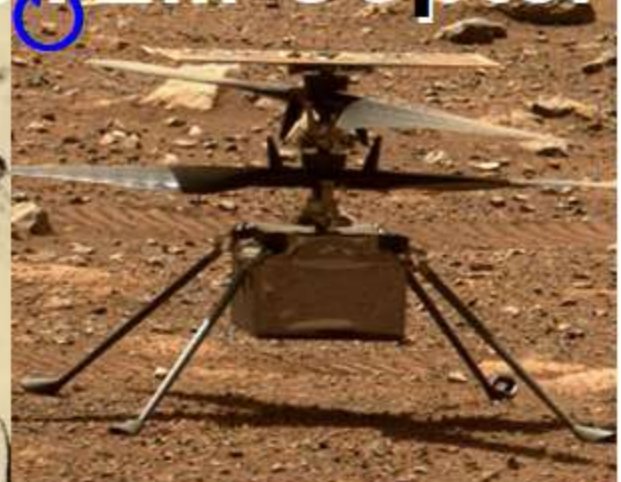
LBSTER

Let's Build Something Together Engineering Resources

Ingenuity!

Spinning STEM Copter



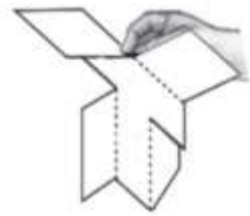


GIANT SCIENCE FROM THE SCIENCEGIANT

ScienceGiant Spinning S.T.E.M. Copters

S.T.E.M. connections

Science: Can you control variables of position, rate, and center of mass?
Technology: Can you find what works best for a helicopter, a glider, or a plane?
Engineering: Can you improve the Copter so that it twirls faster?
Math: Can you cut paper to create positive/negative faces with symmetry? Can you create a graph showing the calculated rate of descent?



Materials:

STEM Copter template, scissors, paper clips (1-3)

EXPLORE

1. To make Copters ready to fly, **cut** pattern along solid (|) lines of the template with scissors.
2. Once the lines are cut, **fold** the STEM flaps along dotted (⁝) lines in opposite directions. Fold flap A forward, flap B backward, flap C forward, and flap D backward. All four flaps should be at right angles. Just the ScienceGiant logo should be showing
3. Set stopwatch to zero. Note: Your partner will start the stopwatch when you let go of the Copter. Pinch the Copter from the top between its blades.
4. Working with your partner, hold the Copter 1.5 m (150 cm) from the floor and drop while your partner times its descent. *See diagram 1*. Stop the stopwatch when the Copter lands.
5. Record time in your science journals.
6. To determine the average rate of descent, repeat Steps 4-5 for two more trials and average your data.
7. Calculate the rate of descent by using the formula *R = d/t* (Rate = distance divided by time) and record in your science journal.

DIAGRAM 1

__________________ = __________________ ÷ ______________

average rate of decent　　　distance (150 cm) time　　　(# seconds)

8. On Trial # 2, change a variable by attaching a paper clip at the bottom of the Copter, beneath the ScienceGiant logo and between folds C and D, to weigh down the Copter so it stays upright. Repeat steps 3 – 7.

EVALUATE

1. Did all Copters drop the same? Why or why not? Calculate the average rate of descent for the Copters in a trial, and in all trials.
2. What were the variables that you changed in each experiment? Why is it important to keep all other variables constant during an experiment?

EXTENSION

1. Determine if the “blades” turn in a clockwise or counterclockwise direction. Does a Copter prefer to spin in one direction? Bend the “blades” in the opposite direction, so flap A is backward and flap B is forward. Now which way does it prefer to spin?
2. Change the variable of distance, EX: decrease the height from the floor to 1 m (100 cm) and repeat steps 3-7 for Copter Trials #1 and #2. (or increasing to 2 m if safe).
3. After the Copter is dropped, have you and your partner determine relationships between weights, heights, shapes, and length of the “blades” to time or to number of spins. For example, construct a bar graph to show how the Copter weight with and without clips changes time. If it is heavier, then does it fall faster OR does it become more aerodynamic and take longer to drop because it’s more stable?

Clips vs. Time

PREDICTION

4. Try attaching the paper clip in different places. Ask your partner to predict if and how flight would be different if instead of between flaps C and D, clips were next to the ScienceGiant logo, above flap C and D. Point out that it will be the **same** weight, but in a **different** place (different center of mass). Then test your partner’s prediction.
5. Compare the flight to that of leaves, animals or seeds in nature. For example, compare a Copter to maple seed.
   https://www.sciencedaily.com/releases/2009/06/090611142356.htm

EXPLAIN

Gravity causes a STEMCopter to descend. Air resistance on the blades pushes them upwards, producing lift. When blades are slanted up, some of the thrust becomes a sideway push (a horizontal force). The air resistance under the blades pushes one blade one way and the other blade the opposite way, causing the Copter to rotate as it descends. WATCH NASAJPL Edu “Learning Space: Make a Paper Mars Helicopter” https://youtu.be/HrKRWsrZuYc and learn about the first copter to fly on Mars as a part of the robot rover *Perseverance* mission.

Flap A

engineering

Flap B

technology

NAME: ______________ PERIOD: ________

Flap C

science

Flap D

math

Flap A

engineering

Flap B

technology

NAME: ______________ PERIOD: ________

Flap C

science

Flap D

math

ScienceGiant Spinning STEM Copter Level 1 and 2 investigating outcomes

Student	Stage	Key Learning Area	Date
		Science	

Task	Students investigate factors that affect a paper helicopters fall through air.

	Investigating unit outcomes	Beginning	Developing	Achieving
Level 1	Follow directions to conduct simple investigations involving floating, sinking and falling.	Students follow directions to make a simple paper helicopter.	Students follow directions to make a paper helicopter and use it to observe what factors affect its fall.	Students follow directions to make a simple paper helicopter and use it to observe and describe factors that affect its fall.
	Make and share observations.	Students can observe how a paper helicopter falls through the air.	Students can make and share observations about how a paper helicopter falls through the air.	Students can make and share observations about how the helicopter falls through the air, suggesting factors that affect its fall.

	Investigating unit outcomes	Beginning	Developing	Achieving
Level 2	Identify some variables to investigate.	Students can describe what a variable is.	Students can identify a variable in the investigation.	Students can identify a variable in the investigation and suggests how this variable might affect the outcome of the investigation.
	Make and record observations.	Students can make observations.	Students can make and share observations with others.	Students can make, share and record observations.

Evaluate students' work using the following rubric:

4	• Clear blade design and construction of the model copter • Conduct a "fair test" and collect and record data • Reach a conclusion based on the data • Revise hypothesis based on data and conclusion
3	• Some attempt at rotor blade design and construction of the model copter • Attempt to conduct a "fair test" and collect and record data • Attempt to reach a conclusion based on the data • Attempt to revise hypothesis based on data and conclusion
2	• Construction of the model without a design copter • Some attempt to conduct a "fair test" and collect and record data • Reach a conclusion based on some of the data • Attempt to revise hypothesis
1	• Little or no blade design and construction of the model copter • No "fair test" conducted • Conclusion not based on data • Limited revision of hypothesis

NGSS K-PS2-2.Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

NGSS 3-PS2-1.Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

NGSS MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

NGSS HS-PS2-3.Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Build Your Own Mars Helicopter

Suggested Grades: 3-8

Activity Overview

NASA is sending a helicopter to Mars! This helicopter is called Ingenuity and is designed to test whether or not flight is a good way to study distant bodies in space.

We have sent spacecraft to other planets, but this is the first aircraft that will fly on another world. In this activity, you will learn about this amazing feat of engineering as you build your own Mars helicopter model.

Time: 30 minutes

Materials

- 1 Large marshmallow
- 4 Small marshmallows
- 5 Toothpicks
- Cardstock (to print out the last page of this document)
- Scissors

Steps

1. The large marshmallow will represent Ingenuity's fuselage. Ingenuity is fairly small, about 19 inches tall and weighing about 4 pounds, and the fuselage is about the size of a softball. The fuselage contains batteries, sensors, and cameras to power and control Ingenuity's flight. It is insulated and has heaters to protect the equipment in the cold Martian environment where it can reach -130 $_{o}$C at night.

2. Insert the four toothpicks into the marshmallow so they come out at angles as shown in *Figure 1*. The toothpicks represent the four hollow carbon-fiber legs on Ingenuity.

   Ingenuity's legs are designed to be lightweight while still supporting the helicopter when it's on the Martian surface. To take up less space, Ingenuity's legs are folded while it's being carried to Mars.

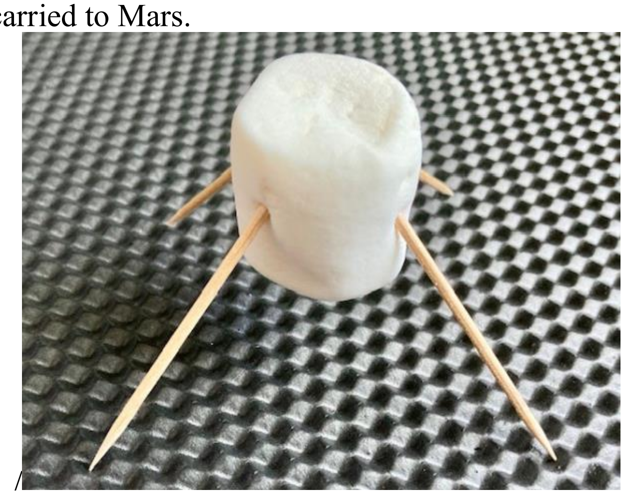


Figure 1. Insert the four toothpicks into the marshmallow to represent Ingenuity's legs.

3. Place a small marshmallow at the end of each of the four toothpicks as shown in *Figure 2*. These make the ends of the legs rounded, just like on Ingenuity.

   The rounded ends of the legs help the helicopter sit firmly, even on mildly uneven ground.

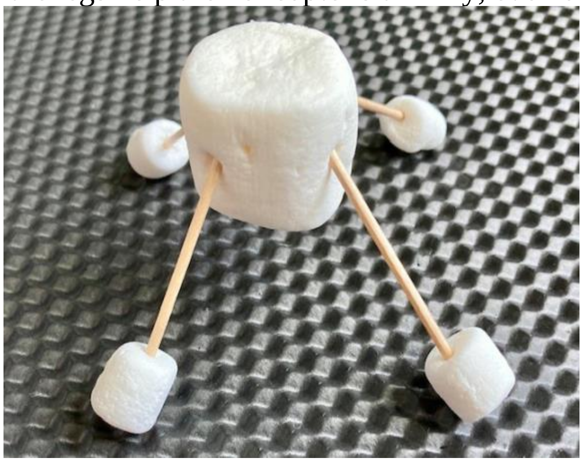


Figure 2. Small marshmallows are added on to the ends of the four toothpicks.

4. Print out the final page of this document on cardstock or other stiff paper. As shown in *Figure* 3, you will need to cut out one set of parts (a solar panel and two rotor blades) for each helicopter you are making. NOTE: The final page contains two sets in case you are making multiple models – you only need **one** set per model.

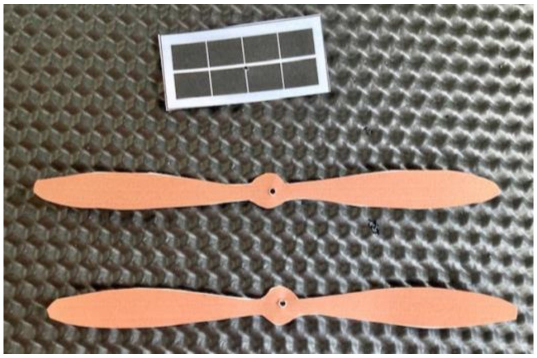


Figure 3. Cut out one set of parts for your helicopter.

5. Make a small hole (see *Figure* 4) in the middle of each of the parts you cut out in the previous step. This can be done using a pushpin or other sharp object. This is to allow the toothpick to be pushed through the paper. Be careful poking the hole – you may need the assistance of an adult.

Figure 4. Poke a small hole in the center of each of the parts you cut out in the previous step.

6. Push a toothpick through the hole in the center of one of the rotor blades. The rotor blade should be about 3/4 of an inch from the end of the toothpick as shown in *Figure 5*.

   On Ingenuity, each rotor blade is about 4 feet long and rotates very fast (about 2800 revolutions per minute). The rotor blades need to be this large and rotate so quickly in order to create enough lift, the upward force on the helicopter, in the extremely thin Martian air.

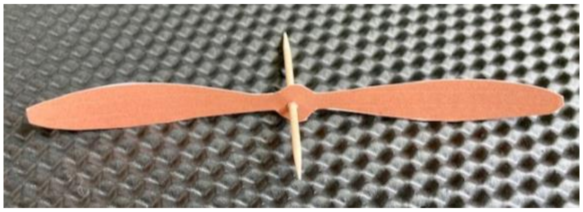


Figure 5. Push the toothpick through the hole in the center of one of the rotor blades.

7. Push the toothpick through the hole in the second rotor blade and adjust the blades so that they are aligned in different directions as shown in *Figure 6*. There should be a space of about 1/8 inch between the two rotors.

   Ingenuity has two rotor blades in order to create enough lift. Additionally, the two rotor blades rotate, or spin, in opposite directions. Normally when a rotor blade spins, it creates a force on the fuselage. By rotating in opposite directions, the forces created by the two rotor blades cancel each other out.

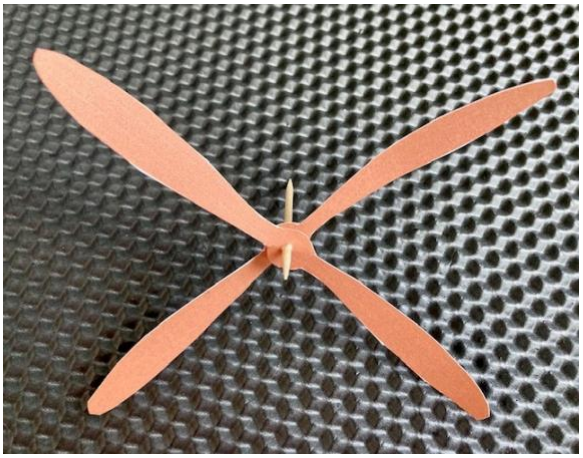


Figure 6. Push the toothpick through the second rotor blade and adjust the blades so they are aligned in opposite directions.

8. Push the end of the toothpick with the rotor blades on it through the hole in the center of the solar panel as shown in *Figure 7*. There should be about ¼ inch of the toothpick sticking out from the top of the solar panel. This piece of the toothpick represents the antenna located atop Ingenuity.

   On Ingenuity, the solar panel converts the Sun's energy into electricity to charge the batteries. The antenna allows Ingenuity to communicate with the Mars rover, Perseverance, which can then communicate with NASA personnel back on Earth.

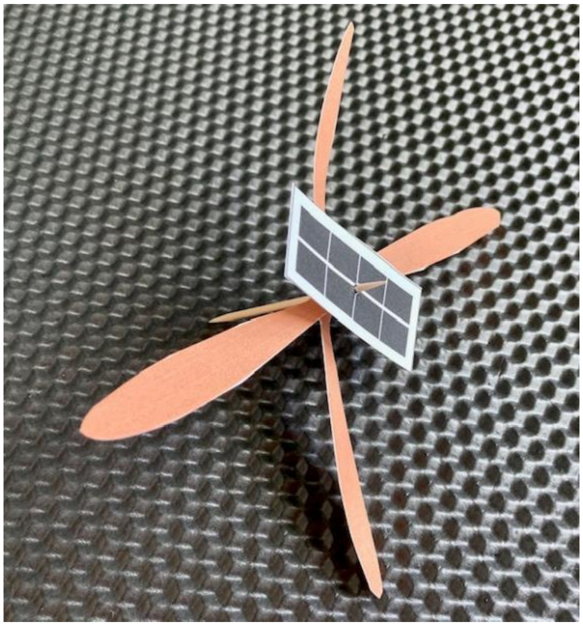


Figure 7. The toothpick is pushed through both rotor blades and the solar panel.

9. Push the end of the toothpick which is furthest from the solar panel down through the center of the top of the large marshmallow as shown in *Figure 8*.

Figure 8. The toothpick containing the rotor blades and the solar panel is pushed through the top of the large marshmallow.

Optional: Put your helicopter on Mars! NASA has sent several rovers to Mars and has made many images of the Martian surface available. You can find some of them at:

https://www.nasa.gov/mission_pages/mars/images/index.html

You can print out a picture of the Martian surface and display your completed model on that picture.

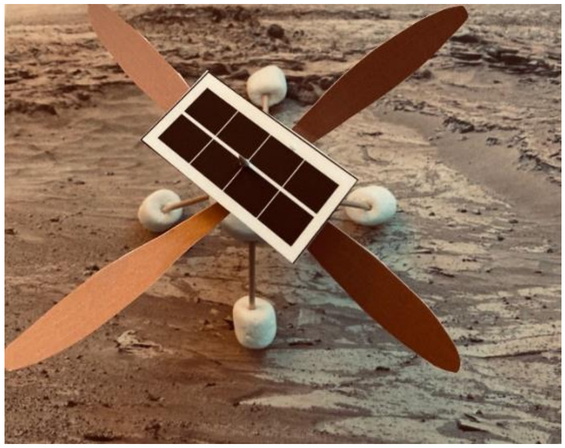


Figure 9. The completed model on the Martian surface

Further Information

The purpose of Ingenuity is to demonstrate that flight is possible on distant worlds such as Mars. It will be deployed from the Mars rover, Perseverance, before conducting a series of short flights above the Martian surface. Each flight will last only up to 90 seconds and reach a maximum altitude of about 15 feet.

Since there isn't a consistent magnetic field on Mars, compasses cannot be used for navigation. Ingenuity will determine its position by looking at the Sun and the Martian surface.

Hopefully, Ingenuity will pave the way for future missions involving flight. Flying rovers can study areas of the Martian surface that cannot be reached by ground based rovers.

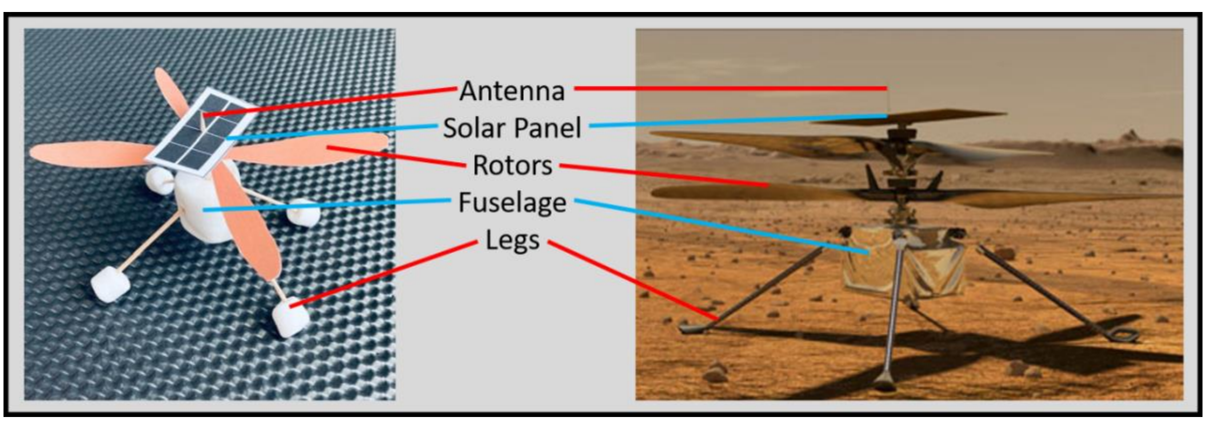
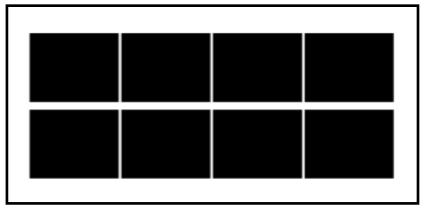


Figure 10. Comparison of your model to the actual Mars helicopter.

Mars Helicopter Parts

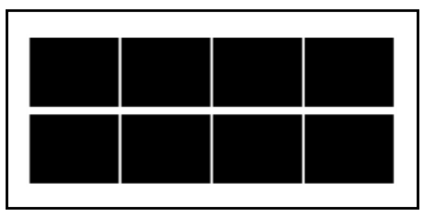
Print on cardstock or other stiff paper



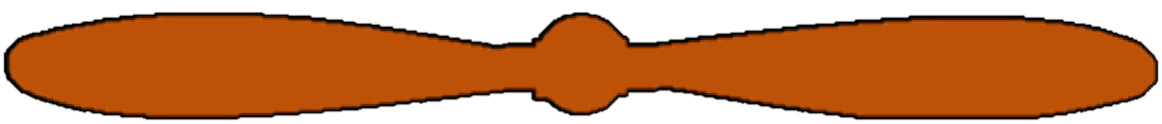
Solar Panel

Rotor Blade

Rotor Blade



Solar Panel



Rotor Blade

Rotor Blade

News

FIRST IN FLIGHT: The Mars helicopter Ingenuity underwent tests in March. Ingenuity could be the first powered aircraft to fly on another planet.

CORY HUSTON/NASA

A MARS HELICOPTER PREPS FOR LAUNCH

The first drone to fly on another planet will hitch a ride on NASA's Perseverance rover

If ever there was life on Mars, NASA's Perseverance rover should be able to find signs of it. The rover, scheduled to launch from Kennedy Space Center, in Florida, in late July or early August, is designed to drill through rocks in an ancient lake bed and examine them for biosignatures, extract oxygen from the atmosphere, and collect soil samples that might someday be returned to Earth.

But to succeed at a Mars mission you always need a little ingenuity, and that's literally what Perseverance is carrying. Bolted to the rover's undercarriage is a small autonomous helicopter called Ingenuity. If all goes as planned, it will become the first aircraft to make a powered flight on another planet.

Flying a drone on Mars sounds simple, but it has been remarkably difficult to design a workable machine. Ingenuity's worst enemy is the planet's atmosphere, which is less than 1 percent as dense as Earth's and can drop to -100 °C at night at the landing site.

"Imagine a breeze on Earth," says Theodore Tzanetos, flight test conductor for the project at NASA's Jet Propulsion Laboratory, in Pasadena, Calif. "Now imagine having 1 percent of that to bite into or grab onto for lift and control." No earthly helicopter has ever flown in air that thin.

Perseverance and Ingenuity are set to land in a crater called Jezero on 18 February 2021 and then head off to explore. About 60 Martian days later, the rover should lower the drone to the ground, move about 100 meters away, and watch it take off.

While the car-size Perseverance has a mass of 1,025 kilograms, the drone is just 1.8 kg with a fuselage the size of a box of tissues. Ingenuity's twin carbon-fiber rotors sit on top of one another and spin in opposite directions at about 2,400 rpm, five times as fast as most helicopter rotors on Earth. If they went any slower, the vehicle wouldn't be able to get off the ground. Much faster and the outer edges of the rotors would approach supersonic speed, possibly causing shock waves and turbulence that would make the drone all but impossible to stabilize.

Ingenuity is intended as a technology demonstration. Mission managers say they hope to make up to five flights over a 30-day period. No flight is planned to last more than 90 seconds, reach altitudes of more than 10 meters, or go more than 300 meters from takeoff to landing.

"It may be a bit less maneuverable than a drone on Earth," says Josh Ravich, the project's mechanical engineering lead at JPL, "but it has to survive the rocket launch from Earth, the flight from Earth to Mars, entry, descent, and landing on the Martian surface, and the cold nights there."

That's why engineers struggled through years of design work, trying to meet competing needs for power, durability, maneuverability, and weight. Most of the drone's power, supplied by a small solar panel above the rotors and stored in lithium-ion batteries, will be spent not on flying but on keeping the radio and guidance systems warm overnight. They considered insulating the electronics with aerogel, a super-lightweight foam, but decided even that would add too much weight. Modeling showed that the Martian atmosphere, which is mainly carbon dioxide, would supply some thermal buffering.

The team calculated that the best time of day for the first flight will be late in the Martian morning. By then, the light is strong enough to charge the batteries for brief hops. But if they wait longer, the sun's warmth would also cause air to rise, thinning it at the surface and making it even more difficult to generate lift.

To see if the drone would fly at all, they put a test model in a three-story chamber, filled with a simulated Martian atmosphere. A wire rig pulled up on it to simulate Mars's 0.38-*g* gravity. It flew, but, says Ravich, the real test will be on Mars.

If Ingenuity succeeds, future missions could use drones as scouts to help rovers—and perhaps astronauts—explore hard-to-reach cliff sides and volcanoes. "We've only seen Mars from the surface or from orbit," says Ravich. "In a 90-second flight, we can see hundreds of meters ahead." —NED POTTER

POST YOUR COMMENTS AT
spectrum.ieee.org/ingenuity-jul2020

U.S. CITIES PILOT CONNECTED-VEHICLE TECH

Enabling conventional vehicles to communicate could save lives right now

Drivers can use a number of signals to communicate with other drivers: taillights, high beams, the horn. But car manufacturers envision a future where cars themselves will exchange messages about where they're going and where they've been.

Connected vehicles—those fitted with technology that allows them to communicate with other drivers, pedestrians, and nearby infrastructure—are increasingly being tested around the world. In July, Columbus, Ohio, will be the latest city to launch a connected-vehicle pilot.

Connected vehicles have long been overshadowed by their more famous cousins—autonomous vehicles. Although all autonomous vehicles have aspects of connectivity, adding certain technologies to ordinary cars could prevent accidents and save lives in the near term.

The Connected Vehicle Environment project in Columbus will see up to 1,800 public and private vehicles fitted with special onboard units and dashboard-mounted head-up displays. Drivers will be able to receive messages from traffic lights at 113 intersections, including some of the city's most dangerous crossings. The aim is to study the impacts of connectivity on safety and traffic flow. Orga-