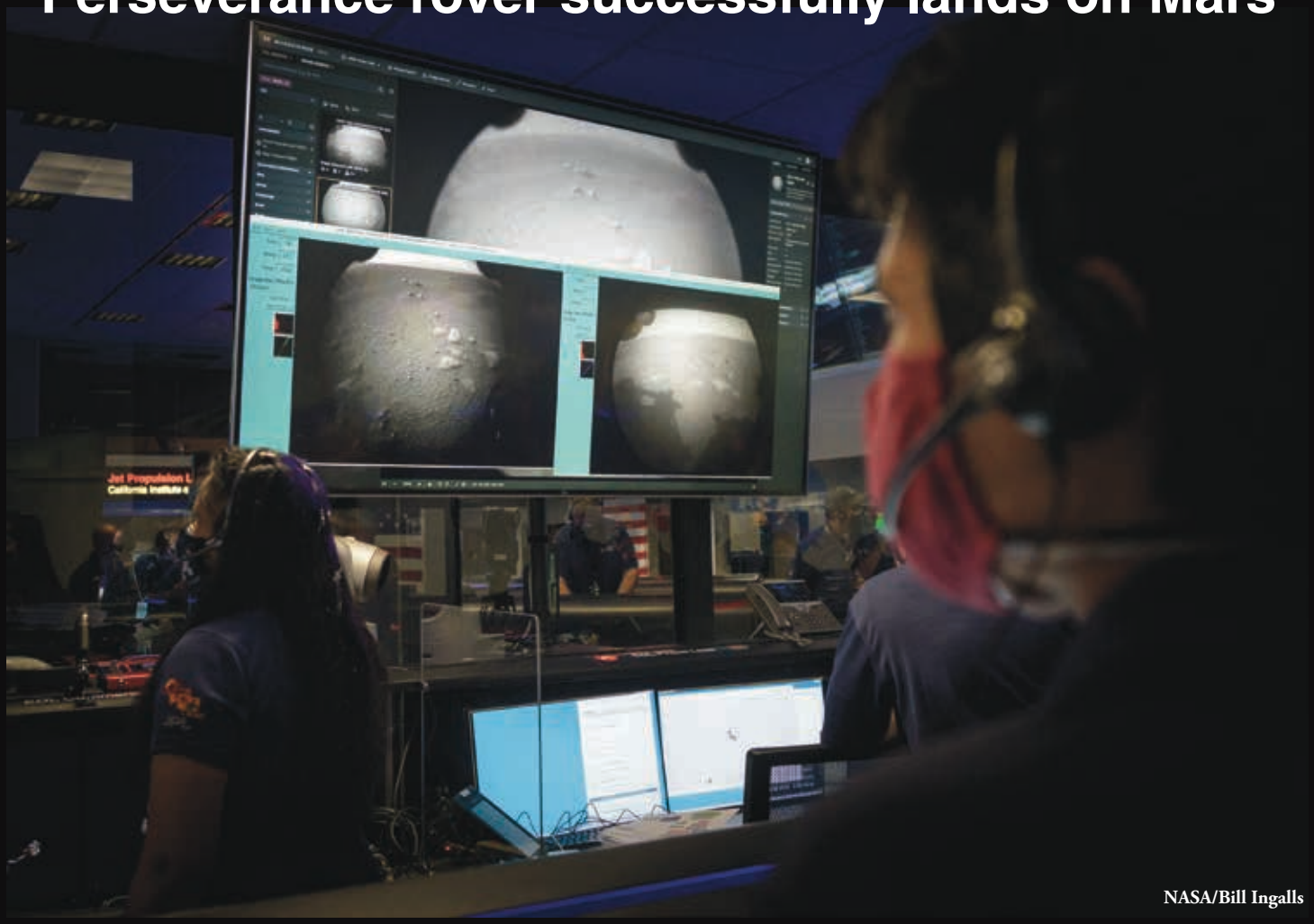
National Aeronautics and Space Administration

THE ARMSTRONG
X-PRESS

Volume 63 Number 3 March 2021

Touchdown!

Perseverance rover successfully lands on Mars



NASA/Bill Ingalls

Members of NASA's Perseverance Mars rover team watch in mission control at NASA's Jet Propulsion Laboratory as the first images arrive moments after the spacecraft successfully touched down on Mars Feb. 18. A key objective for Perseverance's mission on Mars is astrobiology, including the search for signs of ancient microbial life. The rover will characterize the planet's geology and past climate, pave the way for human exploration of the Red Planet, and be the first mission to collect and cache Martian rock and regolith. *See story, page 4-7.*

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A perfect landing

Armstrong-managed program helped mature technology

By Nicole Quennelle
NASA Flight Opportunities Program

After a nearly seven-month journey to Mars, NASA's Perseverance rover landed Feb. 18 at the Red Planet's Jezero Crater, a rugged expanse chosen for its scientific research and sample collection possibilities.

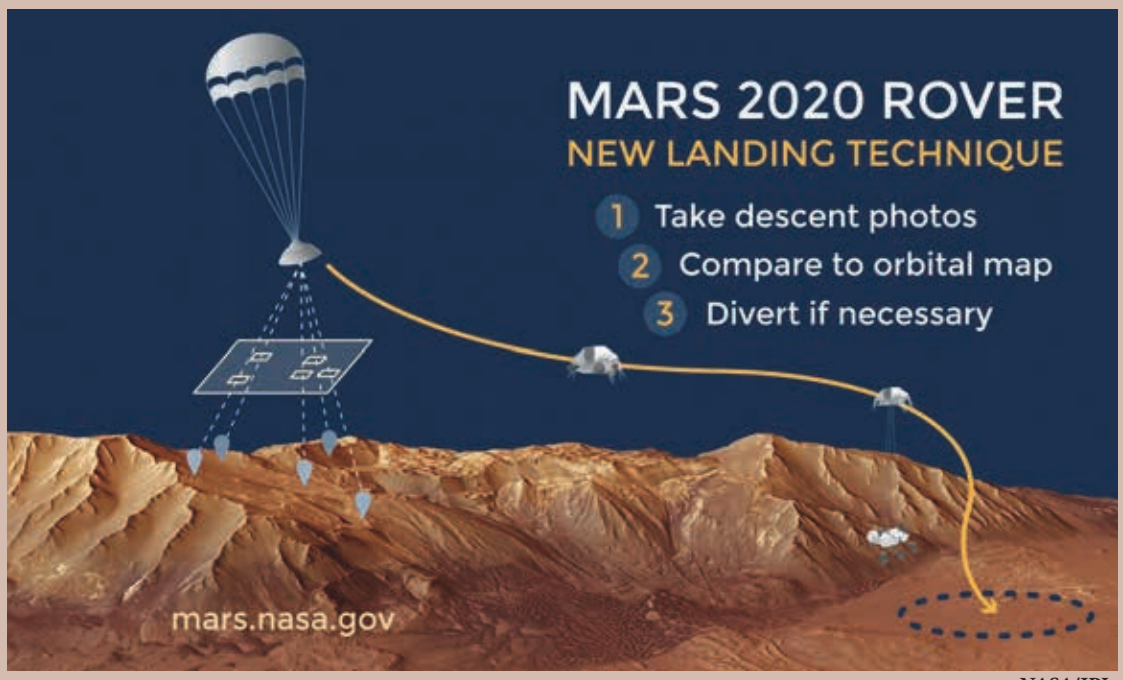
But the very features that make the site fascinating to scientists also made it a relatively dangerous place to land – a challenge that motivated rigorous testing on Earth for the lander vision system (LVS) the rover counted on to safely touch down.

"There were some large areas in the landing elipse that were fairly safe, but during the actual landing the spacecraft drifted away from those into terrain with numerous rocks and dunes," said Andrew Johnson, principal robotics systems engineer at NASA's Jet Propulsion Laboratory.

"If Perseverance had landed on one of those hazards, it could have been catastrophic to the mission," he added. "But the LVS estimated the rover's position correctly and the safe target selection feature picked a landing site that was surrounded by hazzards but very safe. The lander touched down around five meters from this targeted site."

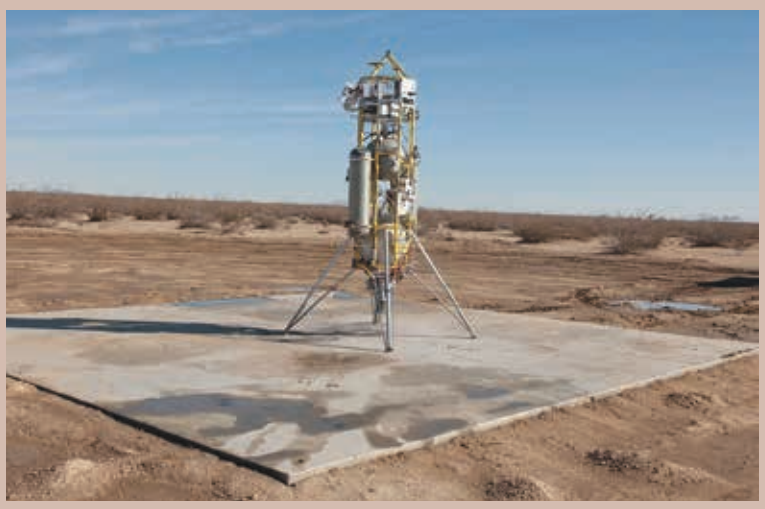
Terrain-Relative Navigation (TRN), a mission-critical technology at the heart of the LVS, captured photos of the Mars terrain in real time and compared them with onboard maps of the landing area, autonomously directing the rover to divert around known hazards and obstacles as needed.

"The LVS used the position information from the TRN to figure out where the rover was relative to safe spots between those hazards," explained Johnson.



NASA/JPL

The Mars 2020 Perseverance rover is equipped with a lander vision system based on terrain-relative navigation, an advanced method of autonomously comparing real-time images to preloaded maps that determine the rover's position relative to hazards in the landing area. Divert guidance algorithms and software can then direct the rover around those obstacles.



Masten Space Systems

Masten's Xombie VTVL system sits on a launchpad in Mojave, California in December 2014, prepared for a flight test that would help prove lander vision system capabilities for the Mars 2020 Perseverance rover mission.

Johnson was confident that LVS would work to land Perseverance safely because the system allows the rover to determine its position relative to the ground with an accuracy of about 200 feet or less. That low margin of error and high degree of assurance are by design, and the result of extensive testing in the lab and in the field.

"We have what we call the trifecta of testing," explained JPL's Swati Mohan, guidance, navigation, and control operations lead for Mars 2020.

Mohan said that the first two testing areas – hardware and simulation – were done in a lab.

"That's where we test every condition and variable we can. Vacuum, vibration, temperature, electrical compatibility – we put the

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AFRC2019-0277-176 NASA/Lauren Hughes

NASA's all-electric X-57 Maxwell prepares for ground vibration testing, or GVT, at NASA Armstrong. Accomplished in parallel with cruise motor controller testing, the GVT tested the vehicle at various vibration levels, helping engineers examine and validate the integrity of the vehicle for flight conditions. A goal of X-57 is to help the Federal Aviation Administration set certification standards for emerging electric aircraft markets.

X-57 progresses

High-voltage ground testing set to begin for all-electric experimental aircraft

By Matt Kamlet
NASA Armstrong Public Affairs

NASA is set to start high-voltage functional ground testing of the agency's first all-electric X-plane, the X-57 Maxwell, which will perform flights to help develop certification standards for emerging electric aircraft. NASA is also supporting these new electric aircraft by developing quiet, efficient, reliable technology these vehicles will need in routine use.

The testing will take place at NASA Armstrong, marking a pivotal milestone for the project as NASA proceeds from the component design and prototype phase to operation of the vehicle as an integrated aircraft, taking a critical step closer toward taxi tests and first flight.

The X-57, currently in its first configuration as an electric aircraft called Mod 2, will use a battery support system for this phase of testing. It will be drawing power from a large, high-voltage power supply as development on the X-plane's battery control system nears completion.

Testing is expected to start with low power, checking the startup and shutdown sequences and verifying the new motor control software boots up and controls the motors as expected. This software and other major components were recently redesigned based on lessons learned from previous testing by the project's prime contractor, Empirical Systems Aerospace, or ESAero, of San Luis Obispo, California.

These tests will include higher-power operation of the vehicle. The first pair of electric cruise motors to fly on the X-57, which were delivered by ESAero, will be powered up and activated, allowing engineers to ensure the vehicle's propellers spin as designed.

This will be followed by throttling up the motors to make

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News at NASA

First drive a success

NASA's Mars 2020 Perseverance rover performed its first drive on Mars March 4, covering 21.3 feet (6.5 meters) across the Martian landscape. The drive served as a mobility test that marks just one of many milestones as team members check out and calibrate every system, subsystem and instrument on Perseverance. Once the rover begins pursuing its science goals, regular commutes extending 656 feet (200 meters) or more are expected.

"When it comes to wheeled vehicles on other planets, there are few first-time events that measure up in significance to that of the first drive," said Anais Zarifian, Mars 2020 Perseverance rover mobility test bed engineer at NASA's Jet Propulsion Laboratory. "This was our first chance to 'kick the tires' and take Perseverance out for a spin. The rover's six-wheel drive responded superbly. We are now confident our drive system is good to go, capable of taking us wherever the science leads us over the next two years."

The drive, which lasted about 33 minutes, propelled the rover forward 13 feet (4 meters), where it then turned in place 150 degrees to the left and backed up 8 feet (2.5 meters) into its new temporary parking space. To help better understand the dynamics of a retrorocket landing on the Red Planet, engineers used Perseverance's Navigation and Hazard Avoidance Cameras to image the spot where Perseverance touched down, dispersing Martian dust with plumes from its engines.

NASA/JPL-Caltech

Members of NASA's Mars 2020 Perseverance rover mission were jubilant on Feb. 18 after the spacecraft successfully touched down on Mars. They are in Mission Control at the NASA Jet Propulsion Laboratory.

Success on Mars

By DC Agle
NASA Jet Propulsion Laboratory

The largest, most advanced rover NASA has sent to another world touched down on Mars Feb. 18, after a 203-day journey traversing 293 million miles (472 million kilometers). Confirmation of the successful touchdown was announced in mission control at NASA's Jet Propulsion Laboratory.

Packed with groundbreaking technology, the Mars 2020 mission launched July 30, 2020, from Cape Canaveral Space Force Station in Florida. The Perseverance rover mission marks an ambitious first step in the effort to collect Mars samples

NASA/JPL-Caltech

This high-resolution still image is part of a video taken by several cameras as NASA's Perseverance rover touched down on Mars on Feb. 18. A camera aboard the descent stage captured this shot.

NASA/JPL-Caltech

This is the first high-resolution, color image to be sent back by the hazard cameras (Hazcams) on the underside of NASA's Perseverance Mars rover after its landing on Feb. 18.

and return them to Earth.

"This landing is one of those pivotal moments for NASA, the United States, and space exploration globally – when we know we are on the cusp of discovery and sharpening our pencils, so to speak, to rewrite the textbooks," said acting NASA Administrator Steve Jurczyk. "The Mars 2020 Perseverance mission embodies our nation's spirit of persevering even in the most challenging of situations, inspiring, and advancing science and exploration. The mission itself personifies the human ideal of persevering toward the future and will help us prepare for human exploration of the Red Planet."

About the size of a car, the 2,263-pound (1,026-kilogram) robotic geologist and astrobiologist will undergo several weeks of testing before it begins its two-year science investigation of Mars' Jezero Crater. While the rover will investigate the rock and sediment of Jezero's ancient lakebed and river delta to characterize the region's geology and past climate, a fundamental part of its mission is astrobiology, including the search for signs of ancient microbial life. To that end the Mars Sample Return campaign, being planned by NASA and ESA (European Space Agency), will allow scientists on Earth to study samples collected by Perseverance to search for definitive signs of past life using instruments too large and complex to send to the Red Planet.

"The mission will enable the first pristine samples from carefully documented locations on another planet to take another step closer to being returned to Earth," said Thomas Zurbuchen, associate administrator for science at NASA. "Perseverance is the first step in bringing back rock and regolith from Mars. We don't know what these pristine samples from Mars will tell us. But what they could tell us is monumental – including that life might have once existed beyond Earth."

Some 28 miles (45 kilometers) wide, Jezero Crater sits on the western edge of Isidis Planitia, a giant impact basin just north of the Martian equator. Scientists have determined that 3.5 billion years ago the crater had its own river delta and was filled with water.

The power system that provides electricity and heat for Perseverance through its exploration of Jezero Crater is a Multi-Mission Radioisotope Thermoelectric Generator, or MMRTG. The U.S. Department of Energy (DOE) provided it to NASA through an ongoing partnership to develop power systems for civil space applications.

Equipped with seven primary science instruments, the most cameras ever sent to Mars, and its exquisitely complex sample

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caching system – the first of its kind sent into space – Perseverance will scour the Jezero region for fossilized remains of ancient microscopic Martian life, taking samples along the way.

"Perseverance is the most sophisticated robotic geologist ever made, but verifying that microscopic life once existed carries an enormous burden of proof," said Lori Glaze, director of NASA's Planetary Science Division. "While we'll learn a lot with the great instruments we have aboard the rover, it may very well require the far more capable laboratories and instruments back here on Earth to tell us whether our samples carry evidence that Mars once harbored life."

Paving the Way for Human Missions

"Landing on Mars is always an incredibly difficult task and we are proud to continue building on our past success," said JPL Director Michael Watkins. "But, while Perseverance advances that success, this rover is also blazing its own path and daring new challenges in the surface mission. We built the rover not just to land but to find and collect the best scientific samples for return to Earth, and its incredibly complex sampling system and autonomy not only enable that mission, they set the stage for future robotic and crewed missions."

The Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) sensor suite collected data about Mars' atmosphere during entry, and the Terrain-Relative Navigation system autonomously guided the spacecraft during final descent. The data from both are expected to help future human missions land on other worlds more safely and with larger payloads.

NASA/JPL-Caltech

In this illustration, NASA's Ingenuity Mars Helicopter stands on the Red Planet's surface as NASA's Perseverance rover (partially visible) rolls away.

On the surface of Mars, Perseverance's science instruments will have an opportunity to scientifically shine. Mastcam-Z is a pair of zoomable science cameras on Perseverance's remote sensing mast, or head, that creates high-resolution, color 3D panoramas of the Martian landscape. Also located on the mast, the SuperCam uses a pulsed laser to study the chemistry of rocks and sediment and has its own microphone to help scientists better understand the property of the rocks, including their hardness.

Located on a turret at the end of the rover's robotic arm, the Planetary Instrument for X-ray Lithochemistry (PIXL) and the Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) instruments will work together to collect data on Mars' geology close-up. PIXL will use an X-ray beam and suite of sensors to delve into a rock's elemental chemistry. SHERLOC's ultraviolet laser and spectrometer, along with its Wide Angle Topographic Sensor for Operations and eNgineering (WATSON) imager, will study rock surfaces, mapping out the presence of certain minerals and organic molecules, which are the carbon-based building blocks of life on Earth.

The rover chassis is home to three science instruments, as well. The Radar Imager for Mars' Subsurface Experiment (RIMFAX) is the first ground-penetrating radar on the surface of Mars and will be used to determine how different layers of the Martian surface formed over time. The data could help pave the way for future sensors that hunt for subsurface water ice deposits.

Also with an eye on future Red Planet explorations, the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) technology demonstration will attempt to manufacture oxygen out of thin air – the Red Planet's tenuous and mostly carbon dioxide atmosphere. The rover's Mars Environmental Dynamics Analyzer (MEDA) instrument, which has sensors on the mast and chassis, will provide key information about present-day Mars weather, climate, and dust.

Currently attached to the belly of Perseverance, the diminutive Ingenuity Mars Helicopter is a technology demonstration that will attempt the first powered, controlled flight on another planet.

Project engineers and scientists will now put Perseverance through its paces, testing every instrument, subsystem, and subroutine over the next month or two. Only then will they deploy the helicopter to the surface for the flight test phase. If successful, Ingenuity could add an aerial dimension to exploration of the Red Planet in which such helicopters serve as a scouts or make deliveries for future astronauts away from their base.

Once Ingenuity's test flights are complete, the rover's search for evidence of ancient microbial life will begin in earnest.

"Perseverance is more than a rover, and more than this amazing collection of men and women that built it and got us here," said John McNamee, project manager of the Mars 2020 Perseverance rover mission at JPL. "It is even more than the 10.9 million people who signed up to be part of our mission. This mission is about what humans can achieve when they persevere. We made it this far. Now, watch us go."

More About the Mission

A primary objective for Perseverance's mission on Mars is astrobiology research, including the search for signs of ancient microbial life. The rover will characterize the planet's geology and past climate and be the first mission to collect and cache Martian rock and regolith, paving the way for human exploration of the Red Planet.

Subsequent NASA missions, in cooperation with ESA, will send spacecraft to Mars to collect these cached samples from the surface and return them to Earth for in-depth analysis.

The Mars 2020 Perseverance mission is part of NASA's Moon to Mars exploration approach, which includes Artemis missions to the Moon that will help prepare for human exploration of the Red Planet.

JPL, a division of Caltech in Pasadena, manages the Mars 2020 Perseverance mission and the Ingenuity Mars Helicopter technology demonstration for NASA.

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hardware through its paces," said Mohan. "Then with simulation, we model various scenarios that the software algorithms may encounter on Mars – a too-sunny day, very dark day, windy day – and we make sure the system behaves as expected regardless of those conditions."

But the third piece of the trifecta – the field tests – require actual flights to put the lab results through further rigor and provide a high level of technical readiness for NASA missions. For LVS's early flight tests, Johnson and team mounted the LVS to a helicopter and used it to estimate the vehicle's position automatically as it was flying.

"That got us to a certain level of technical readiness because the system could monitor a wide range of terrain, but it didn't have the same kind of descent that Perseverance would have," said Johnson. "There was also a need to demonstrate LVS on a rocket."

That need was met by NASA's Flight Opportunities program, which facilitated two 2014 flights in the Mojave Desert on Masten Space Systems' Xombie – a vertical takeoff and vertical landing (VTVL) system that functions similarly to a lander. The flight tests demonstrated LVS's ability to direct Xombie to autonomously change course and avoid hazards on descent by adopting a newly calculated path to a safe landing site. Earlier flights on Masten's VTVL system also helped validate algorithms and software used to calculate fuel-optimal trajectories for planetary landings.

"Testing on the rocket laid pretty much all remaining doubts to rest and answered a critical question for the LVS operation affirmatively," said JPL's Nikolas Trawny, a payload and pointing control systems engineer who worked closely with Masten on the 2014 field tests. "It was then that we knew LVS would work during the high-speed vertical descent typical of Mars landings."

Johnson added that the suborbital testing in fact increased the technology readiness level to get the final green light of acceptance into the Mars 2020 mission.

"The testing that Flight Opportunities is set up to provide was really unprecedented within NASA at the time," said Johnson. "But it's proven so valuable that it's now becoming expected to do these types of flight tests. For LVS, those rocket flights were the capstone of our technology development effort."

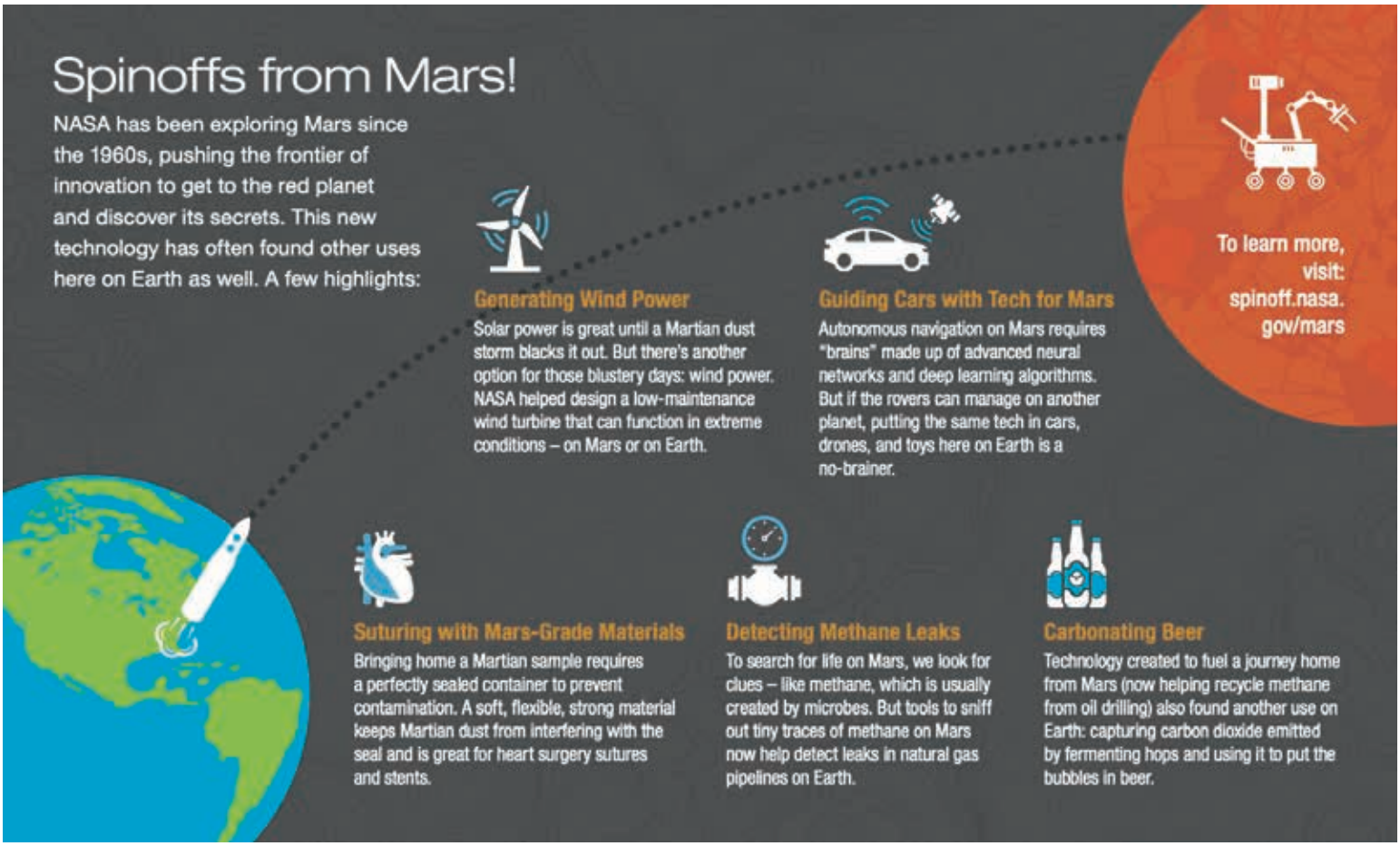
With the technology accepted for Mars 2020, the mission team began to build the final version of LVS that would fly on Perseverance. In 2019, a copy of that system flew on one more helicopter demonstration in Death Valley, California, facilitated by NASA's Technology Demonstration Missions program. The helicopter flight provided a final check on over six-years of multiple field tests.

But Mohan pointed out that even with these successful demonstrations, there was more work to do to ensure a safe landing. She was at Mission Control for the landing, monitoring the health of the system every step of the way.

"Real life can always throw you curve balls. So, we monitored everything during the cruise phase, checked power to the camera and made sure the data was flowing as expected," Mohan said. "And once we got the signal from the rover that said, 'I've landed and I'm on stable ground,' then we could celebrate."

About Flight Opportunities

The Flight Opportunities program is funded by NASA's Space Technology Mission Directorate and managed at NASA Armstrong. NASA Ames Research Center manages the solicitation and evaluation of technologies to be tested and demonstrated on commercial flight vehicles.



Here's a look at NASA's AAM helicopter

By Teresa Whiting
NASA Armstrong Public Affairs

NASA's Advanced Air Mobility (AAM) National Campaign, referred to as NC for short, is one step closer to its vision of a new type of air transportation system. NASA and the Federal Aviation Administration or FAA are working together to make this a reality.

The NC Integrated Dry Run tests, having completed their first phase Dec. 2-4, 2020, will continue with the next phase in March with a Bell OH-58C Kiowa helicopter, provided by Flight Research Inc. in Mojave, California, to act as a stand-in advanced air mobility vehicle.

The FAA and Flight Research Inc. test pilots are flying different types of maneuvers with the helicopter at NASA Armstrong to help assess procedures and infrastructure while also developing a data baseline for future industry partnership flight testing.

AFRC2020-0128-05 **NASA/Ken Ulbrich**

A Bell OH-58C Kiowa helicopter provided by Flight Research Inc. of Mojave, California, flies at NASA Armstrong the first week of December 2020. The Advanced Air Mobility National Campaign project used the helicopter as a stand-in advanced air mobility vehicle to develop a data baseline for future flight testing.

"These initial flights enabled feedback in two key areas of Urban Air Mobility operations: pilot feedback on UAM approach procedures and helipad markings that will support research flight tests," said Starr Ginn, AAM National Campaign lead.

The data collected during these flights will be used in developing lessons learned in operational procedures.

The final round of dry run testing will collect even more flight characteristics data and finalize the National Campaign flight test infrastructure development prior to deployment and flights with industry partners.

This will also prepare the National Campaign for the next step in the process – the developmental test with partner Joby Aviation planned for spring 2021.

Testing with Joby's AAM vehicle will include activities to prepare for NC-1 in 2022, such as designing flight scenarios for the NC-1 participants to fly, exercising range deployment, and data collection protocols across operational safety use cases.

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sure they provide all the power intended, validating the vehicle's instrumentation system and verifying whether all the sensors installed across the aircraft are functional.

This high-voltage testing will feed directly into final verification and validation testing, a critical final step before taxi tests begin.

"Many of the team members operating this test will be the same ones who will be sitting in the control room for flight, and that's why I'm excited," said Sean Clarke, NASA's X-57 principal investigator. "We've turned a corner from system design and lab tests, to turning it over to the NASA flight systems and operations engineers to actually operate the vehicle. What they're learning in this test they'll take with them into the control room for first flight."

The X-Press is published the first Friday of each month for civil servants, contractors and retirees of the NASA Armstrong Flight Research Center.

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