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Space Administration

KENNEDY SPACE CENTER'S

SPACEPORT magazine

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KENNEDY SPACE CENTER'S

SPACEPORT MAGAZINE

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An artist illustration of NASA's Kennedy Space Center in Florida, with the Vehicle Assembly Building and Launch Control Center in the foreground surrounded by a view of the Earth. Elements above representing future missions include the International Space Station, the Moon and Mars. Image credit: Amy Lombardo

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Kennedy Space Center has its own monthly podcast. Welcome to the "Rocket Ranch." Listen to **Episode 6: Starting Up the Space Station**. In this episode we sit down with the Space Shuttle commander who officially began construction of the ISS in space. Our own Center Director Bob Cabana recounts his experiences as the first American on station and turning on the lights. Read the full transcript and catch up on missed episodes at **https://www.nasa.gov/kennedy/rocketranch**.

THE SPACEPORT MAGAZINE TEAM

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I am KENNEDY

SPACE CENTER

LUIS BERRIOS

Working as a design specialist in the Communication and Public Engagement Directorate allows me to help inspire the next generation of explorers through experiential outreach at the Kennedy Space Center Visitor Complex.

I am part of a passionate creative team producing powerful, story-driven guest experiences that emotionally connect the excitement of humankind's greatest adventure, the daring exploration of space. I enjoy seeing ideas come to life from conceptual thumbnail sketches and creative treatments to exciting finished immersive productions.

My work helps to make NASA cool, relevant and accessible to everyone. It is very rewarding to see guests enjoying their time and joining the NASA family at least for that day.

I provide concept ideas, creative guidance and oversight by collaborating with my visitor complex team members on projects for exhibits, experiences, content and collections. Storytelling is the basis for successful experience design. My first project assignment when I joined NASA, was to work on the Shuttle Launch Experience in 2004. It was the first truly experiential and immersive simulation attraction for the visitor complex that allows everyone to feel the sights, sounds and sensations of launching onboard the powerful space shuttle.

I have always been amazed by NASA's innovative spirit and excited about what smart, courageous people can accomplish when they work together as a team.

Don't just communicate, fascinate: Use storytelling to humanize technology and evoke emotional connections about technical things. The NASA story is a "people" story. NASA has been launching our future for 60 years, and we are just scratching the surface of the possibilities out there.

COUNTDOWN *Rehearsal*

Kennedy launch team prepares for Exploration Mission-1

BY BOB GRANATH

A rehearsal can ensure everyone and everything is ready for a big performance. In the business of launching rockets, NASA and contractor engineers and managers at NASA's Kennedy Space Center in Florida recently performed the first terminal countdown demonstration for the inaugural flight of the agency's **Space Launch System** (SLS) rocket and **Orion** spacecraft.

When sending humans into space, "practice makes perfect" is taken literally by the Exploration Ground Systems (EGS) team.

As Launch Director, NASA's Charlie Blackwell-Thompson leads the EGS team of SLS and Orion experts performing the demonstration and she was eager to begin.

"I can't wait to see what today holds," she said addressing those in **Firing Room 1** of Kennedy's Launch Control Center (LCC). "I look forward to seeing what the simulation team has in store. With that, NTD (NASA Test Director), you've got a go to proceed."

Taking place on Dec. 14, the demonstration was intended to validate the launch team's capability to perform an EM-1 countdown and respond to problems put into the system for practice.

"This demonstration was designed to give the launch team an understanding of what to expect with a new vehicle," said Blackwell-Thompson. "This also will help us gauge where we are as a team in our preparations for future simulations and the upcoming EM-1 mission."

The first integrated test of the new vehicles will be EM-1 – **Exploration Mission 1**, a key step in NASA's deep space exploration program designed to send humans to distant destinations, such as the Moon and Mars.

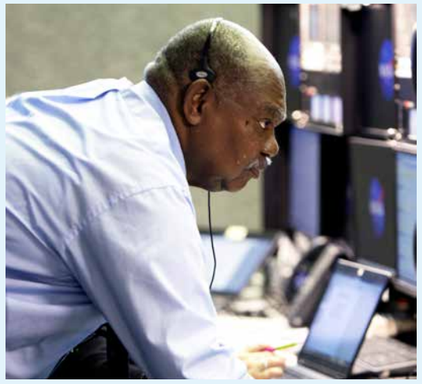
While there was no SLS at Kennedy's **Launch Complex 39B** for the recent demonstration, software called an "emulator" provided launch controllers with a virtual experience of what would be happening with the rocket. Video monitors depicted a realistic image of the SLS and Orion at Pad 39B.

"We had the full launch team of 91 experts, test conductors, engineers and managers, at their consoles in the Firing Room for the demonstration," Blackwell-Thompson said. "It's a smaller group than in the past, but we're striving for efficiency."

The size of the group in the LCC Firing Room has been significantly streamlined since the days of Apollo and the space shuttle. Over 450 were required to support Saturn V launches to the Moon. That was cut more than half to about 200 for shuttle.

"About two years ago we did a console positon assessment," Blackwell-Thompson said. "We studied workload, the number of commands sent by controllers and launch commit criteria. Tests like this will help us get to the ideal staffing before launch."

An overall view of Firing Room 1 at the Kennedy Space Center's Launch Control Center shows the launch team at work during a terminal countdown demonstration for Exploration Mission-1 (EM-1). Taking place on Dec. 14, 2018, the countdown demonstration was intended to validate the launch team's capability to perform an EM-1 countdown and respond to challenges put into the system for practice. Photo credit: NASA/Kim Shiflett



Arthur Howard, senior Safety console operator with Jacobs, NASA's Test and Operations Support Contractor, monitors operations during a terminal countdown demonstration for Exploration Mission-1. Photo credit: NASA/Frank Michaux

NASA Launch Director Charlie Blackwell-Thompson makes notes at her console in Firing Room 1 at the Kennedy Space Center's Launch Control Center during a terminal countdown demonstration for Exploration Mission-1. Photo credit: NASA/Kim Shiflett

The countdown the team worked is a carefully planned set of procedures leading up to ignition of a rocket's engine and liftoff. The "terminal count" is the crucial activities taking place at 1 hour, 20 minutes prior to liftoff. At that point, propellant loading to the SLS core stage and upper stage have been completed. The terminal countdown "demo" was designed to prepare for a full Terminal Countdown simulation training event, early next year. There are a series of these planned as the team readies for EM-1.

"This countdown demo also was intended to show the capabilities of our simulators and emulators to go through a launch countdown," Blackwell-Thompson said. "This is important because next year we get into our full training regime using these capabilities."

But it's not just about everything going as planned, the EGS launch team had to deal with simulated problems.

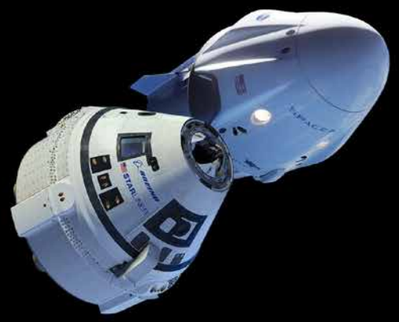
"Then we go through the countdown occasionally having to deal with simulated problems that will be put into the system," Blackwell-Thompson said. "The key is for those in the Firing Room to learn how to work individually and as teams to quickly develop solutions as problems arise."

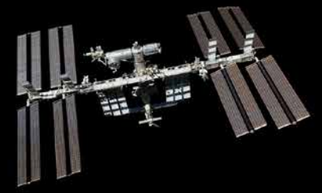
The final stages to the countdown included a built-in hold at the T-minus 10 minute mark and culminated in a simulated ignition of the SLS main engines and ended at T-Zero.

"The whole process took about three hours," Blackwell-Thompson said.

EM-1 will be an unpiloted flight test, the first in a series of increasingly complex missions, providing a foundation for human deep space exploration. During the first mission, Orion will travel 280,000 miles from Earth, thousands of miles beyond the Moon over the course of about a three-week flight. The second Orion flight, **Exploration Mission 2**, will include a crew testing the spacecraft's systems preparing for future trips to the Moon, and eventually to Mars.

Illustration of a Space Launch System liftoff. Image credit: NASA





NASA, partners update Commercial Crew launch dates

NASA and its Commercial Crew Program providers Boeing and SpaceX have agreed to move the target launch dates for the upcoming inaugural test flights of their next generation American spacecraft and rockets that will launch astronauts to the **International Space Station**.

The agency now is targeting March 2 for launch of SpaceX's Crew Dragon on its uncrewed Demo-1 test flight. Boeing's uncrewed Orbital Flight Test is targeted for launch no earlier than April.

These adjustments allow for completion of necessary hardware testing, data verification, remaining NASA and provider reviews, as well as training of flight controllers and mission managers.

The uncrewed test flights will be the first time commercially-built and operated American spacecraft designed for humans will dock to the space station. The first flights are dress rehearsals for missions with astronauts aboard the vehicles. Commercial crew has continued working toward these historic missions throughout the month of January.

"The uncrewed flight tests are a great dry run for not only our hardware, but for our team to get ready for our crewed flight tests," said Kathy Lueders, Commercial Crew Program manager. "NASA has been working together with SpaceX and Boeing to make sure we are ready to conduct these test flights and get ready to learn critical information that will further help us to fly our crews safely. We always learn from tests."

In January, SpaceX successfully completed a static fire test of its Falcon 9 with Crew Dragon atop the rocket at Kennedy Space Center's Launch Complex 39A in Florida, in preparation for Demo-1.

Boeing's CST-100 Starliner continues to undergo testing in preparation for its Orbital Flight Test, and United Launch Alliance is conducting final processing of the Atlas V rocket that will launch Starliner from Space Launch Complex 41 at Cape Canaveral Air Force Station in Florida.

"There still are many critical steps to complete before launch and while we eagerly are anticipating these launches, we will step through our test flight preparations and readiness reviews," said Lueders. "We are excited about seeing the hardware we have followed through development, integration, and ground testing move into flight."

NASA's Commercial Crew Program will return human spaceflight launches to U.S. soil, providing safe, reliable and cost-effective access to low-Earth orbit and the space station on systems that meet safety and performance requirements.

To meet NASA's requirements, the commercial providers must demonstrate their systems are ready to begin regular flights to the space station. After the uncrewed flight tests, Boeing and SpaceX will complete a flight test with crew prior to being certified by NASA for crew rotation missions. The following planning dates reflect inputs by the Commercial Crew Program and the two companies and are current as of Feb. 4, 2019.

TEST FLIGHT PLANNING DATES:

SpaceX Demo-1 (uncrewed): March 2, 2019
Boeing Orbital Flight Test (uncrewed): NET April 2019
Boeing Pad Abort Test: NET May 2019
SpaceX In-Flight Abort Test: June 2019
SpaceX Demo-2 (crewed): July 2019
Boeing Crew Flight Test (crewed): NET August 2019

SpaceX also completed a **pad abort test** in 2015. Following the test flights, NASA will review performance data and resolve any necessary issues to certify the systems for operational missions. Boeing, SpaceX and the Commercial Crew Program are actively working to be ready for the operational missions. As with all human spaceflight vehicle development, learning from each test and adjusting as necessary to reduce risk to the crew may override planning dates.

SPACEX DEMO-1 STATIC FIRE.

BOEING'S CST-100 STARLINER.

2018 THE YEAR IN REVIEW

JANUARY 2018

Underway Recovery Test 6

NASA's Exploration Ground Systems and the U.S. Navy conducted the weeklong Underway Recovery Test 6 in the Pacific Ocean, testing and improving their processes and ground support hardware to recover astronauts in the Orion capsule once they splash down in the Pacific Ocean. Aboard the USS Anchorage, the combined team rehearsed through a variety of sea conditions, time of day and equipment scenarios.

JANUARY 2018

NASA Initiates First Grow-out in APH on Station

The Advanced Plant Habitat, a fully automated plant growth facility aboard the International Space Station, initiated its first grow-out with the help of Expedition 54 astronaut Joe Acaba and researchers at Kennedy Space Center. Investigation data from the small crop of Arabidopsis and dwarf wheat seeds will help the agency prepare crews to grow their own food in space during deep space missions.

FEBRUARY 2018

Orion Crew Access Arm Installed on Mobile Launcher

NASA reached an important milestone on the path to Exploration Mission-1 with the installation of the crew access arm at about the 274-foot level on the 380-foot-tall mobile launcher tower. Astronauts will step across the crew access arm to board the Orion spacecraft when it is in place atop the Space Launch System (SLS) rocket.

MARCH 2018

GOES-S Launched Aboard Atlas V

NOAA's Geostationary Operational Environmental Satellite-S (GOES-S) lifted off aboard a United Launch Alliance Atlas V rocket from Cape Canaveral Air Force Station's Space Launch Complex 41. GOES-S was the second in a series of next-generation GOES weather satellites.

FEBRUARY 2018

Falcon Heavy Launch a Multi-User Spaceport Success Story

SpaceX launched a Falcon Heavy rocket on its demonstration flight from Kennedy's Launch Complex 39A. The successful liftoff of the new vehicle signaled that the center is continuing to grow as the nation's premier, multi-user spaceport. NASA has partnerships with more than 90 companies that enable commercial space manufacturing, processing and launch operations along Florida's Space Coast.

FEBRUARY 2018

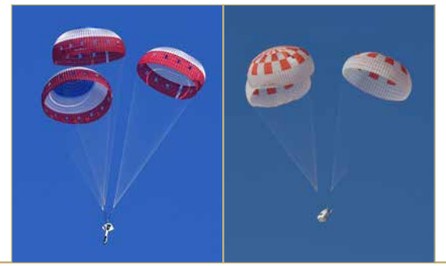
Vice President Pence Hosts National Space Council at Kennedy

Vice President Mike Pence returned to Kennedy to chair a meeting of the National Space Council. Pence also visited facilities at Kennedy and Cape Canaveral Air Force Station. Re-established in 2017 by President Donald Trump, the National Space Council's role is to advise the president on America's space policy and strategy, and review the nation's long-range goals for space activities.

MARCH 2018

Parachute Testing Lands Partners Closer to Crewed Flight Tests

Crew safety is paramount in the return of human spaceflight launches from Florida's Space Coast, and a round of parachute testing provided valuable data to help industry partners Boeing and SpaceX meet NASA's requirements for certification. Boeing conducted the first in a series of parachute reliability tests for its Starliner flight drogue and main parachute system in February 2018. SpaceX performed its 14th overall parachute test supporting Crew Dragon development in March 2018.



APRIL 2018

SpaceX Launched 14th Commercial Resupply Mission

SpaceX launched a Falcon 9 rocket and Dragon cargo spacecraft on the company's 14th commercial resupply services mission for NASA from Cape Canaveral Air Force Station's Space Launch Complex 40. The Dragon carried science, research, crew supplies and hardware to the International Space Station.

APRIL 2018

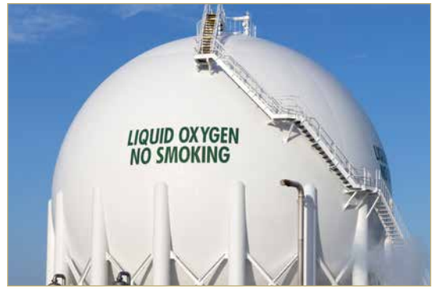
TESS Launched Aboard Falcon 9

NASA's Transiting Exoplanet Survey Satellite (TESS) spacecraft launched from Space Launch Complex 40 at Cape Canaveral Air Force Station aboard a SpaceX Falcon 9 rocket. TESS is the first space-based, all-sky surveyor to search for Earth-like planets that are outside our solar system but close enough for further study.

APRIL 2018

Launch Pad 39B LOX Tank Test

Exploration Ground Systems conducted a six-hour pressurization test of the liquid oxygen (LOX) tank at Launch Pad 39B, which has been upgraded for the agency's SLS rocket. The SLS will use both liquid oxygen and liquid hydrogen propellants. Results of the test confirmed that the tank was functioning as needed to achieve proper pressurization.



MAY 2018

InSight Launched Aboard Atlas V

NASA's Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) spacecraft launched from Space Launch Complex 3 at California's Vandenberg Air Force Base aboard a United Launch Alliance Atlas V rocket. InSight is the first interplanetary mission to launch from the West Coast and will be the first mission to look deep beneath the surface of Mars. It will measure the Red Planet's heat output and listen for marsquakes to develop a map of its deep interior.

JUNE 2018

SpaceX Launched 15th Commercial Resupply Mission

SpaceX launched a Falcon 9 rocket and Dragon cargo spacecraft on the company's 15th commercial resupply services mission for NASA from Cape Canaveral Air Force Station's Space Launch Complex 40. The Dragon carried science, research, crew supplies and hardware to the International Space Station.

JULY 2018

Tail Service Mast Umbilicals Installed on Mobile Launcher

Two 35-foot-tall tail service mast umbilicals were installed on the zero-level deck of the mobile launcher. When the Space Launch System rocket stands atop the mobile launcher, these umbilicals will connect to the aft section of the vehicle's core stage, providing liquid hydrogen fuel as well as electricity prior to launch.

AUGUST 2018

Parker Solar Probe Launched Aboard Delta IV Heavy

NASA's Parker Solar Probe launched from Space Launch Complex 37 on Cape Canaveral Air Force Station aboard a United Launch Alliance Delta IV Heavy rocket. During its mission to "touch" the Sun, Parker Solar Probe will use gravity assists from Venus seven times over nearly seven years to gradually bring its orbit closer to the Sun. It will fly directly through the Sun's atmosphere, as close as 3.8 million miles from the star's surface.

AUGUST 2018

Crews Assigned to First Flights on Commercial Spacecraft

NASA announced the first U.S. astronauts who will fly on American-made, commercial spacecraft to and from the International Space Station – an endeavor that will return astronaut launches to U.S. soil. The agency assigned astronauts to crew the first test flight and mission of both Boeing's CST-100 Starliner and SpaceX's Crew Dragon. In January 2019, astronaut Michael Fincke replaced Eric Boe for Boeing's Crew Flight Test 2.

AUGUST 2018

Ascent Abort-2 Data Recorders Drop Test

NASA successfully tested the approach to collect and retrieve valuable data in support of an upcoming test of the abort system for the agency's Orion spacecraft. Ejectable data recorders were released from a helicopter 5,000 feet in the air and splashed into the Atlantic Ocean off the spaceport's coast. The floating devices were then located through beacons transmitting GPS coordinates and scooped up with fishing nets by NASA personnel operating boats.

AUGUST 2018

Mobile Launcher Moves to Launch Complex 39B, VAB

The mobile launcher to be used in support of the Space Launch System rocket and Orion spacecraft made milestone moves during 2018. Carried atop the crawler-transporter, the mobile launcher moved from its construction site near the Vehicle Assembly Building (VAB) out to Launch Pad 39B, where it remained for several days of testing. Next, it traveled into the VAB to continue preparations for Exploration Mission-1.

SEPTEMBER 2018

ICESat-2 Launched Aboard Delta II

NASA's Ice, Cloud and land Elevation Satellite-2 (ICESat-2) spacecraft launched from Space Launch Complex-2 at California's Vandenberg Air Force Base aboard a United Launch Alliance Delta II rocket. It was the final flight of the Delta II after 29 years in service. ICESat-2 will make high-resolution data measurements documenting changes in the Earth's polar ice caps and improving forecasts of sea level rise bolstered by ice sheet melt in Greenland and Antarctica.

NOVEMBER 2018

Boeing CST-100 Starliner Arrives

The spacecraft destined to fly astronauts to the International Space Station on Boeing's Crew Flight Test was inspected following removal from its shipping container inside the company's testing facilities in El Segundo, California. The company's CST-100 Starliner will undergo a series of environmental tests designed to simulate what it will experience during different stages of flight as part of NASA's Commercial Crew Program.

NOVEMBER 2018

European Service Module Arrives for Orion EM-1

The European Service Module (ESM) was unpacked after it arrived inside Kennedy's Neil Armstrong Operations and Checkout Building high bay. The ESM will supply the main propulsion system and power to the uncrewed Orion spacecraft for Exploration Mission-1 (EM-1), a mission around the Moon. The ESM also will house air and water for astronauts on future missions.

OCTOBER 2018

EGS Conducts Water Deluge Test at Launch Pad 39B

A flow test of the Ignition Overpressure Protection and Sound Suppression water deluge system was completed at Launch Pad 39B. At peak flow, the water reached about 100 feet in the air above the pad surface. It flowed at high speed from a holding tank through new and modified piping and valves, the flame trench, flame deflector nozzles and mobile launcher interface risers. The test is part of Exploration Ground System's preparation for the new Space Launch System rocket.

OCTOBER 2018

SpaceX Conducts Emergency Egress Training

Teams from NASA, the Department of Defense Human Space Flight Support and SpaceX conducted a joint medical triage and medical evacuation (medevac) training exercise at Kennedy Space Center. It was the second of two emergency medical services simulations performed before commercial crew flight tests.

NOVEMBER 2018

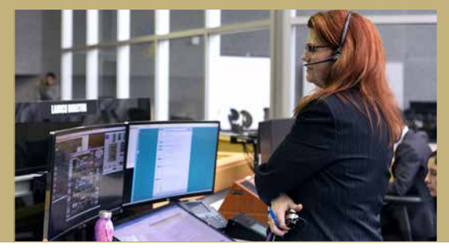
EGS Conducts Orion Underway Recovery Test-7

At night, a test version of the Orion capsule is pulled into the well deck of the USS John P. Murtha during Underway Recovery Test-7 (URT-7) in the Pacific Ocean. URT-7 was one in a series of tests conducted by the Exploration Ground Systems Recovery Team to verify and validate procedures and hardware that will be used to recover the Orion spacecraft after it splashes down in the Pacific Ocean following deep space exploration missions.

DECEMBER 2018

EGS Completes Countdown Demonstration in Firing Room 1

During a terminal countdown demonstration for EM-1, NASA Launch Director Charlie Blackwell-Thompson stands next to her console in Firing Room 1. The launch will be the first integrated test of the Space Launch System rocket and Orion spacecraft that will eventually take astronauts beyond low-Earth orbit to destinations such as the Moon and Mars. The countdown demonstration was intended to validate the launch team's capability to perform an EM-1 countdown and respond to challenges put into the system for practice.



DECEMBER 2018

Orion Test Module Prepared for Launch Abort System Test

Workers removed cover plates from a mock Orion crew module inside Kennedy's Multi-Payload Processing Facility. The crew module will be used during a full stress test of the Launch Abort System, called Ascent Abort-2, scheduled for 2019.

DECEMBER 2018

Rocket Lab Electron Rocket Launches ELaNa 19 Payload

A Rocket Lab Electron rocket lifted off from Launch Complex-1 at Māhia Peninsula in New Zealand carrying NASA's Educational Launch of Nanosatellites-19 (ELaNa-19) payload. The liftoff marked the first flight of a payload under NASA's Venture Class Launch Services (VCLS). Managed by NASA's Launch Services Program at Kennedy Space Center in Florida, VCLS was developed to provide increased access to space specifically for these small spacecraft, called CubeSats.

DECEMBER 2018

SpaceX CRS-16 Launches to International Space Station

The two-stage Falcon 9 launch vehicle lifted off from Space Launch Complex 40 at Cape Canaveral Air Force Station, carrying SpaceX's Dragon resupply spacecraft to the International Space Station on the company's 16th commercial resupply services mission.

DECEMBER 2018

ULA First Stage Arrives for Boeing's CST-100 Starliner Orbital Flight Test

The first stage of the rocket that will launch Boeing's CST-100 Starliner spacecraft to the International Space Station on the company's uncrewed Orbital Flight Test arrived at Cape Canaveral Air Force Station in Florida. It is the final piece of hardware that United Launch Alliance needs to launch the first Boeing Starliner. The ULA two-engine Centaur upper stage arrived at the Atlas Spaceflight Operations Center for preliminary checkouts in October.

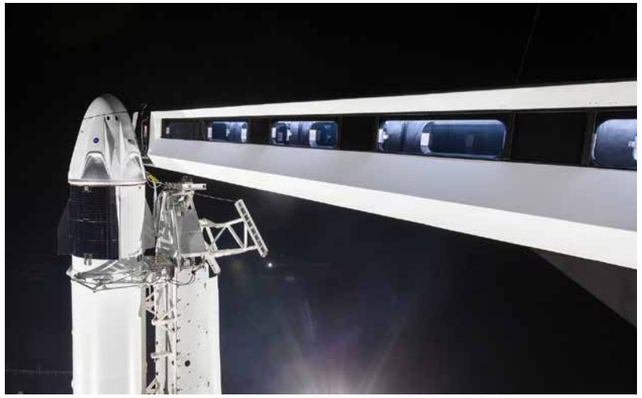
A Florida scrub jay perches in a tree in an area called Wilson's Corner in the Merritt Island National Wildlife Refuge near NASA's Kennedy Space Center in Florida. The bird is one of more than 330 native and migratory bird species that call Kennedy and the wildlife refuge home. Also, 25 mammal species, 117 different fishes and 65 types of amphibians and reptiles also live at Kennedy and the wildlife refuge. Photo credit: NASA/Glen Benson

LOOK AHEAD 2019

COMMERCIAL CREW PROGRAM

In 2019, NASA and commercial partners, Boeing and SpaceX, will make history as they prepare to launch humans to the **International Space Station**. The upcoming flights of the CST-100 Starliner and Crew Dragon will be the first time in history NASA has sent astronauts to space on systems owned, built, tested and operated by private companies. This also will be the return of American astronauts, launching on American spacecraft and rockets from American soil to the space station since 2011. Before the companies can begin regularly flying long-duration missions to the orbiting laboratory, they first need to demonstrate their system's capabilities through a series of flight tests.

The goal is safe, reliable and cost effective crew transportation to the space station. The investment in commercial industry allows NASA to continue paving the way to destinations **beyond low-Earth orbit**. Before that goal can be achieved, the space systems will be put to challenging flight tests bringing together the rocket, the spacecraft, the ground support systems, integrated launch teams and the astronaut crew.



At NASA Kennedy Space Center's Launch Complex 39A, the crew access arm has been extended to the SpaceX Crew Dragon spacecraft on Jan. 3, 2019. Mounted atop the company's Falcon 9 rocket, both will undergo checkouts prior to its liftoff for Demo-1, the inaugural flight of one of the spacecraft designed to take NASA astronauts to and from the International Space Station. Photo credit: SpaceX

Flight Tests:

Last year, NASA added to the astronauts training to fly on commercial crew missions. Now, **nine U.S. astronauts** are working with Boeing or SpaceX for specific mission training. The astronauts also are preparing to live and work aboard the space station where they could stay for up to six months. The astronauts go through significant preparation for space station missions, including learning how to conduct spacewalks, maintain the space station and perform a myriad of research investigations covering all scientific disciplines.

In 2019, the astronauts will continue to participate in nominal and off-nominal mission simulations, studying every aspect of their spacecraft, as well as launch, on-orbit and landing procedures. This intense work ensures they are prepared for any situation that may arise during their mission.

The first stage of the rocket that will launch Boeing's CST-100 Starliner spacecraft to the International Space Station on the company's uncrewed Orbital Flight Test arrived at Cape Canaveral Air Force Station in Florida on Dec. 7, 2018. The United Launch Alliance (ULA) Atlas V first stage booster was shipped aboard ULA's Mariner cargo vessel from the company's manufacturing plant in Decatur, Alabama. It is the final piece of hardware that ULA needs to launch the first Boeing Starliner. The booster was transported to the Atlas Spaceflight Operations Center for receiving inspections and checkout. Photo credit: NASA/Cory Huston

Flight Tests:

The Commercial Crew Program started with an idea of turning over human transportation to low-Earth orbit to private industry, similar to the way cargo supplies to the space station have been provided by commercial spacecraft. NASA used its significant spaceflight experience to develop a set of mission and safety requirements for human-rated space systems and developed unique strategies with Boeing and SpaceX to verify each company meets the requirements.

Each company will begin with an uncrewed flight to the space station. Each will launch from Florida's Space Coast, complete system checkouts while in orbit, dock to the space station's forward port, stay for about two weeks and then return home to test the landing systems. NASA will use the valuable data gathered during the flights to certify the crew transportation systems as safe to carry astronauts to and from the station.

Following the uncrewed flights, both companies will conduct tests of their abort systems. Boeing will conduct a Pad Abort Test from a test stand at the U.S. Army's White Sands Missile Range in New Mexico to demonstrate the Starliner's ability to carry astronauts to safety in the unlikely event of a rocket failure at any time on the launch pad or during ascent to orbit. SpaceX will perform an in-flight abort test to demonstrate crew escape capability should an emergency occur after launch during Crew Dragon's ascent.

After the uncrewed flight and abort tests have verified that the spacecraft systems operate as planned in the harsh environment of space and in abort scenarios, both companies will conduct a flight test with U.S. astronauts on board. Boeing's flight, known as the Crew Flight Test (CFT), is targeted for August 2019 and SpaceX's Demo-2 flight test with astronauts is targeted for June 2019. The **astronauts assigned** have a background as military test pilots and have been trained to systematically evaluate each system of a new vehicle.

Path to Certification:

NASA will review the performance data obtained from these flight tests and resolve any issues in order to certify the systems for operational missions. While NASA has not determined which provider will fly an operational mission first, the first two of these missions are targeted to launch in August and December 2019.

ENGINEERING

2019 will be a record-setting year for Kennedy Space Center's Engineering Directorate. For the first time in KSC history, the engineering team will prepare for and support launches from four different spaceflight programs: Commercial Crew Program's Boeing and SpaceX providers, Launch Services Program, and International Space Station.

Engineering will support the SpaceX Demo-1 and Boeing Orbital Flight Test missions, marking the first test flight for each commercial partner. The SpaceX Demo-2 launch will mark the first time in over nine years that Kennedy's engineering team helped to launch humans from American soil.

The organization also will provide engineering expertise to LSP's Ionospheric Connection Explorer, or ICON, mission and various space station servicing missions, including commercial resupply, processing hardware for international partner flights, and multiple research and technology missions. The validation and certification of all Exploration Mission-1 (EM-1) ground support equipment will be completed, and marks a major milestone in the readiness for next year's scheduled EM-1 launch.

Kennedy Space Center's Engineering Directorate held a banner signing event in the Prototype Development Laboratory to mark the successful delivery of a liquid oxygen test tank, called Tardis. The 12-foot-tall, 3,810-pound aluminum tank was shipped to White Sands for testing. Photo credit: NASA/Cory Huston

A close-up view of NASA's crawler-transporter 2 (CT-2) with the mobile launcher (ML) atop as it slowly moves along the crawlerway on its trek to Launch Pad 39B at Kennedy Space Center. Photo credit: NASA/Cory Huston

Engineering will move into the Central Campus facility this year. The facility is a "green," highly efficient building with accent colors representing planets in our solar systems. Also, the dunes restoration project will be completed this year. Engineering supports various projects, including the Mass Spectrometer observing lunar operations (MSolo) to assess lunar environment contamination, and Orbital Syngas/Commodity Augmentation Reactor (OSCAR) to reduce risk of space waste.

Engineering is heavily involved with establishing new programs, such as Gateway, as well as welcoming new users to the center by providing them with systems integrations and engineering expertise in flight, ground and facility systems, and paving the way for new launch site options such as Space Launch Complex-48.

EXPLORATION GROUND SYSTEMS

Exploration Ground Systems (EGS) has a busy year ahead in 2019. The crawler team will finish engine maintenance and crawlerway conditioning—ensuring they are ready for the Space Launch System

(SLS). The mobile launcher will finish up its testing in the Vehicle Assembly Building (VAB) and will roll back out to Launch Complex 39B for its final testing at the pad.

Work for a second mobile launcher should be awarded in the new year, allowing more flexibility for upcoming exploration missions. Engineers and construction workers have a few items on their punch list in VAB High Bay 3, before beginning work on High Bay 4.

At Pad 39B, workers will start to install a new liquid hydrogen tank that will be used for Exploration MIssion-2. In Launch Control Center firing rooms 1 and 2, final upgrades will be made while the launch team finalizes the new countdown procedures for SLS. The team will practice their countdown using new software that provides millions of data points per second—ensuring all systems are go.

By the end of 2019, EGS will begin processing the Orion crew capsule and SLS hardware for the launch of Exploration Mission-1.

EXPLORATION RESEARCH AND TECHNOLOGY

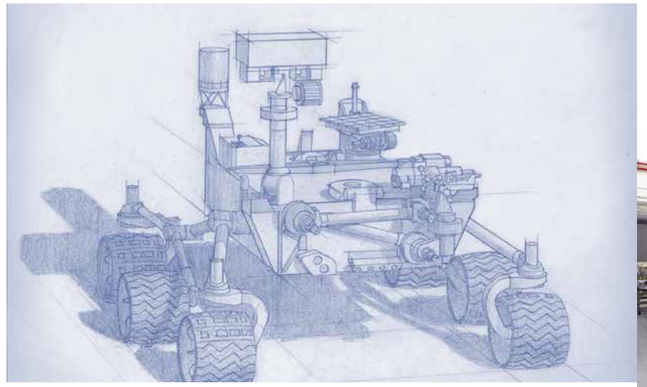
In 2019, NASA Kennedy Space Center's Exploration Research and Technology will have several technologies under development that will have the potential to assist in returning the agency to the Moon and Mars, as well as facilitating people living and working in space.

The team will participate in judging the Recycling in Space Challenge, which is looking for a receptacle and method of processing space trash. This challenge is a crowdsourced effort, and the winning design should be able to interface with the Orbital Syngas/Commodity Augmentation Reactor (OSCAR), a device capable of turning space trash into useful resources such as oxygen. Reusing materials enables missions to explore for longer periods of time, efficiently using every available resource.

Zinnia seeds grown in the Veggie plant growth system on the International Space Station were planted and are growing in the Veggie Laboratory in the Space Station Processing Facility (SSPF) at NASA's Kennedy Space Center on Nov. 27, 2018. Photo credit: NASA/ Ben Smegelsky

In the spring, the Electrodynamic Dust Shield (EDS) Experiment will fly as part of the Materials International Space Station Experiment (MISSE) to the station and spend a year exposed to space undergoing tests. The EDS uses electric fields to repeal dust, which means it can remove dust from a surface, including solar panels or a camera lens, helping mitigate the effect of dust on space exploration.

The center also is preparing the Mass Spectrometer observing lunar operations (MSolo) for the Commercial Lunar Payload Services Landers program. These instruments are commercial off-the-shelf mass spectrometers modified to work in space, and can identify molecules at lunar landing sites. Kennedy also will support several space biology projects and experiments on the space station, including testing new light recipes for growing plants in space using LEDs, the effects of environmental radiation on preserved cells, down-selecting for new crop species on future missions, and the completion of work analyzing the effect of microbiomes on growing plants in space based on data and samples collected in 2018.



An artist rendition of NASA's Mars 2020 rover that will investigate a region of Mars where the ancient environment may have been favorable for microbial life. The rover will probe the Martian rockets for evidence of past life. Throughout its investigation, it will collect samples of soil and rock, and cache them on the surface for potential return to Earth by a future mission. Image credit: JPL/California Institute of Technology

LAUNCH SERVICES PROGRAM

NASA's Launch Services Program, or LSP, at Kennedy Space Center is already preparing for the next 20 years with Ionospheric Connection Explorer, or ICON, which will study the layer of charged particles high in our atmosphere where Earth's weather meets space weather. NASA and Northrop Grumman will launch ICON on a Pegasus XL rocket from Cape Canaveral Air Force Station (CCAFS). In addition, the second Venture Class Launch Services, on Virgin Orbit's LauncherOne, will take off from the Mojave Desert carrying the Educational Launch of Nanosatellites (ELaNa-20) CubeSats. LSP continues to act in an advisory capacity for the Commercial Crew Program's missions: SpaceX's Demonstration Mission-1 (uncrewed) and Demonstration Mission-2 (crewed), and Boeing's Orbital Flight Test (uncrewed) and Crew Flight Test (crewed); and Commercial Resupply Services' (CRS) missions SpaceX CRS-17, CRS-18 and CRS-19.

The year 2020 will showcase these five missions: Solar Orbiter launching on a United Launch Alliance Atlas V 411, a joint mission with the European Space Agency (ESA), which will be placed into an elliptical orbit around the Sun; Mars 2020 launching on a United Launch Alliance Atlas V 541, which will use a drill to collect core samples and store them in a "cache" on the surface of Mars; Sentinel 6A launching on a SpaceX Falcon 9 Full Thrust, which will take high-precision ocean altimetry measurements and collect high-resolution vertical profiles of temperature; and Landsat-9, launching on a United Launch Alliance Atlas V 401, an Earth-observing satellite that will provide land imaging for the U.S. Geological Survey (USGS).

LSP also recently awarded the Lucy mission, which currently is targeted to launch in October 2021 on a United Launch Alliance Atlas V 401 rocket from CCAFS. LSP is looking to award the Double Asteroid Redirection Test (DART) mission, which will be the first demonstration of the kinetic impact technique to change the motion of an asteroid in space, and the Imaging X-ray Polarimetry Explorer (IXPE) mission, which will fly three space telescopes with cameras capable of measuring the polarization of cosmic X-rays later this year.

Inside the Launch Abort System Facility (LASF) at NASA's Kennedy Space Center in Florida, workers assemble the Launch Abort System (LAS) on Feb. 5, 2019, that will be used for the Orion Ascent Abort-2 (AA-2) Flight Test. AA-2 is a full-stress test of the LAS, scheduled for Spring 2019. Photo credit: NASA/Kim Shiflett

ORION PROCESSING

Exploration Mission-1

The Orion Crew Module will have all of the outer thermal protection system tiles installed and will go through final processing before being integrated with the European Service Module. The combined stack, called the Crew Service Module (CSM), will fly aboard NASA's Guppy aircraft to NASA's Plum Brook Station in Sandusky, Ohio, which houses the world's largest and most powerful space environment simulation facilities. Once the CSM returns from Ohio it will undergo final checks and processing before being transferred to Exploration Ground Systems for integration.

Exploration Mission-2

The pressure vessel for Exploration Mission-2 (EM-2), Orion's primary structure that holds the pressurized atmosphere astronauts will breathe and work in, arrived at Kennedy for flight processing in August of 2018. Since its arrival, it has been undergoing structure testing and alignments. In 2019, the pressure vessel will undergo several tests, have welding done for the environmental control system, and have pre-fits of both the outer back shells and heatshield. EM-2 will be the first crewed test flight of the Orion spacecraft.

Ascent Abort-2 Flight Test

Throughout 2018, all critical parts for the Ascent Abort-2 (AA-2) Flight Test arrived for processing at Kennedy. In 2019, all segments will be processed and integrated for flight. AA-2 is a full-stress test of Orion's Launch Abort System (LAS). During the test, a booster provided by Northrup Grumman will launch from Space Launch Complex 46 at Cape Canaveral Air Force Station, carrying a fully functional LAS and a 22,000-pound Orion test vehicle to an altitude of 31,000 feet and traveling at more than 1,000 miles an hour. The test will verify the LAS can steer the crew module and astronauts aboard to safety in the event of an issue with the Space Launch System (SLS) rocket when the spacecraft is under the highest aerodynamic loads it will experience during a rapid climb into space.

SPACEPORT INTEGRATION AND SERVICES

In 2019, Spaceport Integration and Services will continue its mission of working to secure America's future in space by providing exceptional customer service at the world's premier multi-user spaceport. The completion of the shore restoration project at Kennedy Space Center is one of the key milestones the organization is working towards this year. The organization will continue to provide the center with the institutional services and capabilities required to support mission needs while developing and implementing policies to effectively maintain, sustain and protect the Kennedy workforce, its infrastructure and the environment in accordance with NASA and external requirements.

An aerial view of a portion of the Launch Complex 39 area at NASA's Kennedy Space Center. Photo credit: NASA/Kim Shiflett

STATUS TO LAUNCH

Exploration Ground Systems gears up for Exploration Mission-1

BY JIM CAWLEY

NASA's **Exploration Mission-1 (EM-1)** will utilize the most powerful rocket in the world to fly **Orion** farther than any spacecraft built for humans has ever flown. The uncrewed flight from Launch Complex 39B at Kennedy Space Center in Florida will provide a foundation for human deep space exploration and demonstrate our commitment and capability to extend human existence to the Moon and beyond.

Preparing for such a momentous mission involves extraordinary collaboration. From Exploration Ground Systems at Kennedy, to the Space Launch System (SLS) Launch Vehicle at Marshall Space Flight Center, to the Orion Spacecraft at Johnson Space Center and Kennedy, NASA employees, programs and centers are coming together to make EM-1 possible.

Here is Exploration Ground Systems' "Status to Launch" for EM-1, the first integrated test of the agency's deep space exploration systems:

ASSET: MOBILE LAUNCHER

STATUS: Roughly 90 percent of the construction has been completed. Testing is planned through summer 2019.

THE LOWDOWN: The mobile launcher left the construction site and completed a test rollout on the crawler to Launch Pad 39B in late August 2018. It remained there for several days to allow for fit checks with the pad. In early September 2018, it was moved into the Vehicle Assembly Building (VAB) to begin multi-element verification and validation (V&V) testing. This testing will continue through the end of April 2019. The ML will then roll out to the pad for more V&V testing, which is slated to run through August 2019.

WHAT THEY'RE SAYING: "We are just eight months of testing and two rolls away from turning the mobile launcher over for SLS stacking in the VAB as it gets prepped for launch of EM-1."
— Cliff Lanham, Mobile Launcher senior project manager

FUN FACTS:
The mobile launcher weighs 10.5 million pounds.
The base of the structure has the square footage of 10 three-bedroom houses.
The mobile launcher contains more than 80 miles of cabling. "As I like to tell people when I'm giving tours, technologically, we're not breaking new ground," Lanham said. "But the complexity of the mobile launcher systems integration is off the charts."

ASSET: CRAWLER

STATUS: 100 percent complete. "We're mission ready now," said Crawler Project Manager John Giles. "We could roll SLS to the pad today."

THE LOWDOWN: Work began on the upgrading of the crawler in 2011. The biggest overall change was lifted weight. With the space shuttle, the crawler was designed to lift 12 million pounds. The new SLS rocket requirement is 18 million pounds. Ames Research Center conducted a study on what would be required to strengthen the crawler to carry 18 million pounds. The main work completed on the crawler includes: replacing all of the traction roller bearings; strengthening the structural integrity of the trucks; replacing the A/C generators to create more available power; installing a new brake system; replacing the jacking equalization and leveling system, which contains the massive hydraulic cylinders that lift up the mobile launcher with SLS; and rebuilding all 16 gear boxes. The crawler successfully took the mobile launcher on a test run to and from Pad 39B in late August through early September 2018.

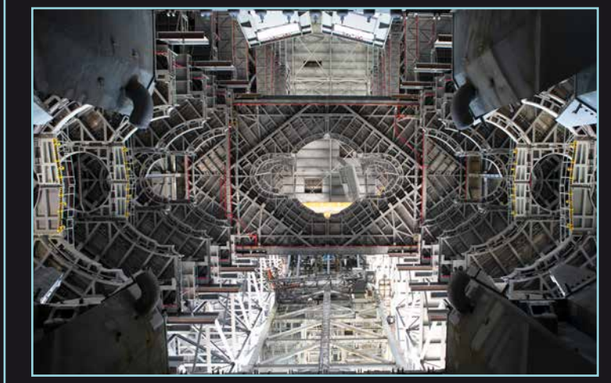
WHAT THEY'RE SAYING: "Our upgraded crawler is a beast — and our team knows how to tame it."
— John Giles, crawler project manager

FUN FACTS:
The crawler's gears are 5 feet in diameter and a foot thick.
The vehicle's top speed is about 2 mph, but don't expect to see it going that fast. Its normal traveling speed is about 1 mph.

ASSET: VEHICLE ASSEMBLY BUILDING (VAB)

STATUS: Platform installations are 99 percent complete. There are some modifications remaining, which will be finished by May 2019.

THE LOWDOWN: Though the platforms are nearly completed, some of the remaining work must wait for the mobile launcher to leave high bay 3. Right now, the main focus is on conducting multi-element verification and validation to test all of the mobile launcher components connected to the VAB. Other current work includes modifying railings on the platforms. Construction of the platforms began in March 2014, with the first platform installation occurring in December 2015.



WHAT THEY'RE SAYING: "My team's biggest achievement was working together with operation, construction and designers to construct and install state-of-the-art platforms in high bay 3, which laid the groundwork for launching America's next greatest rocket."
— Jose Perez Morales, VAB element project manager

FUN FACTS:
There are 10 levels of platforms. Each level has two halves, and each half weighs approximately 300,000 pounds.
These new dynamic platforms can be moved vertically 10 feet up or down to account for vehicle deviation. Inserts can be modified and are interchangeable with all of the platforms.

ASSET: **LAUNCH PAD 39B**

STATUS: 98 percent complete. Multi-element verification and validation with the mobile launcher is essentially all that remains.

THE LOWDOWN: Launch Pad 39B, which has undergone extensive upgrades beginning 11 years ago, is transitioning from a construction state to an operational state. Major work included: demolition of the fixed service structure/rotating service structure, construction of new lightning towers, replacing the flame trench bricks and constructing a new flame deflector, replacing all of the instrumentation and communication systems and modifying the environmental control system.

WHAT THEY'RE SAYING: "We gave the 50-year-old Pad 39B a complete makeover. We have replaced, refurbished or repaired every system on the pad."
— Regina Spellman, senior project manager for Launch Pad 39B

FUN FACTS:
Launch Pad 39B utilizes a combination of the Apollo Program, Space Shuttle Program and EGS systems and infrastructure. "We are really bringing together three generations to support the SLS," Spellman said.
The pad measures 2 miles around the perimeter.
The water tower holds 400,000 gallons, and it empties in 25 seconds.

ASSET: **LAUNCH CONTROL CENTER (LCC)**

STATUS: Approximately 90 percent complete; this includes extensive hardware and software components, along with additional capabilities.

THE LOWDOWN: Firing Room 1, which was used for the Apollo Program, Space Shuttle Program and Ares I-X test flight as part of the Constellation Program, has been completely upgraded. This includes a new console layout, updated furniture and a new command and control system that features advanced capabilities and tools. The software within the LCC is state-of-the-art, handling critical command functions and hundreds of thousands of data changes each second. Also, changes were made in the launch team structure and how it functions. "We have a different model now," NASA Launch Director Charlie Blackwell-Thompson said. "We tried to take the best of what we believe industry and government have done previously and incorporate it into our concept." A key simulation training event in Firing Room 1 is targeted for spring 2019. The team will work through launch scenarios, including potential problems and challenges that could occur, as they take the launch countdown close to T-zero.

WHAT THEY'RE SAYING: "My launch team isn't limited to the folks who are in the firing room on launch day; our team is everyone who is getting us one step closer, each and every day, to launch."
— Charlie Blackwell-Thompson, NASA launch director

FUN FACTS:
The LCC has been in operation since 1965. That year, it won an architectural award for industrial design of the year.
There is a tradition in the LCC — dating back many years — of eating beans and cornbread post-launch.
The launch director's office has a window with a total view of the control room. "Being a test director for many years, one of the big things that we always paid attention to was when the launch director's light came on," Chief NASA Test Director Jeremy Graeber said. "That really kind of sent a signal to the team. We were already on our A-game, but now we needed to go on our A-plus game because the launch director is here."

VENTURE-CLASS ERA

Rocket Lab Electron launches NASA CubeSats

BY ANNA HEINEY

Small satellites now have the option of flying to space on rockets designed especially for their unique needs. A Rocket Lab Electron rocket lifted off Dec. 17, 2018, from the company's New Zealand launch site, carrying a host of these small spacecraft, called CubeSats. Ten of them flew to orbit as NASA's Educational Launch of Nanosatellites-19 payload, or ELaNa-19.

It was the first flight of a payload under NASA's Venture Class Launch Services (VCLS), a new effort developed to provide increased access to space and a launch experience that's tailor-made to suit the satellites' mission and science goals.

"This successful launch demonstrates how small spacecraft can get a first-class ticket to the orbit their science requires, instead of having to ride as secondaries that might not place them in their ideal science orbit," said Justin Treptow, ELaNa small payloads manager for NASA's Launch Services Program.

Rocket Lab's Electron rocket is a two-stage vehicle that stands nearly 56 feet tall. The company builds the rocket components at its facility in Huntington Beach, California, then ships it all to New Zealand for liftoff from Launch Complex-1, located at remote Mahia Peninsula.

Although the Electron rocket set to carry NASA's ELaNa-19 payload was ready to fly Dec. 12, strong winds kept the mission on the ground. Finally, at 6:33 a.m. UTC on Dec. 17 (1:33 p.m. EST on Dec. 16), the rocket's Rutherford engine ignited, sending the CubeSats on their way and officially kicking off the venture-class era.

"VCLS has been incredibly exciting," Treptow said. "Seeing rocket designs and new rocket companies go from paper design to rockets on the launch pad in such a short period of time is the thing engineers dream of."

The ELaNa-19 CubeSat payloads that flew aboard the Electron rocket on this first venture-class mission were selected by NASA's CubeSat Launch Initiative Program. CubeSats are built to standard units of 10 cm (about 4 inches) that also can be configured in units of two, three or six cubes.

On board were the Advanced Electrical Bus (ALBus), developed by NASA's Glenn Research Center in Cleveland, Ohio; CubeSat Compact Radiation Belt Explorer (CeREs), developed by NASA's Goddard Space Flight Center in Greenbelt, Maryland; CubeSat Handling of Multisystem Precision Time Transfer (CHOMPTT), a collaboration between the University of Florida in Gainesville and NASA's Ames Research Center in Mountain View, California; CubeSail, developed by the University of Illinois at Urbana-Champaign; DaVinci, developed by the North Idaho STEM Charter Academy in Rathdrum, Idaho; Ionospheric Scintillation Explorer (ISX), developed by SRI International and California Polytechnic University; NMTSat, built by students primarily from New Mexico Institute of Mining and Technology in Socorro, New Mexico; RSat, developed by the U.S. Naval Academy in Annapolis, Maryland; Shields-1, developed by NASA's Langley Research Center in Hampton, Virginia; and Simulation-to-Flight 1 (STF-1), a collaboration between the NASA Independent Verification and Validation Program, West Virginia University and West Virginia small businesses.

The Educational Launch of Nanosatellites 19 (ELaNa 19) payload was encapsulated inside the Rocket Lab Electron rocket payload fairing on Dec. 1, 2018, at the company's facility in New Zealand. The liftoff marks the debut of the agency's innovative Venture Class Launch Services effort, managed by NASA's Launch Services Program at Kennedy Space Center in Florida. Photo credit: Rocket Lab

The next Venture Class launch, carrying the ELaNa-20 payload, is slated to fly aboard Virgin Orbit's LauncherOne in the first half of 2019.

A new entrance at the Kennedy Space Center Visitor Complex opened Dec. 17, 2018, at a new access road, located off of Space Commerce Way. The entrance includes a new parking plaza, designed to resemble the shape of NASA's crawler-transporter. The crawler carried the massive Saturn V rocket, the space shuttles, and in the near future, NASA's Space Launch System to their launch pads. Photo credit: Kennedy Space Center Visitor Complex

NASA's Kennedy Space Center
Innovators' Launchpad:

Matt Romeyn

NASA's Matt Romeyn in the Veggie Lab of the Space Station Processing Facility at the agency's Kennedy Space Center. Photo credit: NASA/Cory Huston

Please explain your job in a single sentence.

I perform research and build hardware to develop in-situ **food production capabilities** in support of deep space exploration.

What do you find most exciting about your job as a project scientist with NASA's Kennedy Space Center for Exploration Research and Technology Programs' Utilization and Life Sciences Office?

Sending experiments and hardware to space is the most exciting for me. Nothing beats watching something you spent a large amount of time on launch to space and then having the pleasure to **interact with the crew** while they perform your experiment or install your hardware.

What is a typical day like for you?

A typical day is a mix of time spent in the lab and office. In the morning, I check on the numerous plant experiments that are ongoing at Kennedy, tracking plant growth and development. I look for things such as signs of stress, adequate hardware function and for signs of microbial growth. The rest of the day is usually spent collaborating with teams, working on new experimental planning and communicating with partners and stakeholders. When an experiment is underway on the **International Space Station**, there is not a typical day, because supporting in-orbit operations with the crew on station generally takes priority over everything else.

Was the work you did your first month at NASA anything like your current work?

The overall work is similar, but the time I spend on specific tasks has changed. My first month at NASA I spent most of my time in the lab prepping experiments, growing plants and conducting general experiments, spending less time working on planning and big picture activities. Currently, I spend a good amount of time working on experimental design, manuscripts, partnerships and strategy, and less time in the lab.

What is your educational background and why did you choose to study those areas?

I have a bachelor's degree in molecular biology and a master's degree in ecology. Molecular biology and genetics gained my interest, because it is one of the core unifying themes of biology that is applicable to multiple biology disciplines and is a field with many unknowns still to be discovered. Ecology is a multi-disciplinary field that is focused on understanding how biological systems interact with one another and their physical environment. I have found an ecological mindset to be very beneficial in my work at NASA, as the entire system of a spacecraft needs to be taken into account when attempting to **cultivate crops**.

How do the era and place in which you grew up shape how you approach your work?

I grew up in a rural manufacturing town in Michigan. This made me want to escape and find better, smarter ways to do things in more desirable locations.

What motivated you to want to work for NASA?

A desire to work on and **solve meaningful problems** for which answers cannot simply be found on the internet.

Why does conducting research and developing new technology matter to you?

Research and development is about improving the way we do things and obtaining new capabilities. It is essential in maintaining forward progress and productivity. R&D is ever-changing and solutions often are found in unlikely places.

How do you think your NASA research or the agency as a whole benefits people on Earth?

I think research and development groups benefit society as a whole with intended and unintended advancements and discoveries. NASA is exceptional due to the immense technical and scientific challenges it encounters every day. My specific field at NASA already has produced numerous trickle-down technologies that have benefitted terrestrial agriculture, especially in the realm of sustainability.

Do you have any advice for people trying to foster innovation in the workplace?

Innovation is a byproduct of performing work to solve challenging problems.

TECHNOLOGY OF THE FUTURE

Innovative liquid hydrogen storage to support Space Launch System

BY BOB GRANATH

As NASA continues preparations for the first launch of its **Space Launch System** (SLS) rocket and **Orion** spacecraft that will send humans beyond low-Earth orbit, **Exploration Ground Systems** (EGS) at the agency's Kennedy Space Center in Florida is preparing to build the world's largest liquid hydrogen storage tank. It will involve new technologies developed by researchers at the spaceport's **Cryogenics Test Laboratory**.

The innovation is like going from an ice box to a modern refrigerator.

When NASA launched the first astronauts to the Moon, propellants for the **Saturn V's** second and third stages were liquid hydrogen and liquid oxygen. Prior to being loaded into the launch vehicle, they were stored in 850,000 gallon spherical containers – each about 1,500 feet from the pad. These storage tanks served the same purpose during the 30-year **Space Shuttle Program**.

But the equipment design was dated, explains James Fesmire, senior principal investigator for Kennedy **Exploration Research and Technology Programs**.

"The technology for storing large quantities of liquid oxygen was developed during the early stages of World War II," he said. "Material and process for the liquid hydrogen and liquid oxygen tanks at Pads 39A and B were made of stainless steel, developed in the 1950s."

The ongoing problem during **Apollo** and the shuttle era was significant boil off or evaporation and the operational limitations.

While liquid hydrogen and liquid oxygen are excellent, high-performance rocket propellants, they are cryogenic – meaning super cold. The oxygen in liquid state is minus 297 degrees Fahrenheit and hydrogen is minus 423 degrees Fahrenheit. Because of ambient temperatures, storing these commodities is like storing ice in an oven.

The storage tank illustrated on the left, depicts how liquid hydrogen and liquid oxygen have been stored at NASA's Kennedy Space Center for more than 50 years. The insulated tank slowed boil off, or evaporation. But the cryogenic commodities boil off and the gas is vented. At right, the efficient system planned for the new 1.25 million gallon hydrogen tank will use technology called Integrated Refrigeration and Storage (IRaS) and glass "bubble" thermal insulation in the space around the inner vessel. IRaS is a refrigeration system allowing control of the fluid inside the storage tanks. This will provide direct removal of heat energy using an integrated heat exchanger together with a cryogenic refrigeration system. Image credit: Kennedy Space Center Cryogenic Test Laboratory

"The existing storage tanks were vacuum-jacketed with three-foot-thick perlite insulation," said Adam Swanger, a research engineer in Kennedy Engineering. "They were state-of-the-art in 1965. But boil off was an ongoing problem and substantial losses were unavoidable."

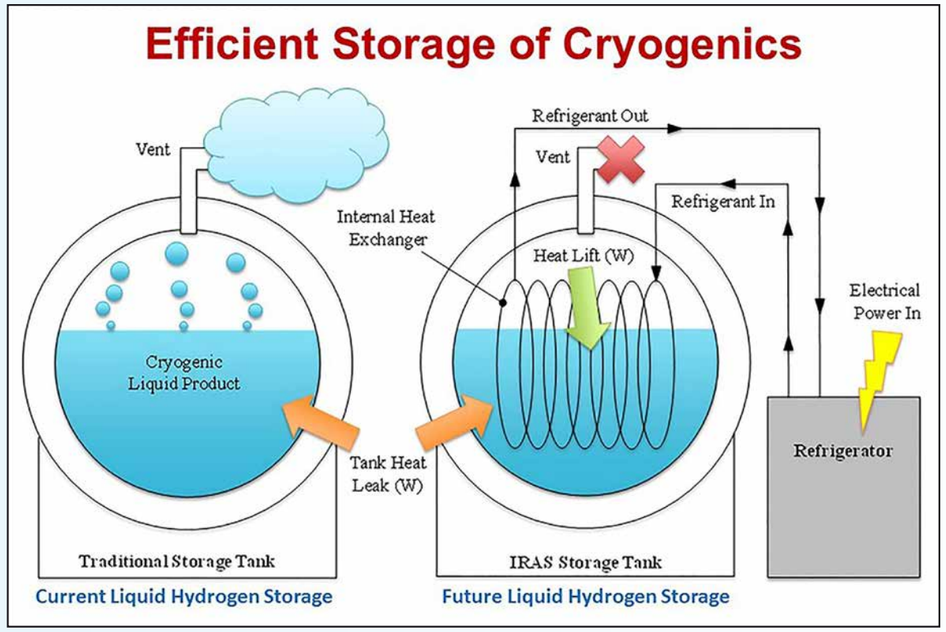
Fesmire noted that roughly half of the liquid hydrogen purchased to fuel the space shuttle's three main engines was lost due to boil off evaporation.

"We felt like there had to be a better way," he said.

Since 2001, Dr. Bill Notardonato, a principal investigator in Kennedy's Exploration Research and Technology Programs, and Dr. Jong Baik, of the Florida Solar Energy Center, have been working at the center's Cryogenics Test Laboratory pioneering a technology to mitigate these loses.

Integrated Refrigeration and Storage, or IRaS, is a refrigeration system allowing control of the fluid inside the storage tanks. This approach provides direct removal of heat energy using an integrated heat exchanger together with a cryogenic refrigeration system. Studies of the new technology began with analysis, modeling and a series of laboratory research tests.

"IRaS is important because it allows unprecedented control in storing cryogenic liquids," Notardonato said. "The normal



A liquid hydrogen (LH2) storage tank is in the foreground as NASA's mobile launcher (ML) atop crawler-transporter 2 makes its way up the ramp at Launch Pad 39B on Aug. 31, 2018, at the agency's Kennedy Space Center in Florida. The LH2 tank, along with a similar sphere for liquid oxygen (LOX) supported space shuttle launches for 30 years. The tanks are designed to store super-cooled LH2 and LOX. They were refurbished to prepare them to support the launch of NASA's Space Launch System (SLS) and Orion spacecraft. Exploration Ground Systems is preparing the ground systems necessary to launch SLS and Orion on Exploration Mission-1, missions to the Moon and on to Mars. Photo credit: NASA/Cory Huston

evaporation rate or 'boil off' can now be a thing of the past."

The new technology also is being coupled with new glass "bubble" insulation to replace perlite powder. Based on various field demonstration tests completed at Kennedy and NASA's Stennis Space Center in Mississippi in 2015, IRaS and glass bubble insulation will result in an estimated 46 percent reduction in liquid hydrogen losses through boil off. This will be especially important for the new liquid hydrogen tank that will hold 1.25 million gallons.

Comparatively speaking, it's like going from storing ice in a foam cup to keeping it in a freezer. While insulation in a foam cup will slow melting, it won't stop it and there is no control. Similarly, cryogenic liquids evaporate when stored in an insulated container, even one with the highest performance vacuum-jacketing.

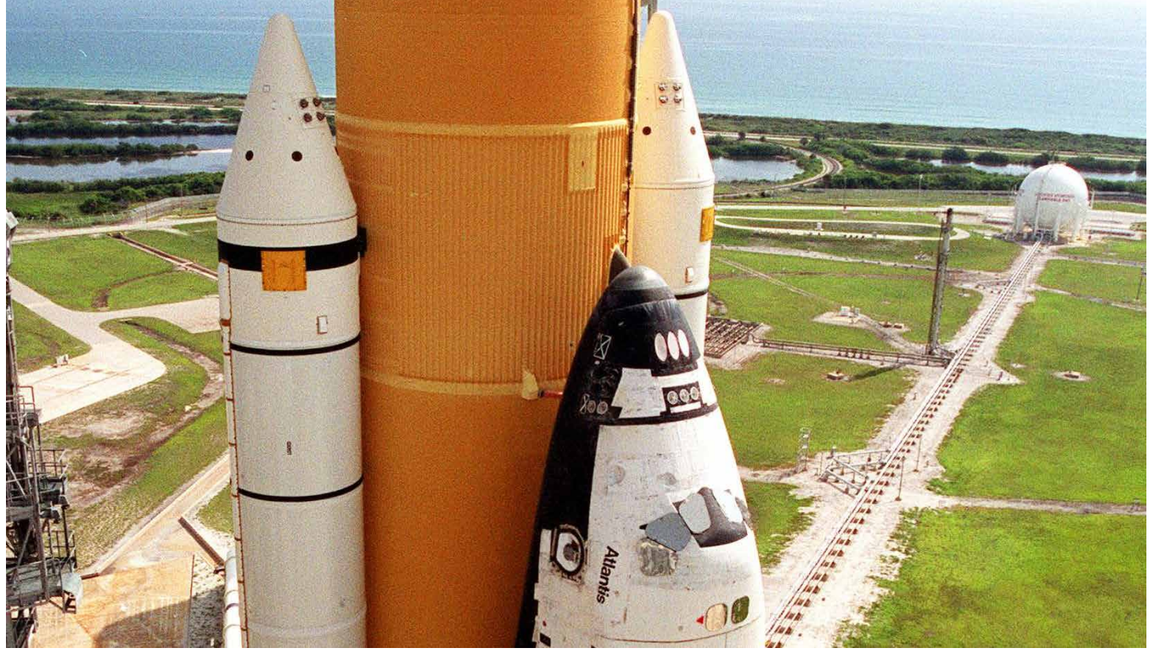
In a freezer with temperature control, ice can be stored indefinitely. The same is true with liquid hydrogen using IRaS -- spending about 15 cents in electricity saves $1 in hydrogen.

To support fueling of NASA's SLS rocket, Kennedy's EGS Program soon will begin construction of the new liquid hydrogen storage tank at Pad 39B. The SLS rocket is designed to launch the agency's Orion spacecraft, sending humans to distant destinations, such as the Moon and Mars. The **SLS core stage** and **in-space stage** will require 730,000 gallons of liquid hydrogen and liquid oxygen to fuel the four core stage and single upper stage engine.

"The larger tank will allow us to attempt SLS launches on three consecutive days," Fesmire said. "In the past, we had to stand down after two attempts so additional liquid hydrogen could be trucked in and loaded into the storage tank."

Swanger noted that NASA at Kennedy is developing state-of-the-art technologies that not only support agency missions, but commercial companies and partners such as SpaceX and Blue Origin as part of the center's role as a premier, multi-user spaceport.

"By choosing to implement the new IRaS technologies, EGS is effectively creating the future," he said. "It's an innovation that could impact how things are done here and throughout the cryogenic Industry for generations to come."



(Above) Atop the mobile launcher platform on June 21, 2001, the space shuttle Atlantis sits on Launch Pad 39B while being prepared for the STS-104 mission to the International Space Station. In view at right is the spherical 850,000-gallon-capacity liquid hydrogen storage tank. Running on the ground from the tank to the pad is 1,500 feet of vacuum-jacketed transfer line. Photo credit: NASA

(Below) Agency and contractor managers break ground for a new liquid hydrogen tank on Dec. 19, 2018, at Launch Complex 39B at NASA Kennedy Space Center. Participating, from the left, are Todd Gray, president of Precision Mechanical, prime contractor for the project; Charlie Blackwell-Thompson, launch director; Shawn Quinn, director of Engineering; Bob Cabana, center director; Bill Hill, deputy associate administrator for Exploration Systems Development at NASA Headquarters in Washington; Mike Bolger, program manager for Exploration Ground Systems (EGS); Jennifer Kunz, deputy program manager for EGS, Andy Allen, general manager for Jacobs, NASA's Test and Operations Support Contractor; and Regina Spellman, launch pad senior project manager in EGS. The storage facility will hold 1.25 million gallons of the propellant for NASA's Space Launch System rocket designed to boost the agency's Orion spacecraft, sending humans to distant destinations such as the Moon and Mars. Photo credit: NASA/Kim Shiflett

The two of three motors for Orion's Launch Abort System (LAS) are shown inside the Launch Abort System Facility (LASF) at NASA's Kennedy Space Center. Designed and built by NASA and Lockheed Martin, the jettison motor is on the left with the abort motor on the right. The motors arrived on Sept. 10, 2018, and are being stored in the LASF during processing for a full-stress test of the LAS called Ascent Abort-2. Photo credit: NASA/Frank Michaux

Motors arrive for flight safety test of Orion Launch Abort System

By Bob Granath

Launch Abort System, or LAS, motors are being assembled and checked out at NASA's Kennedy Space Center in Florida for an upcoming test of the Orion spacecraft designed to send astronauts on trips to the Moon, and support human exploration to Mars.

Orion is designed to launch atop the agency's **Space Launch System** (SLS) rocket that will take astronauts into deep space. Before flying astronauts, the **Ascent Abort-2** (AA-2) flight test will help verify that the LAS can pull astronauts to safety in the event of a problem during launch. The crew escape system will be attached to the top of the spacecraft.

According to Carlos Garcia of Orion Production Operations at Kennedy there are three motors on the LAS- the abort, attitude control and jettison motors. The abort motor can propel the crew module away from the rocket in milliseconds should there be an issue with SLS on the pad or during launch. The attitude control motor would steer the spacecraft during the maneuver. The jettison motor will pull the LAS away from the crew module, allowing Orion's parachutes to deploy with the spacecraft safely landing in the ocean.

The abort and jettison motors for the test arrived on Aug. 27 and Sept. 10, 2018 respectively, and the attitude control motor was delivered Dec. 15.

"As the motor segments come in, we align and mate them to the motor truss assembly," Garcia said. "We're working on the electrical connections now."

All are being checked out and processed in the **Launch Abort System Facility**, or LASF, prior to final assembly.

"Once the LAS assembly and checkout are complete, we'll do a soft mate to the Orion crew module mock-up," Garcia said. "That test will help us make sure everything is working as intended."

For AA-2, a test version of Orion equipped with 284 sensors will launch atop a booster provided by Northrop Grumman from Space Launch Complex (SLC) 46 at Cape Canaveral Air Force Station. The test booster is being processed in the space center's Vehicle Assembly Building and later will be transported to SLC 46.

"After the LAS is mated to Orion, the combination will be moved to the Cape for mating to the booster," Garcia said.

Targeted for May 2019, AA-2 will test an LAS abort under the highest aerodynamic loads it would experience in flight. The booster will accelerate to 31,000 feet, traveling at more than 1,000 miles an hour. The LAS abort motor then will ignite, pulling the crew module away from the booster.

The jettison motor separates the LAS from the crew module. The AA-2 test will conclude as data recorders are jettisoned for retrieval in the Atlantic Ocean.

Day of Remembrance

Kennedy Space Center honors fallen space explorers

BY DANIELLE SEMPSROTT

During NASA's Annual Day of Remembrance, Kennedy Space Center employees and guests gathered at the Space Mirror Memorial at Kennedy's Visitor Complex in Florida, Feb. 7, 2019, to honor all astronauts who have given their life in the pursuit of space exploration. The observance pays tribute to the crew members of Apollo 1, space shuttles Challenger and Columbia, and all other members of the NASA family who have perished in the line of duty.

Thad Altman, president and chief executive officer of the Astronauts Memorial Foundation (AMF), opened the ceremony stating that every year "we gather to remember those who have paid the 'ultimate sacrifice,'" but that we also work every day of the year for them.

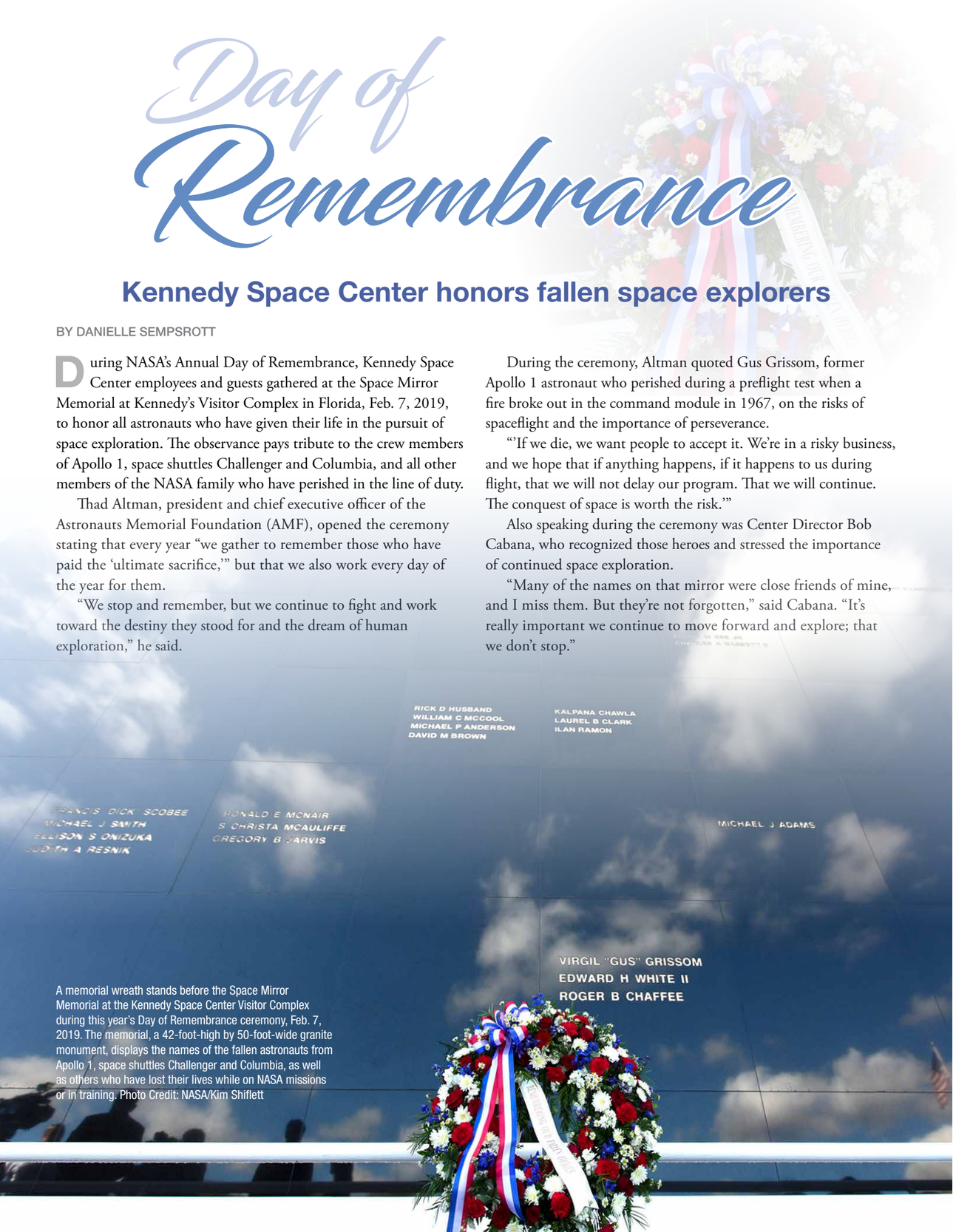
"We stop and remember, but we continue to fight and work toward the destiny they stood for and the dream of human exploration," he said.

During the ceremony, Altman quoted Gus Grissom, former Apollo 1 astronaut who perished during a preflight test when a fire broke out in the command module in 1967, on the risks of spaceflight and the importance of perseverance.

"'If we die, we want people to accept it. We're in a risky business, and we hope that if anything happens, if it happens to us during flight, that we will not delay our program. That we will continue. The conquest of space is worth the risk.'"

Also speaking during the ceremony was Center Director Bob Cabana, who recognized those heroes and stressed the importance of continued space exploration.

"Many of the names on that mirror were close friends of mine, and I miss them. But they're not forgotten," said Cabana. "It's really important we continue to move forward and explore; that we don't stop."



A memorial wreath stands before the Space Mirror Memorial at the Kennedy Space Center Visitor Complex during this year's Day of Remembrance ceremony, Feb. 7, 2019. The memorial, a 42-foot-high by 50-foot-wide granite monument, displays the names of the fallen astronauts from Apollo 1, space shuttles Challenger and Columbia, as well as others who have lost their lives while on NASA missions or in training. Photo Credit: NASA/Kim Shiflett

This year's ceremony was hosted by the AMF, which was founded after the shuttle Challenger accident in 1986 to honor the sacrifices of fallen astronauts each year, as well as inspire future generations through hands-on science, technology, engineering and mathematics or STEM learning activities. The AMF also built and maintains the Space Mirror Memorial, a 42-foot-high by 50-foot-wide granite monument that displays the names of the fallen astronauts from Apollo 1, shuttles Challenger and Columbia, as well as others who have lost their lives while on NASA missions or in training. In 1991, the memorial was dedicated as a national memorial by Congress and President George H. W. Bush.

During the ceremony, a memorial wreath was placed at the Space Mirror Memorial by Cabana, Altman, Kennedy Deputy Director Janet Petro, Kennedy Associate Director Kelvin Manning, Mike Leinbach, former shuttle launch director, and Sheryl Chaffee, daughter of Apollo 1 astronaut Roger Chaffee and AMF vice chair. The ceremony also included a presentation of colors by the Brevard County Fire Rescue Honor Guard, followed by the national anthem sung by retired Army Lt. Col. Cynthia Watkins.

This year marks 52 years since Apollo 1, 33 years since the shuttle Challenger and 16 years since the shuttle Columbia accidents. With the development of three new spaceflight vehicles underway (two of which are part of NASA's Commercial Crew Program), Cabana emphasized the importance of crew safety, open communication, and learning, while never forgetting the past as NASA works to return human spaceflight to the United States.

"It's critically important that we fly crews to the International Space Station on a U.S. rocket from U.S. soil this year," Cabana said. "We have to make that happen. But we have to do it right."

(Above) Guests place flowers in front of the Space Mirror Memorial at the Kennedy Space Center Visitor Complex during this year's Day of Remembrance ceremony, Feb. 7, 2019. Photo Credit: NASA/Kim Shiflett

(Below) During this year's Day of Remembrance ceremony at the Kennedy Space Center Visitor Complex, from left, Kennedy Associate Director Kelvin Manning, former Shuttle Launch Director Michael Leinbach, President and Chief Executive Officer of the Astronauts Memorial Foundation (AMF) Thad Altman, AMF Vice Chair Sheryl Chaffee, Kennedy Deputy Director Janet Petro, and Kennedy Center Director Bob Cabana stand in a moment of silence after placing a memorial wreath in front of the Space Mirror Memorial. Photo Credit: NASA/Kim Shiflett

"Many of the names on that mirror were close friends of mine, and I miss them. But they're not forgotten. It's really important we continue to move forward and explore; that we don't stop."

Bob Cabana
Director, Kennedy Space Center

(Left) In recognition of Black History Month, the Black Employee Strategy Team hosted a panel discussion featuring some of the future leaders of NASA's Kennedy Space Center on Feb. 13, 2019. Participants from left, are Tamiko Fletcher, Kennedy's chief security information officer in IT Security; Anthony Harris, chief, Facility Systems Branch in Safety and Mission Assurance; Charmel Anderson-Jones, senior cross program quality engineer in the Safety and Mission Assurance Directorate, Exploration Ground Systems Division; and Malcolm Boston, contracting officer representative in the Launch Services Program. They shared personal testimony about their journey toward NASA employment, leadership styles and keys to their success. Photo credit: NASA/ Frankie Martin

Black History Month

Black History Month, also known as African-American History Month in the United States, is an annual observance celebrated in February. Americans have recognized black history annually since 1926. Since 1976, every U.S. president has officially designated the month of February as Black History Month. It is also an annual observance in Canada, the Netherlands, and the United Kingdom. It began as a way for remembering important people and events in the history of the African diaspora.

(Above) NASA Kennedy Space Center's Black Employee Strategy Team (BEST) held its first coat drive in December. Due to the generosity of many Kennedy workers, the team collected several large bins of coats, blankets and socks. In February, they were delivered to the North Brevard Sharing Center in Titusville, and the Central Brevard Sharing Center in Cocoa. From left, are Joe Robinson, executive director of the North Brevard Charities Sharing Center Inc.; and Daren Etienne, mission and support office in Kennedy's Exploration Research and Technology Programs, with several of the bins delivered to the sharing center in Titusville. Etienne served as the coat drive organizer for BEST.

Apollo's Lunar Module

Bridging the technological leap to the Moon

BY BOB GRANATH

On May 25, 1961, President John F. Kennedy challenged America to meet the goal of "landing a man on the Moon and returning him safely to the Earth."

A first step in that technological leap for NASA was deciding how.

At the time, many NASA managers and engineers believed the most feasible method was "**direct ascent**," -- a spacecraft launched by an enormous rocket traveling directly to the Moon and landing as one unit. After exploration of the surface, a portion of the lander blasts off, returning to Earth.

Another approach, called "Earth Orbit Rendezvous," involved launch of several Saturn 1 rockets. A spacecraft, similar to the direct method, would be assembled in space for the lunar mission.

But a small group of engineers, including Dr. John Houbolt, assistant chief of the Dynamic Loads Division at NASA's Langley Research Center in Virginia, had an idea called, "**Lunar Orbit Rendezvous**." In a 1961 letter to Dr. Robert Seamans, NASA's associate administrator, Houbolt proposed separate vehicles, one to land on the surface while another circled the Moon.

The risky part was the landing craft must rendezvous with the "mother ship" in lunar orbit so the astronauts can return home. At that time, bringing two spacecraft together in space had never been tried. But the landing could require a much smaller spacecraft.

"Rendezvous in lunar orbit is quite simple," Houbolt believed. "I would rather bring down 7,000 pounds to the lunar surface than 150,000 pounds."

In his 2005 NASA book, "**Project Apollo-The Tough Decisions**," Seamans wrote that he saw great merit in lunar orbit rendezvous.

"Houbolt explained the orbital maneuvers and noted the savings in weight," he said.

While initially a skeptic, Dr. Wernher von Braun, director of NASA's Marshall Spaceflight Center in Huntsville, Alabama, agreed that the lunar orbit rendezvous approach would simplify reaching Kennedy's goal in a timely manner.

"A drastic separation of these functions into two separate elements is bound to greatly simplify the development of the spacecraft system and result in a very substantial saving of time," he said.

Von Braun led the team that developed the **Saturn V** rocket to launch the two spacecraft.

Studies and debates continued during the following months.

In a July 11, 1962, news conference, NASA Administrator James Webb announced the decision.

"We have studied the various possibilities for the earliest, safest mission," he said. "We find that by adding one vehicle to those already under development, namely, the lunar excursion vehicle, we have an excellent opportunity to accomplish this mission with a shorter time span, with a savings of money and with equal safety."

Initially dubbed the lunar excursion module, the name was later changed to simply **lunar module**, or LM. According to George Low, manager of the **Apollo** Spacecraft Program Office, NASA believed the word "excursion" might sound frivolous.

The contract for designing and building the LM was awarded to Grumman Aerospace in November 1962. A year earlier, North American Aviation began work on the "mother ship" called the **command/service module**.

Initial LM designs included large curved windows and seats and a redundant forward docking port. But, redesigns were required to save weight and enhance safety.

The cockpit windows were replaced with smaller triangular versions. A rectangular overhead window was included for use in rendezvous with the command module after leaving the lunar surface.

A forward hatch was designed to make it easier to climb out while wearing the bulky space suits with their backpacks.

While there were many key LM systems, nothing was more important than the engines that would allow the spacecraft to land on the Moon and another to return to the command module.

At the base of the LM was the descent propulsion system. The variable throttle rocket engine allowed astronauts to control the final decent from about 50,000 feet, including hovering as the commander picked out the best spot to land.

President John F. Kennedy speaks in front of an early design for the Apollo lunar module. The large windows were later replaced with smaller, down-facing windows. NASA Administrator James Webb, Vice President Lyndon Johnson, Dr. Robert Gilruth, director of NASA's Manned Spacecraft Center (now Johnson Space Center) in Houston, and others participate in the activity on Sept. 12, 1962. Photo credit: White House/Cecil Stoughton

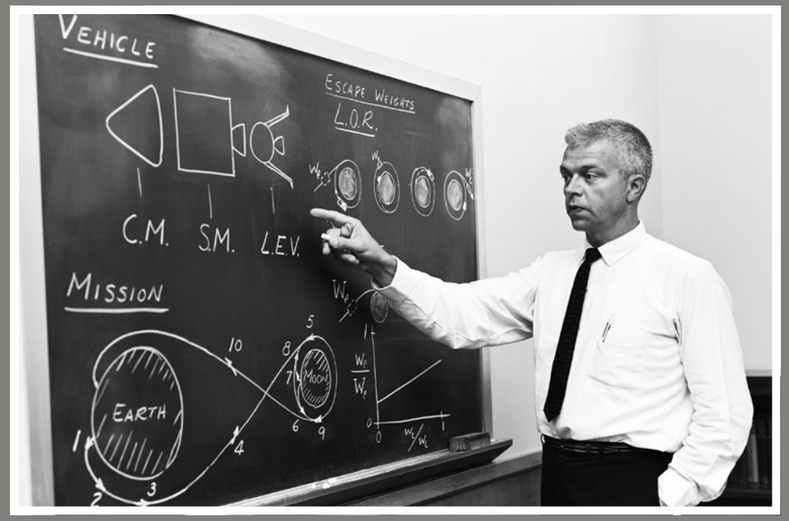
This panorama of the Moon shows the lunar module during the first Apollo 17 moonwalk. In the background, mission commander Eugene Cernan test drives the lunar roving vehicle. Photo credit: NASA/Jack Schmitt

The upper half of the LM served as the ascent stage. It contained the crew cabin with flight controls. The ascent propulsion system engine fired to liftoff from the Moon's surface and into a trajectory for rendezvous with the command module in lunar orbit.

The ascent module also included 16 reaction control system thrusters mounted in groups of four, for maneuvering in both landing and ascent.

The LM's first unpiloted flight test was **Apollo 5,** launched Jan. 22, 1968. The mission successfully verified operation of the spacecraft's performance, including the descent and ascent propulsion systems. Piloted test flights preceded the first Moon landing attempt. On **Apollo 9** in March 1969, the LM was flown in Earth orbit. During **Apollo 10** in May 1969, a LM descended to 50,000 feet above the lunar surface.

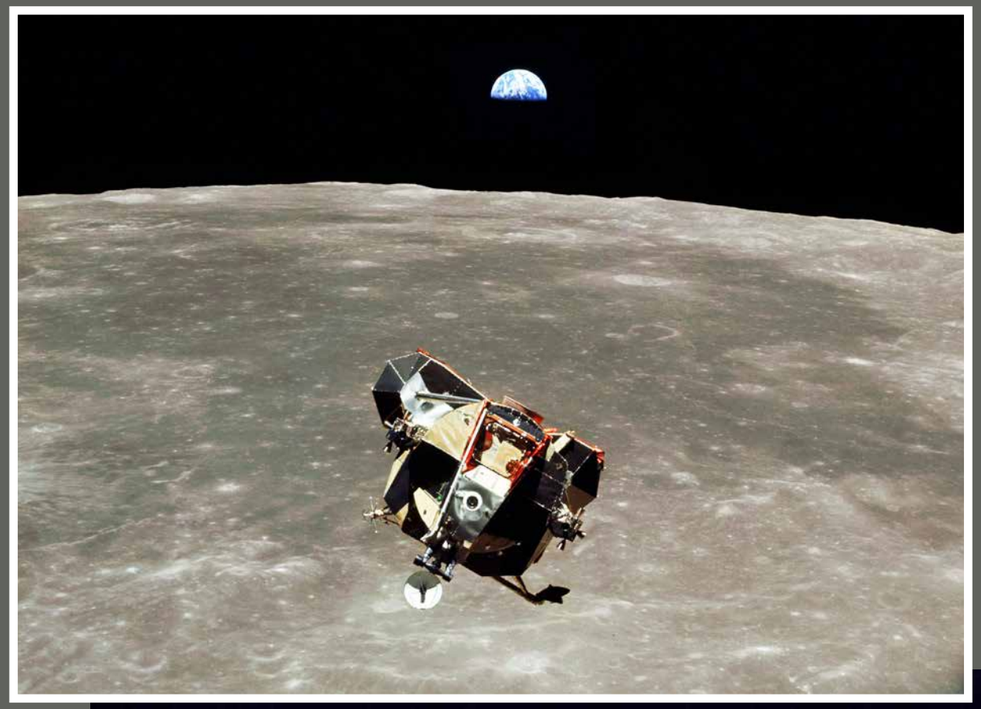
The venerable lunar module showed its versatility serving as a "lifeboat" when the **Apollo 13** command/service module was disabled by an oxygen tank explosion en route to the Moon in April 1970. But the LM will be remembered for its role between July 1969 and December 1972 as six of the spacecraft successfully landed 12 American astronauts on the Moon.



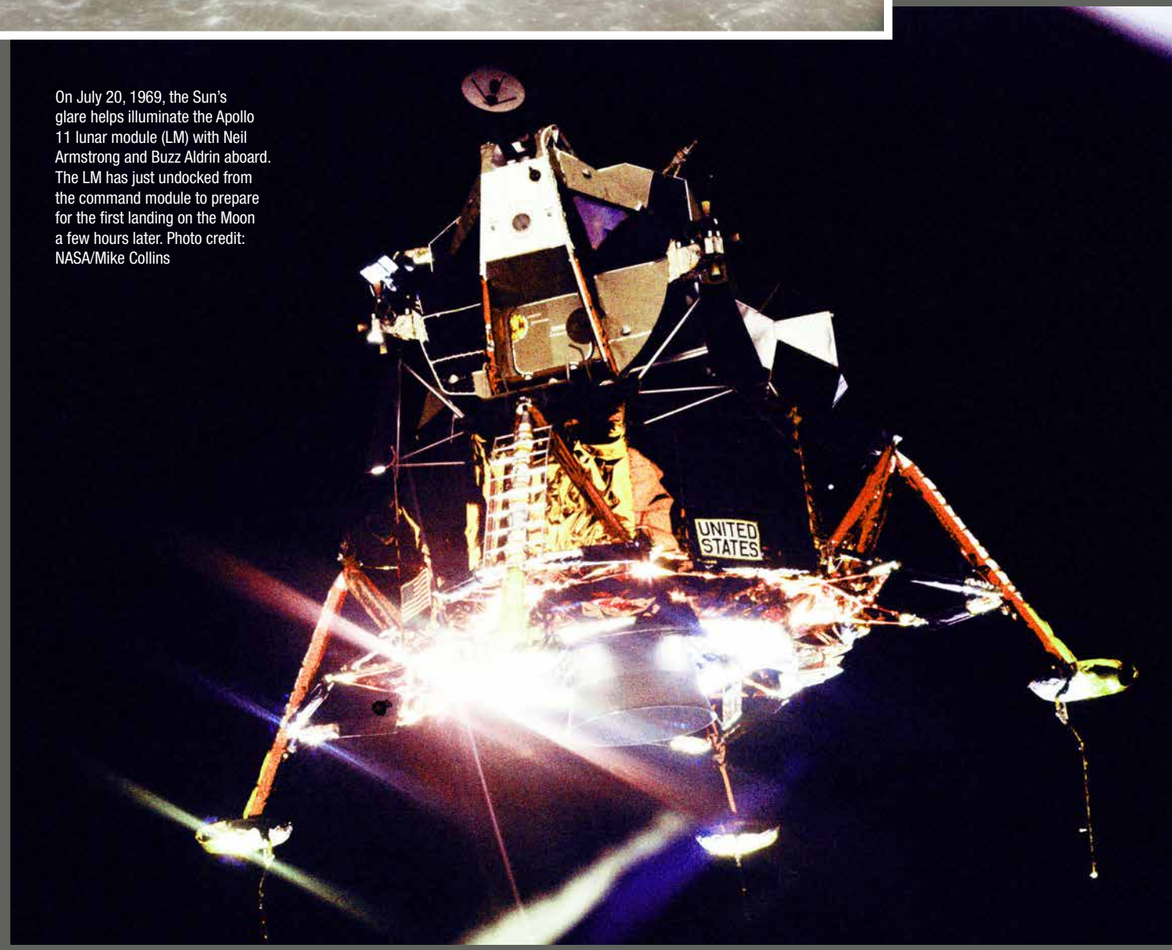
Dr. John Houbolt explains his lunar orbit rendezvous concept for landing on the Moon on July 24, 1962. His approach calling for a separate lander saved weight from the direct ascent design in which the entire spacecraft landed on the lunar surface. Photo credit: NASA

(Above) In the Manned Spacecraft Operations Building (now the Neil Armstrong Operations and Checkout Building) at NASA's Kennedy Space Center in Florida, the lunar module for Apollo 10 is being moved for mating with the spacecraft lunar module adapter. Apollo 10 orbited the Moon in May 1969 and served as a "rehearsal" for the first lunar landing. Photo credit: NASA

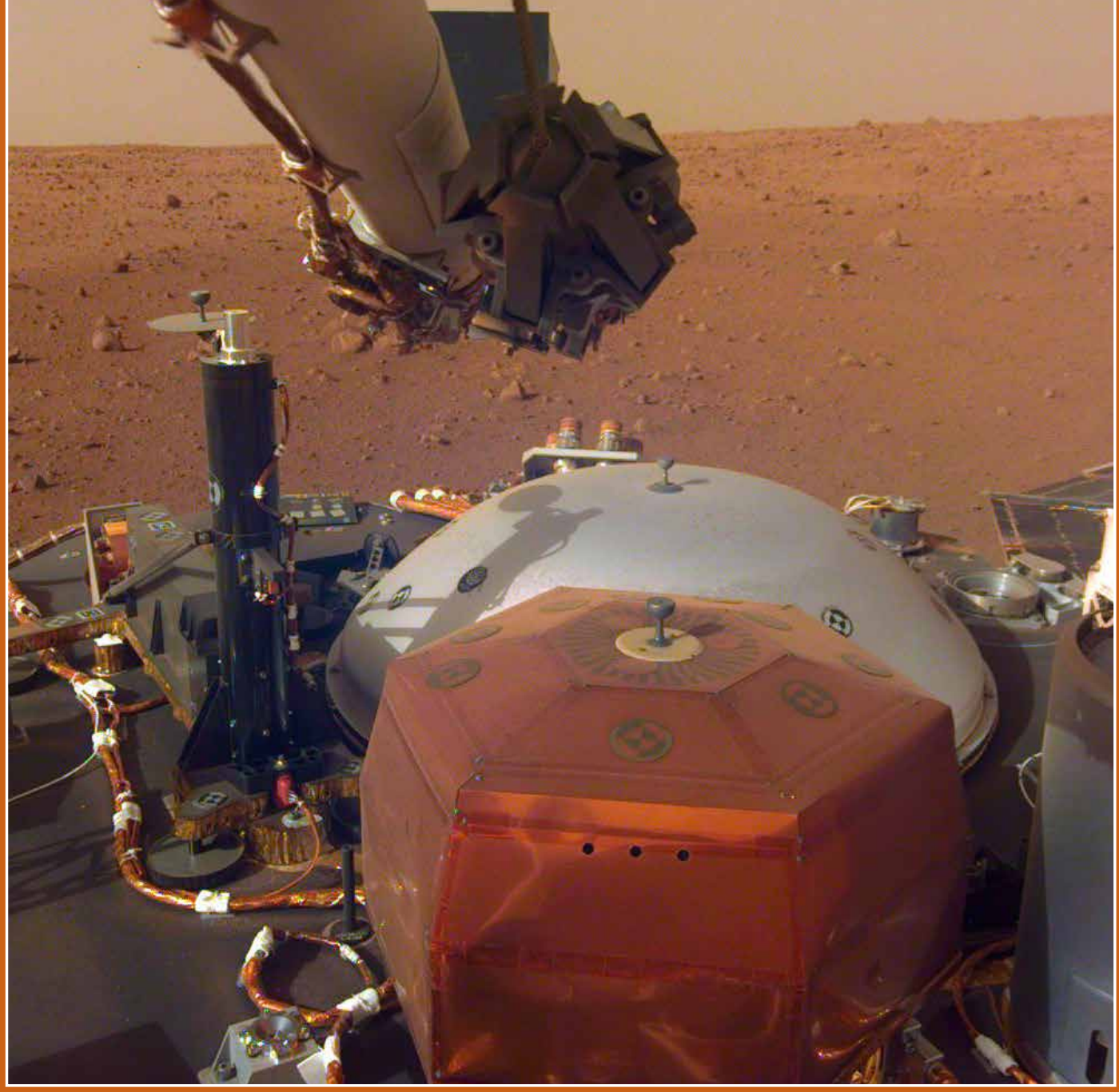
(Left) Apollo 11 commander Neil Armstrong participates in training on June 19, 1969, in the Apollo lunar module (LM) mission simulator. Simulators for both LM and command module were located in the Flight Crew Training Building at NASA's Kennedy Space Center. Photo credit: NASA



As the Earth rises above the lunar horizon, the Apollo 11 lunar module's ascent stage is seen from the command module. Moon walkers Neil Armstrong and Buzz Aldrin rendezvous with Mike Collins in lunar orbit on July 21, 1969. Eight years earlier, a small group of Langley Research Center engineers, including Dr. John Houbolt, proposed the "Lunar Orbit Rendezvous" approach. The concept proved successful on six Apollo landings. Photo credit: NASA/Mike Collins



On July 20, 1969, the Sun's glare helps illuminate the Apollo 11 lunar module (LM) with Neil Armstrong and Buzz Aldrin aboard. The LM has just undocked from the command module to prepare for the first landing on the Moon a few hours later. Photo credit: NASA/Mike Collins



Gaining ‘InSight’ on Mars

This image from Insight’s robotic-arm-mounted Instrument Deployment Camera shows the instruments on the spacecraft’s deck, with the Martian surface of Elysium Planitia in the background. The color-calibrated picture was acquired on Dec. 4, 2018 (Sol 8). In the foreground, a copper-colored hexagonal cover protects the Seismic Experiment for Interior Structure instrument (SEIS), a seismometer that will measure marsquakes. The gray dome behind SEIS is the wind and thermal shield, which will be place over SEIS. To the left is a black cylindrical instrument, the Heat Flow and Physical Properties Probe (HP3). HP3 will drill up to 16 feet (5 meters) below the Martian surface, measuring heat released from the interior of the planet. Above the deck is InSight’s robotic arm, with the stowed grapple directly facing the camera. To the right can be seen a small portion of one of the two solar panels that help power Insight and part of the communication antenna.

Image credit: NASA/JPL-Caltech

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