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GEORGE WASHINGTON'S CLOSE CALL

AS A YOUNG OFFICER, HE NEARLY LOST HIS LIFE SAVING OTHERS. NEW DISCOVERIES ABOUT A BATTLE THE FUTURE PRESIDENT NEVER FORGOT

photographs by
Brent Humphreys

Astronauts train for different flight scenarios in this simulator of the Orion spacecraft. Right, a mosaic created from some 1,300 images taken by the Lunar Reconnaissance Orbiter.

BRENT HUMPHREYS; MOON: NASA / GSFC / ARIZONA STATE UNIVERSITY by **Linda Shiner**

BACK TO THE FUTURE

NASA's **Artemis program** will soon return astronauts to the moon after more than half a century—with a new spacecraft and a **bold 21st-century vision** for what comes next

One morning this past June, INSIDE THE MISSION CONTROL BUILDING AT NASA'S JOHNSON SPACE CENTER IN HOUSTON, 20 OR SO FLIGHT CONTROLLERS WERE SEATED AT CONSOLES ARRANGED IN NEAT ROWS. THE ATMOSPHERE WAS INTENSE, AS IN A CLASSROOM WHEN A GROUP OF PEOPLE ARE TAKING A TEST, WHICH, IN A WAY, THESE PEOPLE WERE. WHEN I'D ENTERED AT THE BACK OF THE ROOM, NO ONE HAD GLANCED UP.

They were staring at their computer monitors and occasionally looking up at three screens, each 4 feet by 8 feet, mounted on the wall. The left screen was filled with numbers. On the middle screen, an image of Orion, NASA's new deep-space crew capsule, its solar panels deployed, appeared to float motionless in space. The right screen, which resembled an Excel spreadsheet, listed the "caution" and "warning" messages generated by a computer reporting all the real-time data that differed from what was expected—if the flight had been proceeding as planned. A quiet thrum of conversation—the ambient sound of groups of controllers conferring about their data—underlaid the frequent comments I heard through my headset as one controller after another reported system status updates to Brandon Lloyd, the flight director, known as "FLIGHT."

I had come to Houston to observe preparations for NASA's Artemis 2 mission, scheduled to launch as early as February 2026. The approximately ten-day mission's four crew members—Reid Wiseman, Victor Glover, Christina Koch and Jeremy Hansen—will be the first people to venture into space aboard Orion. They will also be the first people hurled off the planet by the Space Launch System (SLS), the most powerful rocket NASA has ever launched, generating about a million more pounds of thrust than the fabled Apollo-era Saturn V.

Artemis 2 is frequently compared to Apollo 8, the 1968 journey that carried the first humans into deep space, flying to within 70 miles of the moon. The general purpose of the two flights is the same—not to land on the moon but to fly around it, preparing the way for a future crew to land—but their mission profiles are different. Apollo 8 went into orbit around the moon; Artemis 2 will not. "It's just a lot riskier," said Na-

MOON: NASA / GSFC / ARIZONA STATE UNIVERSITY

The Artemis 2 crew: Reid Wiseman, Victor Glover, Christina Koch and Jeremy Hansen. During a September press conference at NASA's Johnson Space Center in Houston, the astronauts announced that they had named their Orion spacecraft "Integrity."

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tasha Peake, a flight dynamics engineer assigned to Artemis 1 and 2. "This is the first time we are flying humans on this vehicle. All of the life support systems and many of the other systems are brand new."

The flight plans of Apollo 8 and Artemis 2 differ in other ways. Apollo 8 blasted to Earth orbit and made two revolutions in about three hours. Near the end of the second orbit, the Saturn V third-stage engine fired, and Apollo 8 was out of there. Artemis 2 will also orbit Earth twice, but after the first orbit, the SLS upper stage will fire to push Orion into a gigantic ellipse, with its low point around 115 miles above Earth and its high point about 46,000 miles away. It will take approximately 23½ hours to travel all the way around. During that time, the crew will check the performance of their life support, communications and other critical systems. And they will test drive the spacecraft. "Manual navigation, manual burns, manual targeting, manual communication," Wiseman, the commander, told me. "And that is really going to be fun as an operator."

During that test drive, the spacecraft will separate from the SLS upper stage and perform an automated backflip, reorienting itself to face the upper stage, now a target for rendezvous. Then Wiseman and Glover, the pilot, will operate the spacecraft using hand controllers for a little more than an hour, approaching to within about 30 feet of the SLS upper stage and evaluating Orion's response as they fire a combination of its 24 thrusters to rotate the ship


Reid Wiseman

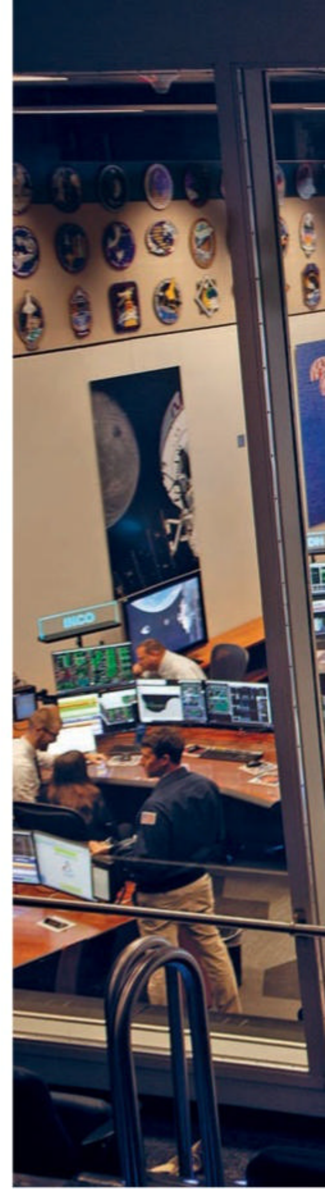
“BEING ON THE INTERNATIONAL SPACE STATION INITIALLY OPENED MY EYES [TO] HOW TO LIVE AND WORK IN SPACE—TO HOW DIFFICULT IT IS.” WISEMAN HAS SAID THAT HE WOULD LIKE TO RETURN TO THE STATION.

and to move it forward, backward and side to side. Orion is designed to be a self-driving spaceship, but the astronauts are developing a guide to manual backups in case one of the automatic systems fails. Once the maneuvers are completed, the spacecraft will resume automatic control and back up from the SLS upper stage, which will eventually re-enter the atmosphere over a remote location in the Pacific Ocean. Then, as long as mission control concludes that Orion has passed its tests, the spacecraft will be cleared to fire its powerful main engine to begin the approximately four-day trip to the moon. But back in Houston’s flight control room, we weren’t there yet.

The Orion spacecraft is made up of 355,056 parts, and to anticipate the ways that any one part, or a combination of them, can fail is impossible. To insure against potential failure, not only does NASA build redundancies into the hardware, but it also employs another strategy designed to give space missions their greatest chance of success—a monthslong training program that poses a single question again and again to the crew and the engineers in mission control: “What if?”

The “what if” training consists of hyper-realistic simulations that run on a very close approximation of the flight software that will drive the actual mission—with a few significant differences. A team of engineers introduces faults into the software that must be overcome for a flight to continue or that, in the judgment of simulation participants, can be safely ignored. Grace Lauderdale, a simulation manager at the Johnson Space Center, told me, “We are the mad scientists who come up with the things that could go wrong—in a fun way.”

The controllers in the simulation I observed did not appear to be having fun. They were working to solve a handful of potentially catastrophic problems as the mission was approaching a “go” or “no-go” decision point, when the flight director would determine whether to continue the mission or abort it. The go or no-go point that morning was the maneuver that would propel Orion to the moon, an engine burn known as translunar injection, or TLI. After the decision to launch, it is the mission’s most critical call because once that engine fires, the crew is committed to a nine-day journey around the moon. As the decision neared, Rick Henfling, another flight director, who was guiding me through the simulation, leaned toward me and whispered, “Nothing happens in the room without FLIGHT’s ‘Go.’”



THE ARTEMIS PROGRAM is named for the twin sister of Apollo, a reverent allusion to the historic lunar voyages of the 1960s and ’70s. The name also reflects one of the program’s original aims: to land the first woman on the moon. The program’s ultimate goal is the creation of a sustained, long-term lunar presence, a base where astronauts will develop the necessary technologies and operations for human exploration of Mars.

But the path has not always been smooth. Artemis 1, a 26-day test flight to show that Orion and the SLS were ready, flew at the end of 2022, six years after its originally planned launch date. “The system is performing exactly as we intended it to,” Mike Sarafin, NASA’s Artemis 1 mission manager, said afterward.

Still, even a perfect child misbehaves now and then. Artemis 1 handed its overseers several heart-stopping surprises. The first came after the SLS third stage fired its engine to send the spacecraft moonward. Two hours later, when the stage separated, the team received indications that Orion’s navigation systems had failed. “We were in an abort condition,” Peake, the flight dynamics engineer, recalled. “We were going to need to turn around and come home.” Her team conferred with Guidance, Navigation and Control (GNC) engineers and determined that “little bits of dust and [debris] from the separation were hanging around Orion,” confusing the capsule’s star trackers—extraordinarily sensitive cam-

“ARTEMIS 2 IS MORE THAN A MISSION TO THE MOON AND BACK....HUMAN SPACEFLIGHT IS LIKE A RELAY RACE.... WE UNDERSTAND OUR ROLE....WE’RE GOING TO DO OUR BEST TO RUN A GOOD RACE, TO MAKE YOU PROUD.”


Victor Glover

JOSH VALCARCEL / NASA (2)

Members of the Flight Operations Directorate in the Mission Control Center at NASA's Johnson Space Center, where they plan the mission and communicate in real time with astronauts on board.

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eras used to capture images of star fields. The navigation system compares the trackers' photographs with a catalog of stars in its database, and the comparison helps determine the spacecraft's position and orientation. The star trackers mistook the bits of dust for stars, which were, of course, not in the catalog, and the system became disoriented. The controllers literally waited for the dust to settle. "Then all was good, and we were able to continue," Peake said.

The other surprise occurred during re-entry. A principal goal of Artemis 1 had been to show that Orion's heat shield would protect the spacecraft during re-entry from lunar orbit, when it slams into Earth's atmosphere at 25,000 miles per hour, generating temperatures as high as 5,000 degrees Fahrenheit. Like a flat stone pitched to skip across a lake, Orion performed a planned "skip guidance entry," dipping in and out of the upper atmosphere to slow down before descending. After the mission, however, when engineers examined the recovered capsule, they found that blocks of the heat shield's Avcoat—the silica-and-epoxy material designed to partially burn off to dissipate extreme heat—had cracked, and that pieces had broken away. NASA had to postpone Artemis 2 until it figured out that the skip profile hadn't allowed temperatures to remain high enough to char the Avcoat evenly and make it uniformly permeable, which caused gases to build inside the heat shield and to crack the Avcoat.

Artemis 2, now programmed with a new re-entry approach, will add humans to the test. And if all goes to plan, Artemis 3 will land astronauts on the moon's unexplored south pole as soon as 2027.

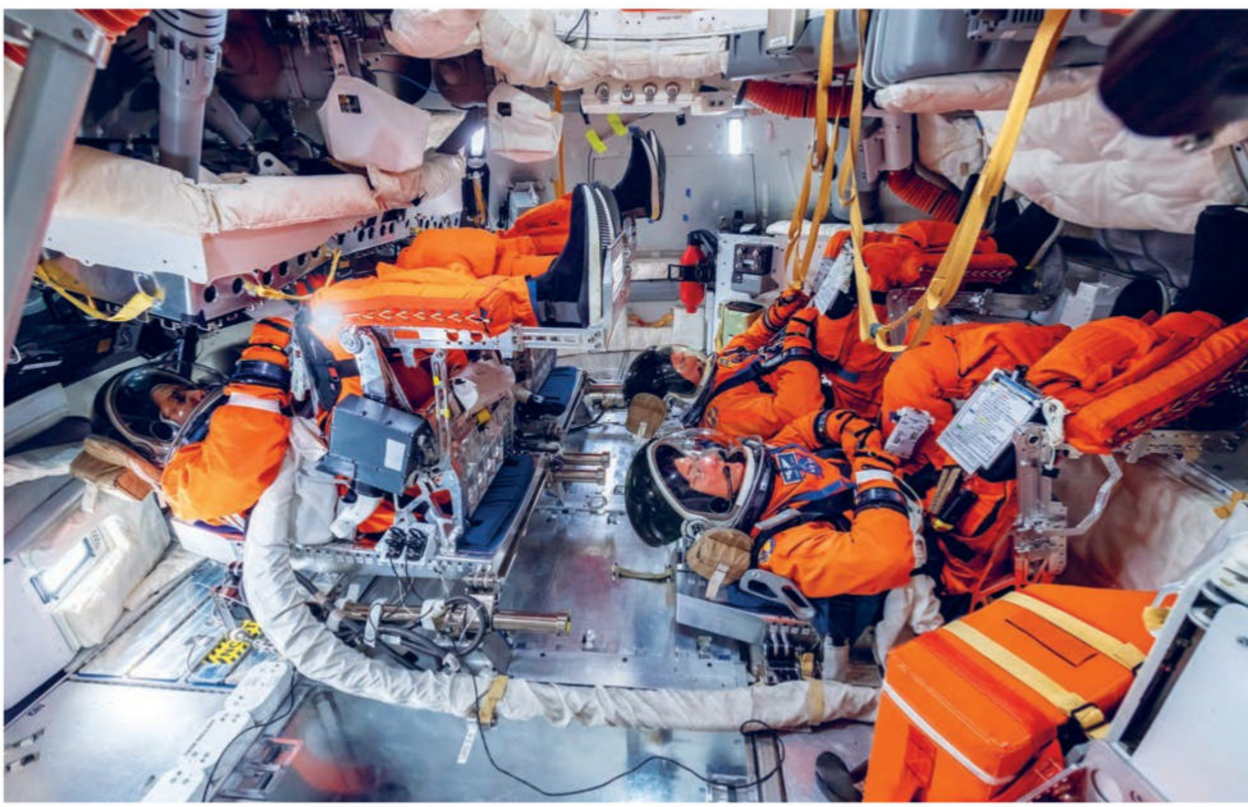
Then, the Artemis program slips into a fog of competing technical decisions and budgetary battles. Some hardware is being built for Artemis 4 and 5, but their launch vehicles and flight plans are in dispute. Until this year, those plans envisioned docking in lunar orbit at a new mini space station, known as the Lunar Gateway. NASA is also considering an alternative scheme for Artemis 4 and 5: a rendezvous in lunar orbit with a lander like the SpaceX Starship, which is already scheduled to transport Artemis 3 astronauts to the lunar surface.

Orion, which will carry the astronauts from Earth into space, remains essential to each mission. Apart from four nearly 23-foot-long solar panels that extend from the spacecraft's service module like tail feathers, Orion looks a lot like the crew module of the Apollo program, but the aluminum alloy used in Orion's pressure vessel is a lighter, more advanced material than was available in the 1960s. In addition, Orion wears a protective cover made of 1,300 heat-resistant tiles, a technology inherited from the space shuttle. At 330 cubic feet, slightly smaller than a Ford Transit van's cargo space, Orion is about 60 percent more spacious than the Apollo command module.

In terms of crew comfort, Orion's greatest advance is surely the Universal Waste Management System—its toilet. Apollo crews had to make do with condom-topped hoses for urination and plastic bags with an adhesive coating that could be attached to the skin, emphasis on the words "could be." (About 18 hours into the flight of Apollo 8, Commander Frank Borman suffered an attack of space sickness that the waste management devices couldn't manage, and his two crewmates had to help him capture tiny globs of vomit and feces with paper towels.) Orion's high-tech toilet is another legacy of the space shuttle, which was crewed by both men and women, but in Orion it is situated in a tighter space. "There won't be privacy," Koch, an electrical engineer and one of Artemis 2's two mission specialists, told me. "I'm not worried about that. We do have a closed-off area, which is actually more private than some of the capsules that go to and from the space station, where there's no curtain, no nothing. You just kind of look the other way."

Koch was an adventurer long before she joined the astronaut corps in 2013. She has been seeking remote places ever since fifth grade, when she cut out a map of Antarctica and put it up on her bedroom wall, committing to "getting there someway, somehow ever since then," she said. She got there in 2004, when, as a research associate in the United States Antarctic Program, she spent the first of two winters at the South Pole, an experience she says prepared her for the 328 days she spent on the International Space Station in 2019 and 2020, the longest single mission a woman has flown in space. "Sensory underload is the biggest thing we fight in long duration," she said. "Not seeing, hearing or smelling new things really, I think, changes how our brain works. But Artemis is a short mission. When I think about 328 days versus 10—it's going to be intense."

"I THINK WE CAN RULE OUT a power problem," MPO was saying over the loop. MPO, the mechanical and power officer, had reported a temperature spike in one of the four lithium ion batteries Orion uses to store power from its solar arrays. Even though Orion can function with only two of the four batteries in good working order, FLIGHT wanted more information and asked about the effect of a lost battery on propulsion. "Get back to you, FLIGHT," MPO replied.



MARK SOWA / NASA

Meanwhile, PROP, the propulsion officer, was monitoring a steady loss of pressure in the main engine's nitrogen tank, indicating a leak. The pressurized nitrogen gas is used to force propellants into Orion's engine for combustion. PROP, reasoning that because the engine needed to fire only once—for translunar injection, the move that would propel them to the moon—

Christina Koch

"SENSORY UNDERLOAD IS THE BIGGEST THING WE FIGHT IN LONG DURATION. NOT SEEING, HEARING OR SMELLING NEW THINGS REALLY, I THINK, CHANGES HOW OUR BRAIN WORKS. BUT ARTEMIS IS A SHORT MISSION."

the nitrogen in the accumulator was sufficient for that purpose. But FLIGHT wondered whether using up the nitrogen could affect abort scenarios downstream, should the crew need to suddenly find a way to propel the ship home.

Then MPO came back on the loop. "We can move the battery from 'degraded' to 'not degraded,'" she said. This apparent success came after the controllers masked the sensor and flipped a circuit breaker to see if the battery would recharge. It did, meaning the temperature reading was a false alarm. The battery fault was removed from the list of warnings. Three left.

Glover knows about false alarms. Five years ago, he was the pilot of another spacecraft, the SpaceX Crew Dragon, which provides taxi service to and from the International Space Station. On the Crew Dragon's second crewed flight, he and three other astronauts were headed to a six-month expedition. It was Glover's first spaceflight, and the engines had just cut off. The crew was still strapped in, but they knew they were weightless because their zero-gravity indicator—a plushy Baby Yoda doll—was floating around the cockpit. The spacecraft separated from the rocket upper stage, and *wham*! The alert lit up: a failure of the Thermal Control System. "And that failure had one procedure," Glover said. "Begin emergency de-orbit. There was no discussion. There was nothing to assess. It was, 'With this failure, you're going back to Earth.'

"I had to go through every corner of the emotional envelope," he recalled. "I was like, 'Whoa! What's this?' . . . Then, 'Oh, I'm the pilot. . . . I have to open a procedure. I have to be ready for emergency de-orbit.'" Glover pulled up the emergency de-orbit procedure on his touchscreen, but he noticed conflicting data: Numbers on his monitor indicated the cooling was OK. So his commander, Michael Hopkins, called the ground. While the crew waited for word from SpaceX mission control, Glover prepared himself for the verdict. "I remember thinking . . . OK, if we're going back to Earth, I am emotionally ready. I really wanted to go to the space station, but, all right, this is what has to happen. It was really interesting to actually feel that." It turned out that the alert was triggered by a transient reading. The mission proceeded, and Glover became the first Black person to live aboard the space station for an extended-stay expedition. Soon, he will become the first Black person to journey to the moon.

Glover has reflected on and wrestled with that distinction. "NASA sometimes wants me to be a Black astronaut or a military astronaut or a test-pilot astronaut," he told me. "I am an astronaut." At the ceremony announcing the Artemis 2 crew, in April 2023,

During a training exercise in Houston in January 2025, the Artemis 2 crew practiced configuring the Orion spacecraft for orbit and its return to Earth.

All of the controls on the Orion cockpit simulator, including its seven switch panels, are functional and connected to a replica of the spacecraft's display devices.

TOP: JOSH VALCARCEL / NASA; BOTTOM: BRENT HUMPHREYS

BYLINES

Linda Shiner, former editor of *Air & Space/Smithsonian*, writes about space science from her home in Maryland.

Brent Humphreys is a freelance editorial and commercial photographer based in Austin, Texas.

Glover delivered an emotional speech. "We need to celebrate this moment in human history, because Artemis 2 is more than a mission to the moon and back," he said. "Human spaceflight is like a relay race. And that baton has been passed generation to generation. . . . We understand our role. . . . We're going to do our best to run a good race, to make you proud. I pray that God will bless this mission, and I also pray that we can continue to serve as a source of inspiration for cooperation and peace, not just between nations but in our own nation."

IN MY HEADSET I HEARD, "Houston, Artemis 2." Then came the reply from the capsule communicator, or CAPCOM. "Go ahead, Artemis 2." The CAPCOM, almost always another astronaut, is the only flight controller who speaks directly with the crew. FLIGHT passes decisions and information to the CAPCOM to relay to the astronauts in space. By tradition and professional discipline more than by rule, the relay is crisp, concise and unemotional. During the simulation, I didn't quite catch the question that was coming in from the crew. What I did catch was that everyone else in the room fell silent. After the quick exchange, Henfling whispered, "Everyone stops talking when the crew is on the loop."


Jeremy Hansen

"COLLABORATION NEEDS TO BE THE GOAL IF EIGHT BILLION OF US ARE GOING TO HAVE A BRIGHT FUTURE ON THIS PLANET. HAVING HUMANITY STOP AND SAY, 'WOW, LOOK AT WHAT WE CAN DO WHEN WE WORK TOGETHER.'"

The Artemis 2 crew is more like the Apollo crews than they would appear at first sight: Three of the four crew members are former military pilots. Like the Apollo commanders, Wiseman has a military bearing and both spaceflight and leadership experience. He spent 165 days on the space station in 2014 and was NASA's chief of the astronaut office from 2020 through 2022. He told me, "Being on the International Space Station initially opened my eyes [to] how to live and work in space—to how difficult it is."

What the Artemis 2 crew has that the Apollo crews would never have had is a Canadian. Hansen's nationality shows that NASA and its political masters have traveled some distance philosophically from the Cold War rivalry of the Apollo era. The International Space Station, for one, has proved how useful global partnerships can be when fights over funding for expensive, long-term projects demand new allies.

Not that rivalries have disappeared altogether. NASA still finds itself in competition: this time, with China. For example, NASA is under pressure to meet its 2027 launch date for Artemis 3 after a Chinese announcement of a credible plan to land its own astronauts, called taikonauts, on the moon by 2030. That pressure is growing as questions loom about the readiness of the landing craft being developed by SpaceX. Still, while the old beat-the-Russians mentality has reappeared in a new space race with the Chinese, NASA clearly embraces other collaborations.

Hansen, who has flown intercept missions for the North American Aerospace Defense Command and holds a master's degree in physics, describes himself as a nerd, but Wiseman told me that he is "probably the funniest human being I've ever met in my life." He once joked on "The Late Show with Stephen Colbert" that he was chosen for Artemis 2 in case "something goes wrong on this mission, then NASA can blame Canada." In fact, he'll fly on Artemis 2 in part because Canada was the first country to accept NASA's invitation to join the Gateway project. If and when assembly in lunar orbit begins, the Canadian Space Agency will provide the station's external robotics. In return, Canada received two tickets to the moon. Hansen is punching one of them. Europe, Japan and the United Arab Emirates have also agreed to contribute various elements to the station—and Japan is building a pressurized lunar rover—all in exchange for transportation to the moon and back.

This is the Artemis generation: diverse, international and mostly seasoned by long-term space station experience. Their mission patch features the symbol AII, which, crew members point out, stands for Artemis 2 but also appears to read "All." "Collaboration needs to be the ultimate goal if eight billion of us are going to have a bright future on this planet," Hansen said at a September press conference. "As we come around the far side, just having humanity stop for a moment and say, 'Wow, look at what we can do when we work together,' let's just set goals to do a better job of that on this planet today."

IN THE FLIGHT CONTROL ROOM, the spreadsheet screen still listed several cautions, all invented by Lauderdale's "mad scientists," and each a potential no-go for the TLI burn. A valve in the Environmental Control and Life Support System was stuck, impeding the evaluation of carbon dioxide removal in the cabin; the nitrogen leak in the main engine's tank was still unresolved; and there was now an increased chance, if the burn were to be executed, of a collision between Orion and a small, unstable object, likely a piece of space junk, that had been reported by the trajectory operations and planning officer. If any one of these persisted, the crew would be forced to abort the mission and try to return home. "This seems bad," I whispered to Henfling. He replied, "The simulations are so intense that it's almost a relief when the actual mission flies."

Before Artemis 2 heads to the moon, the flight dynamics

NASA

This 196,000-gallon liquid oxygen tank, part of the system that will propel the Space Launch System rocket to lunar orbit, keeps the fluid at minus 297 degrees Fahrenheit.

JUDE GUIDARY / NASA

officers—they're called FIDOs—will compute a target line that the spacecraft must follow to re-enter Earth's atmosphere safely. TLI "puts us on what we call a free-return trajectory back to the Earth, which means there are no big burns in between to help adjust your trajectory," Peake explained. In other words, Orion can return to Earth without using fuel: After the moon's gravity accelerates the spacecraft during the flyby, Earth's gravity pulls it home. Because Orion must end up at a precise altitude, latitude and longitude to hit its final destination in the ocean off the coast of San Diego, the FIDOs, using a computer program, work backward. *Here is the spot we want to hit*, they instruct it; *now tell us the most efficient path to get there*. The variables in the equation include Orion's position at the time of the burn and the force gravity imparts as the spacecraft swings around the moon.

If something serious enough to abort the mission goes wrong after TLI, controllers have to decide almost immediately how to get the crew home, because by then the spacecraft is speeding away from Earth at 23,600 miles per hour. "We do have enough propellant loaded on the vehicle [for] what . . . we call a direct abort," Peake said. "Once we get far enough from the Earth, you kind of lose that option. . . . Instead, we have . . . flyby aborts, where we use the moon's gravity to help us get home faster." (Apollo 13 did just that.)

But those considerations are after TLI. First, the controllers had to come up with solutions to the three remaining problems listed on the spreadsheet. After calculating that the probability of a collision with the unknown object was between one in 10,000 and one in 100,000, FIDOs, referring to mission rules, gave FLIGHT a "go" for TLI. PROP recommended "go" too, believing that even if the main engine couldn't be fired again, abort scenarios could be safely executed. Power had also somehow started flowing to the life support system valve, and it had become unstuck (perhaps a touch of mercy from the mad scientists).

It was decision time. The room quieted, and the staccato question-and-answer poll began: "PROP," "go." "GNC," "go." "Control," "go, FLIGHT." "FIDO," "go."

I told myself that this was just a simulation, but listening to the familiar progression around the room, I got goosebumps. The poll complete, FLIGHT at last announced that Orion was "Go for TLI."

The CAPCOM passed along the message to the crew. On the middle screen at the front of the room, Orion's four solar arrays obediently, if slowly, hinged in toward the capsule to protect themselves from the powerful kick that was coming.

Apollo 11 astronaut Michael Collins once expressed some regret that as CAPCOM for Apollo 8, he did not convey to his colleagues the momentousness of that first translunar injection, acknowledging that they would be the first to leave the known world within low-Earth orbit for the unknown territory beyond. In his autobiography *Carrying the Fire*, Collins tried it this way: "After TLI there would be three men in the solar system who would have to be counted apart from all the other billions . . . leaving us stranded behind on this planet, awed by the fact that we humans had finally had an option to stay or to leave—and had chosen to leave."

When Artemis 2 flies, what will the CAPCOM say to Wiseman, Glover, Koch and Hansen in the moments before they begin the push away from Earth's hold on them? CAPCOM could say, "Artemis 2, you are go to wring out that spacecraft and increase the chances of a safe lunar landing for Artemis 3." Or, "Artemis 2, you are go to show the world what a 21st-century generation of explorers can achieve." Or, "Artemis 2, you are go to inspire cooperation and peace, not just between nations but in our own nation."

In all probability, though, CAPCOM, guided by tradition and professional discipline, will say simply, "Artemis 2, you are go for TLI," and the crew will respond, "Roger, Houston. Go for TLI." ◆