National Aeronautics and Space Administration



# IDEAS ON THE RISE

2018 Annual Report

NASA's Langley Research Center

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- Aeronautics
- Earth Science
- Space Exploration
  - Transformation
- Economics and Education 🦱







Langley Research Center's leadership team, pictured left to right: Jill Marlowe, associate director for technical; Cathy Mangum, associate director; Clayton Turner, deputy director; and Dave Bowles, director. For those of us at NASA's Langlev Research Center, 2018 was a year of new beginnings and memorable milestones.

We accomplished great things. Some of them have potential to reverberate around the globe. Our researchers paved

the way for future quiet supersonic passenger flight over land, worked to increase the safety of drones, and made new weather and climate measurements for the benefit of everyone on Earth.

We have great facilities, but it's our employees — smart, resourceful, passionate people — who make it all possible.

At the same time, we strengthened

NASA's ability to extend human exploration deeper into months, we're off to a strong start. our solar system - forward to the Moon and on to Mars. With both fresh ideas and nuts-and-bolts hardware, we prepared for that exciting journey.

There's something deeply satisfying about seeing Langleymade hardware roll through our gates, on the way to an eventual launch.

If a theme emerged this year, it was transformation. That's the label I use to describe a broad range of changes I'm encouraging at the center. I'm convinced that Langley needs to embrace new technologies, partnerships and

It's a privilege to lead an organization with such a fantastic track record of innovation and technical excellence. We have great facilities, but it's our employees - smart, resourceful, passionate people - who make it all possible.

I'm proud to stand with them as we work together to shape a better future for America and our planet.

modes of working to help us better align with the aerospace industry and the world at large.

My vision is for the center to serve as a pathfinder for the agency as we connect with new technologies, advance our

capabilities and accelerate the delivery of breakthroughs for NASA and the American people.

We marked our centennial in 2017. so I considered 2018 the beginning of Langley's next 100 years. As you'll see from this look back at the last 12

Dave Bowles Director, NASA's Langley Research Center

#### From the Director

### EXPLORE FLIGHT

COM NU

Researcher Melissa Rivers and test engineer Scott Goodliff examine the Common Research Model wing in the National Transonic Facility wind tunnel The data collected will validate the computational tools used to design more efficient commercial aircraft.

## Fly Everywhere

Langley aeronautics researchers work to strengthen America's air transportation system by cutting air traffic congestion and pollution, boosting safety and shaping the future of fliaht.

In 2018, a team tested autonomous technologies that could one day help unmanned aerial vehicles (UAVs, or drones) fly safely in city neighborhoods for tasks such as package delivery, infrastructure inspection - even search and rescue.

The team conducted 122 test flights over the streets of the center in a designated test range named **CERTAIN**, short for City Environment for Range Testing of Autonomous

Integrated Navigation. UAVs carried systems forcing them to automatically reroute or land when approaching a no-fly zone.

humming with tests of new and traditional aircraft designs. Tests of a new ramjet/scramjet engine developed by Aerojet Rocketdyne brings our nation closer to a hypersonic aircraft capable of conventional

The center's wind tunnels kept

Researcher Martha Brown works on a project to cut jet engine noise. Engine liners developed at Langley were tested in Washington state as part of a partnership with Boeing.



#### **>> >> >> >> >> >> >>** >>

takeoff. And by helping innovative composite materials and structures reach market faster, NASA fosters lighter, more fuel-efficient aircraft.

Langley and Boeing personnel traveled to Moses Lake. Washington, to test engine liners designed to muffle jet noise. Using an array of some 850 microphones, they charted how the liners helped aircraft soar more quietly.



A team at Langlev conducted a campaign to test autonomous safety technologies for urban flight. The technologies are intended to work like automatic braking systems on cars and could prevent Unmanned Aerial Vehicles (UAVs. often called drones) from flving in prohibited areas

Finally, a project intended to transform air travel picked up speed in 2018. A supersonic X-plane called the Low-boom Flight Demonstrator, or X-59, will cruise at 55,000 feet at speed of 940 mph and create a sound about as loud as a car door closing, instead of a sonic boom.

> Design speed of the Lowboom Fliah

#### Aeronautics 🖱

### EXPLORE FLIGHT

#### **>>>>>**

### *Life at the Lab: Simulation for Safety*

To boost safety, Langley researchers strive to improve the cockpit simulators used to train commercial airline pilots in what to do should they lose control of their aircraft, as in the case of a stall. In partnership with the U.S. Navy, they're refining synthetic vision displays that help pilots learn how to recover when something unexpected strikes.



Aeronautics



NASA is working to open a new commercial aviation market, one made possible by quiet supersonic aircraft built to fly over land, cutting travel time in half.

The Low-boom Flight Demonstration mission, for which Langley plays a management role, aims to erase current bans on faster-than-sound air travel over land by proving that the X-59 Quiet SuperSonic Technology (QueSST) aircraft can produce a softer noise that's not disruptive.

The shape of the X-59 was designed to

produce a barely-audible sonic "thump"

rather than the famously loud "boom"

that's associated with supersonic flight.

Once Lockheed Martin Skunk Works

in Palmdale. California. completes this

first-of-its-kind test plane, NASA pilots will fly it over several U.S. communities

to understand how the public responds

to this new, softer sound. First flights are



Researcher Peter Coen is NASA's Commercia Supersonic Technology proiect manager.

> U.S. and international regulators could use NASA data collected during these tests to write new rules allowing airlines to transport over land passengers at supersonic speeds.

scheduled for 2021.

Federal Aviation Administration rules have prohibited over land supersonic flight since 1973.

To prepare for the X-59's community overflights, NASA conducted preliminary tests called Quiet Supersonic

With typical supersonic aircraft, shockwaves travel outward in all directions from the aircraft and then merge together while moving at different strengths and speeds. This creates a boom. The X-59's shape and on-board technologies prevent shockwaves from combining, so the noise produced is more acceptable to people below.

Flights 2018, or QSF18, in November 2018. The flights will ultimately help NASA understand how to better engage with communities and collect information on resident responses to the supersonic thump. NASA used an F/A-18 research aircraft to perform a unique supersonic dive maneuver that produces a sound similar to what X-59 will make.

Five hundred resident volunteers were recruited to provide reactions to what they heard.

NASA's X-59 aircraft will be an experimental airplane equipped with quiet supersonic technologies that aircraft manufacturers may choose to include in their future designs. One unique feature will be an eXternal Vision System, or XVS, which uses a combination of computers and cameras to create an electronic window for the pilot.

XVS allows a pilot to see other aircraft near the flight path, the airport and runway. The technology also provides visual aids for approaches, landings and takeoffs. Eliminating windshields contributes to X-59's sound-altering shape.

The contours of the X-59 alter the supersonic shockwaves produced, reducing noise reaching the ground to that of a barely detectable thud.

#### Aeronautics

## EXPLORE EARTH

In this shortwave image from CERES FM6, the white and green shades represent thick cloud cover reflecting incoming solar energy back to space. Compare that with the darker blue regions, which have no cloud cover. to get a sense of how clouds affect the balance of incoming and outgoing energy on Earth. The orbiting CERES FM6 - built by Northrop Grumman and managed by Langley - began scanning the Earth in January 2018.

### Understand Our Home Planet

Langley researchers in 2018 studied vast streams of data to improve weather forecasting and better understand the planet's health.

In January, an orbiting instrument called Clouds and the Earth's Radiant Energy System Flight Model 6, or CERES



Langley researchers sit inside the aircraft they used to test a new triple-pulse lidar that can simultaneously measure carbon dioxide and water vapor. It's called Integrated Path Differential

joined five other CERES instruments flying on three other satellites measuring this key contributor to climate. The instrument will extend a 21-year data record.

Meanwhile, development continued on Absorption, or IPDA, lidar, an instrument called Climate Absolute Radiance and Refractivity Observatory

FM6, started scanning the Earth.

Launched the previous November on

a National Oceanic and Atmospheric

Administration satellite system, it

examined solar energy reflected by Earth, the heat the planet emits, and

the role of clouds in that process. It

Pathfinder, or CLARREO Pathfinder, which represents a step toward boosting certainty in many climate measurements.

In September, the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation, or CALIPSO, extended its success as it joined a sister satellite, CloudSat, in a new, lower orbit. Since 2006, CALIPSO has fired more 7,250,000,000 BILLION

CALIPSO

a research aircraft. Plans call for a new version of the technology to be deployed on orbit, giving forecasters an even more powerful tool for hurricane prediction.

The DEVELOP National Program. led from Langley, helps communities use NASA Earth science data to understand environmental challenges. It marked its 20th anniversary in 2018. Recent DEVELOP projects studied floods in South Carolina and deforestation in Colombia. South America.

than 7 billion laser shots to measure clouds and tiny particles in Earth's atmosphere. CALIPSO is a partnership



between NASA and the French Space Agency, the Centre National d'Etudes Spatiales (CNES).

Researchers continued to refine new lidar remote sensing instruments. Langley's High Spectral

Resolution Lidar, which represents the next step in the technology employed by CALIPSO, promises to be a key component in the quest to understand climate. Work also continued with Langley's Doppler Aerosol WiNd lidar instrument, or DAWN, which measures wind speeds at various altitudes when pointed from the belly of



Langley is developing lidar technologies that could one dav measure wind speeds from space, improving weather and storm

#### Earth Science 🦱

### EXPLORE EARTH

# *Life at the Lab: Observing Ozone*

Langley scientists currently monitor ozone recovery with a powerful instrument attached to the International Space Station. Meanwhile, they're also developing a concept that would continue those measurements using innovative cubesats.

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#### Earth Science



### Atmospheric Ozone

A Good News, Bad News Story Jay Al-Saadi, a Langley atmospheric scientist, looks in the HU-25 aircraft that a NASA team used for science flights as part of the Long Island Sound Tropospheric Ozone Study, or LISTOS, during summer 2018. The study is part of a collaborative effort to understand how chemistry affects near-surface ozone when pollution is transported over water. Pollution can become concentrated when it drifts over or near a body of water leading to more intense production of ozone

Ozone is a protector of life on Earth and a pollutant That's the story up high. Down low, it's less encouraging. poisoning the air we breathe.

Langley researchers use powerful tools and innovative techniques to understand both kinds - the helpful stuff located in the upper atmosphere and the hurtful stuff wafting near Earth's surface.

"The reason we focus so much on

ozone in the upper atmosphere is

because it interacts with sunlight,"

said Rob Damadeo, a Langley

physicist who works with orbiting

science instruments.



Langley's Rob Damadeo holds a 3D-printed mockup of a new, smaller version of the SAGE instrument.

ation and produces oxygen. "This ongoing cycle keeps us safe." Damadeo said. Without it, skin cancer would be rampant and crops would fail. "Ozone is critical for the existence of life on this planet."

Today, Langley's Stratospheric Aerosol and Gas Experiment III, or SAGE III, instrument mounted on the International Space Station gathers data to verify the recovery of the ozone layer, on the mend since 1989's Montreal Protocol. And Damadeo is helping to develop a new smaller, cheaper version of SAGE that could be on orbit as early as the mid-2020s.

He explained that 10 to 30 miles up naturally occurring oxygen absorbs ultraviolet ravs from the sun, creating a reaction that produces ozone. Ozone itself then soaks up more ultraviolet radi-

Ozone near Earth's surface is created by nitrogen dioxide and hydrocarbons, gasses emitted by cars and power plants. It's a major cause of poor air quality. If breathed in sufficient concentrations, ozone irritates the lungs, creating risk for those with asthma, children and older adults.

"Up to now, satellite instruments haven't really had the sensitivity to distinguish between near-surface ozone from ozone that's up higher in the atmosphere," said Jay Al-Saadi, a Langley atmospheric scientist. "Profile measurements, like those from the SAGE series, give you that profile in the upper atmosphere, but can't see down to where the bad ozone resides."

To address air quality related to bad ozone, a space instrument called TEMPO, short for Tropospheric Emissions: Monitoring of Pollution, will launch in coming years, offering a more complete view of conditions over North America. TEMPO will measure chemicals that combine in the lower atmosphere to create ozone - nitrogen dioxide and formaldehvde - as well ozone itself.

Ball Aerospace & Technologies Corp. is building TEMPO, which represents an important step toward a global pollution measurement.

"As we get a better handle on our own emissions and things we can do to improve air quality, it becomes a bigger question about what's being blown into your area from further away," Al-Saadi said, "the stuff that you can't control."

#### Earth Science

## EXPLORE MOON to MARS



Reach to Deep Space

Langley researchers made leaps ahead in 2018 as they shaped hardware that NASA needs to propel human exploration to the Moon, Mars and worlds beyond.

By advancing robotic construction in space, Langley helps make it possible for NASA to send astronauts on long, pioneering journeys. Through projects like Robotic Assembly of Modular Space Exploration Systems, or RAMSES,

researchers help NASA prepare for space missions of tomorrow.

Toward that goal, Langley forges public-private partnerships, including those through the In-space Robotic Manufacturing and Assembly project. The Dragonfly reversible precision joint, developed in partnership with Space Systems Loral, will contribute to self-assembly of satellites. Working Northrop Grumman, a team successfully completed tests of a Langley robotic arm called Tendon Actuated Long-reach In-Space Manipulator, or TALISMAN.

Langley also partners with private companies to increase access to destinations in the solar system. Researchers work with Blue Origin to advance sensor suites to enable landing anywhere on the lunar surface and with United

A prototype Orion crew module built

at Langlev for the Ascent Abort-2

flight test is hoisted in preparation

for transit to Joint Base Langlev-

Eustis, where it was painted. The

flight test is scheduled for 2019.

Elsewhere, the center contributed entry, descent and landing expertise to planetary missions including Mars InSight and Mars 2020. Work also was underway on Mars Entry, Descent and Landing Instrumentation 2, or MEDLI2, an instrument suite that will gather data during the descent of the Mars 2020 vehicle to the Mars surface. The data it collects will help NASA improve landing systems in years ahead.

Finally, Navigation Doppler Lidar, a technology designed to help spacecraft arrive safely at destinations including the Moon, continued to push forward. Researchers plan to conduct a flight test in 2019. On Earth, the system has potential to improve self-driving cars and autonomous aircraft.

delivering heavy payloads through an atmosphere to the surface of a planet.

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The inflatable heat shield that will travel through the atmosphere in the LOFTID test will be built to withstand temperatures of



Launch Alliance to achieve the Low-Earth Orbit Test of an Inflatable Decelerator, or LOFTID.



Langlev researchers, from left, Carlie Zumwalt, Rob Maddock and Danie Litton used computer models to examine entry, descent and landing scenarios for Mars InSight

### Space Exploration 🦱

### EXPLORE MOON to MARS

Life at the Lab: Caution — Robots Working

In labs and workshops at Langley, researchers are working to devise methods of robotic construction in space. Working with commercial partners, they're creating a technological tool kit that will enable NASA to build structures on orbit — improving efficiency and cutting costs. It's a vital part of NASA's plans for exploration of the solar system, from the Moon to Mars and beyond.

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### Space Exploration

### Another Giant Leap

Langley Guides **Exploration Forward** to the Moon and Mars

Autonomous aggregation in space is a key element of NASA's plans for human exploration of the solar system, from the Moon to Mars and beyond. In this photo, researchers lok Wong, left, and Kyle Doyle work at Langley to set up a demo of two robots designed to assemble truss segments in space.

NASA will once again lead the way as humanity rockets beyond low Earth orbit, toward the Moon and into a new era of deep space exploration.

By 2022, the agency plans to deliver a power and propulsion segment to lunar orbit that represents the foundation of a Lunar Orbital Platform-Gateway, infrastructure for longterm human exploration and development of the Moon.

> Experts at Langley helped to shape plans for the gateway and, in typical fashion,

> they're already thinking about

what comes next. NASA

is implementing President

Donald Trump's Space Policy

Directive 1, which instructs the

agency to work with industry to achieve a human return to

the Moon, followed by mis-

sions to Mars and beyond.

Pat Troutman is a Langlev space architect who has worked on mission concepts for decades, including early plans for the International Space Station.

> "Langley has always blazed the path," said Pat Troutman, who serves as the lead for strategic assessments of the agency's Deep Space Gateway and Transport Activity. He works with a team of about 20 people at Langley who test logistics for new space missions. As the agency's co-lead for Systems Analysis of Human Exploration Systems, Langley's group considers the vehicles, propulsion systems, airlocks, habitats and rovers needed for missions.

"These are folks with a passion for space exploration," Troutman said. "It's one of our designated leadership roles.



We do analysis of the systems, not detailed design, but it's still key. We're always looking forward to the next set of human missions, how they would be formulated, what they would cost."

Langley's team answered those questions for gateway concepts. "Now, we're moving on to the next assignment, returning to the lunar surface," Troutman said. "That's our current task. We're serious about going to the Moon and doing it in a sustainable manner."

He said Langley established a niche in this area because engineers at the center have wide-ranging expertise allowing them to rapidly reformulate concepts as mission goals are juggled. "When requirements change, the architecture has to change," he said. "We're really light on our feet. We can react quickly."

Having worked on plans for the International Space Station from the beginning, Troutman is an experienced space architect. He understands Langley's place in the story of American space exploration – past, present and future.

The gateway and Moon exploration represent a new chapter in that story and a jumping off point for more human exploration of the solar system.

"We want to expand the human sphere of influence beyond Earth in order to further our knowledge, enhance our guality of life and assure humanity's survival," Troutman said.

"It's a really exciting time," he said. "The future is changing and we're going to be part of it."

### Space Exploration

## **EXPLORE** LANGLEY

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Inset is an architectural rendering of the building.



### Build the Future

Langley in 2018 pushed ahead on an ambitious revitalization plan that's changing the face of the center as it promises to boost capabilities, save energy and ensure that Langley remains a vital asset for the nation well into the 21st century.



Construction on the center's five-story Measurement Systems Laboratory began in 2017, but Langley's first new lab in nearly 35 years truly started taking shape in 2018. Its contours were visible to anyone driving past on Commander Shepard Boulevard.

The energy-efficient MSL will contain 175,000 square feet of modern lab space, allowing Langley to remove approximately 200,000 square feet of aging and obsolete facilities. Designed to be versatile, it will house 40 modular labs for research and development and accommodate a staff of nearly 275. A rooftop laser lab will let researchers test lidar instruments that shoot horizontally or vertically.

With exterior concrete and steel completed, general contractor W.M. Jordan Co. of Newport News, Virginia, directed crews to install walls and windows, pipes and wiring.

When completed in 2019, it will be a premier research and development lab enabling advancements in optics, laser and lidar systems, advanced sensors, electromagnetics, electronics, and digital flight systems.

or ALIFT.

as UAVs or drones.



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Rehabilitating existing space represents another essential part of Langley's rehabilitation plan. In 2018, a building that previously contained office space was converted into the center's Safety-Critical Avionics Laboratory. The same building's high-bay area was converted to accommodate the center's new Autonomy Lab for Intelligent Flight Technology,

The ALIFT lab includes internal and external flight areas for unmanned aerial vehicles, known



In the high bay section of Langlev's new autonom lab. which opened in 2018 researcher Derek Goddeau checks on hardware being tested for an in-space assembly project

Leaders also look forward to breaking ground on another new facility, the fifth in Langley's current revitalization effort. The Flight Dynamics Research Facility, or FDRF,



Langley's next major construction project will be the Flight Dynamics Research Facility, a vertical wind tunnel that will help NASA improve designs of aircraft and spacecraft.

will be a highly versatile and cost-effective vertical wind tunnel replacing the center's 77-year-old 20-Foot Vertical Spin Tunnel. In April 2018, NASA signed an agreement with the U.S. General Services Administration to begin design on the building.

#### Transformation

### EXPLORE LANGLEY

### A Lab Comes to Life: Measurement Systems Laboratory

Langley's next new facility will be a 175,000-square-foot lab where new sensor technologies will be developed and tested. Construction on the Measurement Systems Laboratory began in 2017, but — as this time-lapse video shows — it truly began to take shape in 2018.

### **>> >> >> >> >>** >> >> >> >> >> >> >> >>



Transformation



Langley in 2018 launched a campaign to widen the center's embrace of new technologies and encourage modes of working you might not expect from a government agency.

The goal is to better align Langley's culture with the fast-paced, collaborative, technology-driven work styles common in business and industry.

Jill Marlowe leads Langley's efforts to harness the power of new technologies and collaborative modes of working.

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"Those technologies are converging to provide solutions we couldn't have imagined 10 or 20 years ago." Marlowe said.

At the same time, the number of companies entering aerospace and creating new markets around the globe is exploding - along with the number of unexpected, sectorspanning partnerships.

With these changes come opportunities. "To think that NASA is going to be exactly the same as it has been

Researchers have already been pathfinding mission uses of emerging technologies. One example is Lab 77, a team that fosters quicker, more collaborative work in areas like small satellites.

Center Director Dave Bowles championed this transformation campaign.

He directed Marlowe to lead the center's march toward a more inclusive. agile model.

"Fundamentally, this transformation is

acknowledging that the world around

us is changing," said Jill Marlowe,

who in August was appointed to a new leadership position devoted to

charting Langley's future path.

Much of the change Marlowe discribes is driven by digital advances. Improvements in autonomy, machine intelligence, data analytics and sensors are mushrooming.

doesn't make any sense." Marlowe said. "We know our role is going to need to change, too,"

As a result, new initiatives have begun to sprout at Langley. Improvements include a new "smart center" push to provide a seamless collaboration environment, expanded use of mobile apps, automating and streamlining business functions, providing plug-and-play artificial intelligence tools for researchers, and using "internet-of-things" sensors to boost performance in one of the center's busiest wind tunnels

These are important first steps that will help transformation gain momentum, leaders say,

Langley is pushing transformation beyond buzzwords. The center has a proud history of reinventing itself over its 101year history. Reinvention led to pioneering concepts for aviation, space exploration and Earth science. With new transformation initiatives, Langley is positioned to play an expanding role in today's data-driven age.

Making fruitful connections with partners in industry, academia and other areas of government is a big part of the transformation plan. Observers predict NASA will be less monolithic and more collaborative in the days ahead.

"What I hope is that Langley starts to become a mecca for more kinds of technologists," Marlowe said. "If you want to explore how to combine your technology with other advances to enable some radical aerospace mission or product, this is the place to come to get that done."

### Transformation

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\$853M

2017

\$866M

2018

Other Funds

#### Economic Impact of NASA Langley Your Tax Dollars at Work in Fiscal Year 2018



### Through NASA's **SBIR/STTR** program, Langley worked with small BUSINESSES to develop innovative technologies worth more than

### Share Discoveries, Inspire Minds

With captivating products and inspiring educational events, Langley spreads the joy of science, technology, engineering and math.



National Community College Aerospace Scholars, or NCAS, program participants learn about robotics during their time at Langley.

In partnership with

in innovation.

scientific research and

space exploration can

begin with opening young

minds to the possibilities

represented by NASA. By

inviting students of all ages

to join in NASA's quest for

discovery, Langley's Office

of STEM Engagement

helps to build a skilled,

diverse American work-

force that will excel

Newport News Shipbuilding, Jefferson Lab and the Virginia Peninsula Engineers Council, Langley hosted Engineering Career Days in February for approximately 480 Hampton Roads high school students interested in STEM-related careers. Speakers and exhibits shined light on NASA missions, internship opportunities and jobs.

The Virginia Space Grant Consortium held five high-school academies at Langley and center educators partnered with similar groups in Kentucky and South Carolina to provide teacher training in those states. Teachers from North Carolina earned NASA digital badges and toured the center. A group from the West Virginia Space Grant



Pushing the frontiers of ars Program.

agency's website.

Through these efforts and others, Langley shares the passion that helps NASA meet global challenges and explore the solar system - from the Moon to Mars.



Consortium participated in a ThinSat STEM project and the NASA Community College Aerospace Schol-

In collaboration with the Virginia Air & Space Center

Students watch as European Space Agency Astronaut Alex Gerst float aboard the International Space Station. Gerst answered about a dozen questions from regional students

and Space Grant organizations in Virginia, North Carolina, South Carolina, West Virginia and Kentucky, Langley presented an International Space Station downlink event in July. Over 800 students participated along with Pamela Northam, the first lady of Virginia. The 20-minute Earthto-space call was covered by NASA Television and the

Also, Langley educators and researchers collaborated to create a Balancing Act Spacecraft Mass Properties digital badge. The badge supplies teachers with materials about space exploration hardware and related topics in anticipation of NASA's Ascent Abort-2 test scheduled for 2019.

> Students from Saint Thomas More Catholic School in Chapel Hill. North Carolina. tour a prototype space habitat during a

### Economics and Education



# EXPLORE LANGLEY

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https://virtualtour.larc.nasa.gov

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