National Aeronautics and Space Administration

Open Innovation at NASA

Enhancing Problem Solving and Discovery through Prize Competitions, Challenges, Crowdsourcing, and Citizen Science

November 2020

Open Innovation at NASA

The Traditional NASA Community: The Agency, Industry, and Academia

NASA's civil servant workforce of scientists, engineers, program managers, and others have been a critical force in the design, development, test, operation, and management of spacecraft and aeronautics systems and an assortment of scientific research and technology projects ranging from making discoveries throughout the solar system and universe to maintaining a human presence in Earth orbit. Our highly skilled and mission-focused employees, numbering some 17,000 today, remain essential to NASA's ongoing innovation and exploration success.

NASA's greatest accomplishments, however, have hardly been NASA's alone. Working in tandem with the NASA workforce to achieve ambitious goals in space have been tens of thousands more individuals from academic institutions, private companies, and other space agencies. Today, more than 80 percent of NASA's funding supports work the Agency solicits and awards competitively. Companies of all sizes and experts in academia undertake this work through contracts and peer-reviewed grants. In addition, international space agencies and various other organizations engage in hundreds of collaborations each year. These collaborations are conducted on a no-exchange-of-funds basis via signed agreements and memoranda of understanding.

Expanding the NASA Community through Open Innovation

The Agency is further expanding the NASA community to broaden its capacity for innovation and discovery. Many federal agencies and organizations around the world have begun harnessing the perspectives, expertise, and enthusiasm of "the crowd" outside their walls to reduce costs, accelerate projects, enhance creativity, and better engage their stakeholders. NASA, too, has embraced the idea of open innovation, which incorporates challenges and prizes, crowdsourcing, and citizen science. Challenges and prizes select winners in a competitive problem-solving scenario. Crowdsourcing outsources a problem to an undefined public rather than to a specific, named group or individual. Citizen science consists of non-competitive collaborations between scientists and interested members of the public. Together, these constitute open innovation.

NASA increasingly collaborates with a more diverse set of entities in the broader national and international citizenry through a suite of initiatives. These initiatives include problem-focused challenges and prize competitions, data hackathons, and citizen science projects that engage members of the public in lending their skills, ideas, enthusiasm, and time to advance particular goals and objectives. Over the past two decades, we have supported more than 400 such projects. These public-private partnership approaches represent an additional tool in NASA's innovation toolkit—expanding our ability to collect and analyze scientific data, make discoveries, develop technologies and data applications, and solve complex problems. Our public collaborators and project partners derive value also as they gain visibility, employ their skills and acquire new ones, build companies, and more.

This report, *Open Innovation at NASA*, provides an overview of NASA's various open innovation initiatives, sharing the capability of these tools and showing how they help advance the Agency's mission and benefit those who participate. Rather than an exhaustive description of every open innovation project NASA has ever supported, this overview highlights many of our recent successes. Although focused primarily on initiatives seeking public participation, this report also shows how we are using open innovation inside NASA to find and share knowledge across our broad, talented workforce. By sharing the outcomes of these open innovation initiatives, we hope to inspire further efforts to feature the world's people in our work of innovation and discovery—and to show individuals and groups from around the world the value of their participation with NASA, encouraging them to join us in the pursuit of knowledge, innovation, and exploration.

NASA Open Innovation Initiatives

	Centennial Challenges	NASA Tournament Lab	International Space Apps	Student Challenges	Citizen Science	NASA@WORK
Duration	Years	Months	Days or weeks	Months	Years	Weeks
Awards	$100K+ to $Ms	$1K to $250K	Recognition only	Varies	Recognition only	Recognition only
Products	Technology demonstrations	Ideas, design, software	Software apps, technology concepts	Design	Scientific observations and analysis	Ideas and information
Who	U.S.-led (to win prize)	Worldwide, U.S.-led (COMPETES)	Worldwide	U.S. students	Worldwide	NASA only
Authority	NASA prize authority	Procurment, COMPETES Act	Space Act	Space Act, grants, and cooperative agreements	American Innovation and Competitiveness Act	N/A

Centennial Challenges

$8.5M+ Invested in competition by allied organizations

$10M+ Total prize purse awarded

$11M Total participant investment

52 Number of winning teams

39 U.S. states represented

Goal: To stimulate research and technology solutions to support NASA missions and inspire new national aerospace capabilities through public prize competitions.

The Spirit of Competitive Innovation

Centennial Challenges was initiated in 2005 to directly engage the American public in the process of advancing technology development, with winners receiving cash prizes.

In 1927, Charles Lindbergh won the Orteig Prize for crossing the Atlantic Ocean. In 2004, Scaled Composites won the Ansari X Prize for reaching the edge of space in a piloted vehicle. Taking note of these developments, NASA recognized the valuable role that prize competitions could play in stimulating creative ideas. In particular, NASA sought innovation to address the technical hurdles of the Vision for Space Exploration, President George W. Bush's ambitious initiative to return humans to the lunar surface and then send them to Mars. The Agency received legislative authority to use appropriated funds to conduct public prize competitions and consequently established the Centennial Challenges program of prizes for specific achievements.

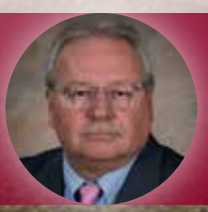
To this day, Centennial Challenges offers incentive prizes to generate revolutionary solutions to problems of interest to NASA and the nation. The 19 challenges conducted so far have supported technology development in areas including: propulsion, robotics, communication and navigation, human health, destination systems, science instrumentation, nanotech, materials and structures, and aerodynamics. In keeping with the spirit of the Wright Brothers and other American innovators, Centennial Challenges seeks innovations from diverse, multi-disciplinary and non-traditional sources including individual citizens as well as academia, industry, and other government agencies. Prize purses have been up to $5 million for a given challenge, and team members must be U.S. citizens or entities to qualify to win cash awards.

Centennial Challenges to Date

- ☐ CO_2 Conversion (2018-)
- ☐ Space Robotics (2016-)
- ☐ Vascular Tissue (2016-)
- ☐ Cube Quest (2015-)
- ☑ 3D Printed Habitat (2015-2019)
- ☑ Mars Ascent Vehicle (2015-2016)
- ☑ Sample Return Robot (2012-2015)
- ☑ UAV Ops (2013-2015)
- ☑ Night Rover (2012-2013)
- ☑ Nanolaunch (2011-2013)
- ☑ Green Flight (2010-2011)
- ☑ General Aviation Tech (2007-2008)
- ☑ Regolith Excavation (2006-2008)
- ☑ Astronaut Glove (2008-2009)
- ☑ Personal Air Vehicle (2006-2008)
- ☑ Lunar Lander (2005-2009)
- ☑ Moon Rox (2008-2009)
- ☑ Strong Tether (2005-2011)
- ☑ Power Beaming (2005-2008)

"The final designs are amazing. They are far beyond our current state of knowledge and will greatly impact our lunar and Mars mission architecture for manufacturing and construction."

— John Vickers, NASA Principal Technologist, on 3D Printed Habitat Challenge



Team Penn State prepares their 3D-printer to begin printing a subscale habitat structure at NASA's 3D-Printed Habitat Challenge, held at the Caterpillar Edwards Demonstration & Learning Center in Edwards, Illinois, May 1-4, 2019. Photo: NASA/ Emmett Given.

3D-Printed Habitat

Developing housing solutions for extended-duration missions on planetary surfaces using 3D construction technology

$3.1M Prize Purse

$2.1M Awarded

- 240 teams: 167 U.S. and 73 international
- 3-phase challenge
- Allied Organization: Bradley University, with sponsorship from Caterpillar Inc., Bechtel Corp., Brick and Mortar Ventures, and American Concrete Institute

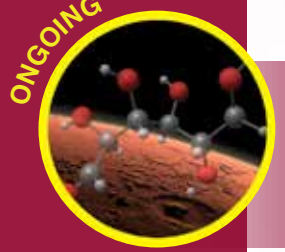
Cube Quest

Advancing CubeSat technologies for operations in low Earth orbit, the Moon, and beyond

$5M Prize Purse

$460K Awarded to Date

- 3 payload slots on Space Launch System Artemis-1
- Currently in second of three challenge levels: Deep Space Derby
- 15 U.S. teams
- NASA-led challenge



CO_2 Conversion

Developing technologies to manufacture a high energy substrate to serve as "food" for microbial reactors

$1M Prize Purse

$250K Awarded to Date

- Human Exploration and Operations (HEO) Mission Directorate and Exploration Research & Technology (ER&T) funding collaboration
- Phase 2 under way
- NASA-led challenge with contractor support

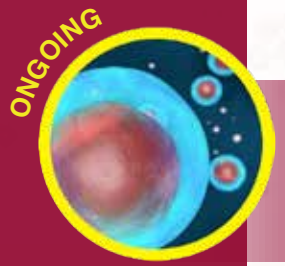
Space Robotics

Advancing robotic software and autonomous capabilities for space exploration missions

$1.9M Prize Purse

$570K Awarded to Date

- 214 teams: 179 U.S. and 35 international
- Phase 2 under way
- Allied Organization: Space Center Houston
- Sponsor: Nine Sigma



Vascular Tissue

Creating thick human vascularized organ tissue in an engineered environment while maintaining tissue function

$500K Prize Purse

$0 Awarded to Date

- Innovation in engineered tissue that can stay viable for more than 30 days
- 22 teams
- Allied Organization: New Organ Alliance

Riding the Wave of Exploration with NASA

For the past 16 years, Centennial Challenges competitions have contributed to NASA's technology goals and needs as well as technologies that are focused on improving life on Earth. In Cube Quest Challenge, teams of academic or private sector "citizen inventors" are breaking new ground in affordable communications, navigation beyond Earth, and long-term survival. These achievements help NASA explore and conduct science in deep space in novel, more affordable ways. The 3D Printed Habitat Challenge enabled teams to showcase revolutionary construction technologies. For example, Branch Technology, a winner of an early phase of the challenge, has patented a 3D-printing process called Cellular Fabrication, C-Fab™, that they demonstrated at the competition. This unique printing method allows material to solidify in open space, creating a matrix of polymer in virtually any shape to create next-generation wall systems.

While NASA retains responsibility for competitions, Centennial Challenges partners with outside organizations that bring the resources and expertise needed to support the execution of competitions, which often involve technology demonstration events. These "allied organizations" reap benefits as they support the competitions. For example, the 3D-Printed Habitat Challenge featured Bradley University as an allied organization. Bradley's partnership with NASA gave the school national and world exposure and provided value to the students by inspiring them in their studies, giving them mentorship opportunities, and showing them successful field practices. Faculty benefited from opportunities to network with those in other universities and companies. Several graduate theses were written and two of the winning teams continued collaboration with NASA. Bradley's sponsors—Caterpillar, Bechtel, and Brick & Mortar Ventures—established relationships with innovators on the competing teams whose work could be disruptive and transformational in the construction industry.

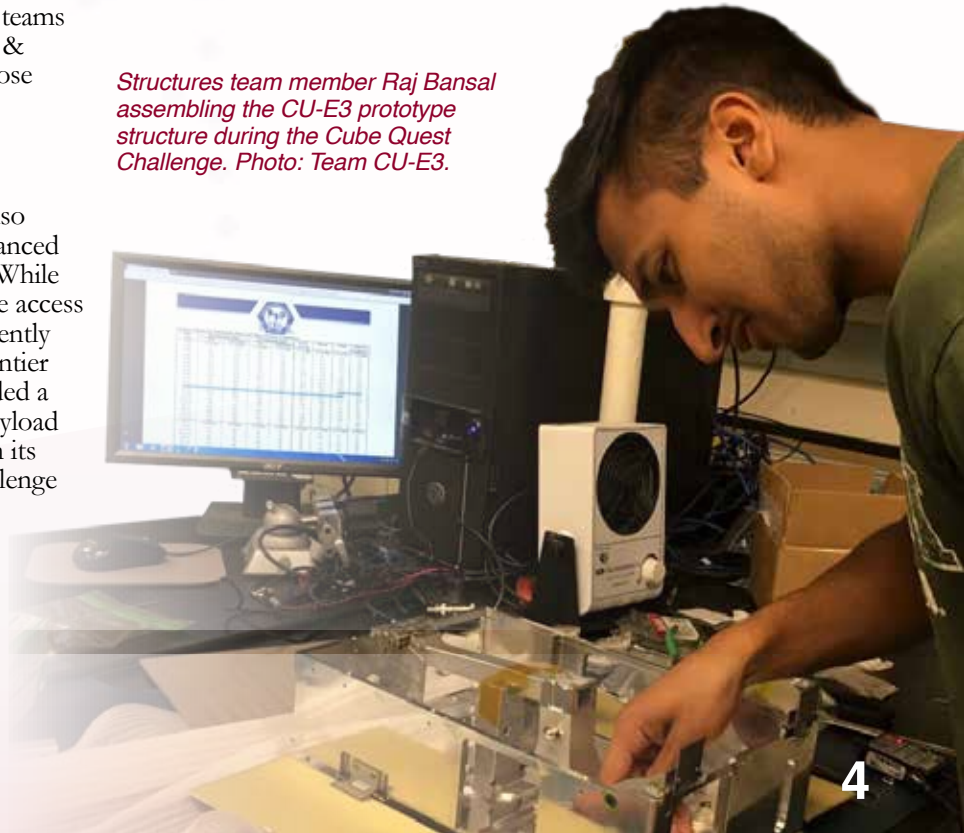
Centennial Challenges competitions are structured to offer visibility and incentives to independent inventors including small businesses, student groups, and individuals to participate in technology development that has a long-term value to NASA and may also have potential for commercialization. Several teams have attracted investment and advanced companies that have gone on to support the aerospace industry and other disciplines. While teams retain all rights to the technologies developed, NASA has the option to negotiate access to the technologies after the competitions. Some Centennial Challenges teams are currently supporting NASA future lunar missions including Masten Space System and Final Frontier Designs. Masten, winner of the 2009 Lunar Lander Challenge competition, was awarded a $75.9 million contract in April 2020 under the terms of NASA's Commercial Lunar Payload Services initiative to deliver eight science payloads to the Moon's south pole in 2022 on its XL-1 lunar lander. Final Frontier Designs, a winner of the 2009 Astronaut Glove Challenge competition, was awarded multiple contracts in June 2020 for components of NASA's next generation xEMU lunar space suit.

"The level of thought that people gave to a really hard problem was commendable."

—Jana Stoudemire, Space Tango
CO_2 Conversion Challenge Phase 1 Judge

"One of the hardest problems you have given the community…these proposals are among the cream of the crop we have ever seen."

—Ian Rowe, U.S. Department of Energy
CO_2 Conversion Challenge Phase 1 Judge



Structures team member Raj Bansal assembling the CU-E3 prototype structure during the Cube Quest Challenge. Photo: Team CU-E3.

NASA Tournament Lab

Crowdsourcing: Reaching Beyond NASA's Orbit

The NASA Tournament Lab (NTL) enables NASA to tap the vast creative potential of people across the world through open innovation in the form of crowdsourcing.

Since 2011, NASA's scientists, engineers, and others have launched more than 300 challenges and crowdsourcing projects through the NTL, seeking innovative, efficient, and optimized solutions for specific, real-world challenges the Agency faces. Technical projects have included ideation, system architecture design, algorithm performance improvement, and the development of software and applications. Non-technical projects have comprised efforts such as graphics and video work.

The NTL offers access to a wide variety of private sector, open innovation platforms to solve problems (or problem-solving platforms) that reach millions of individuals around the world. Some platforms specialize in running competitions while others allow NASA to assign tasks to individuals. In both cases, NASA funds the platform to run the competition, make cash awards for top ideas (in the case of competitions), and in some cases pay for crowdsourced work. In addition to these platforms, the NTL also makes technology search and external data review capabilities available to support NASA's needs.

The NTL is managed by NASA's Center of Excellence for Collaborative Innovation (CoECI) at Johnson Space Center and was established in 2011 at the request of the White House Office of Science and Technology Policy (OSTP). In addition to supporting the needs of NASA employees, CoECI makes its expertise and its suite of contracted platforms available to innovators across the federal government interested in using challenges and crowdsourcing capabilities to support their work. CoECI also manages NASA@WORK, an Agency-wide, virtual platform that seeks to increase innovation by fostering collaboration within NASA (see pages 21-22).

300+ Number of Challenges

92% Met or Exceeded Expectations

80% Reported Cost Savings

Goal: To engage the crowdsourcing community in challenges to create the most innovative, efficient and optimized solutions for specific, real-world challenges being faced by NASA and other Federal Agencies.

NASA's Johnson Space Center Biochemistry Lab needed a better way to collect crew nutrition data on the International Space Station (ISS). The team's Topcoder challenge resulted in an iPad App currently in use by ISS crew with significant improvement in the capture of astronaut nutrition information. Astronaut Peggy Whitson is seen using the app during Expedition 50. Photo: NASA.

"It was helpful to seed our approaches with ideas from folks around the world."

—Dr. Julia Badger, NASA Johnson Space Center, on Robonaut Vision Challenge

NASA Open Innovation Capabilities

70M
Crowdsourcing Members

18
Crowdsourcing Communities

NASA is hoping to use new aerosol monitoring technology to keep astronauts breathing easy. The agency, in collaboration with the Robert Wood Johnson Foundation, selected St. Louis-based Applied Particle Technology, LLC as the $100,000 grand-prize winner of its Earth and Space Air Prize Competition. Jiaxi Fang, pictured here, is CEO and Co-Founder of Applied Particle Technology. Photo: NASA.

"The CoECI team members are irreplaceably great trailblazers!"

— Dr. Paul Mudgett, NASA Biomedical Research and Environment Sciences Division, on Earth and Space Air Prize

A Fertile Base for Creative Problem Solving

Crowdsourced research projects, challenges and prize competitions, hackathons, and public deliberations provide members of the public opportunities to bring their enthusiasm, skills, and ideas to bear on NASA science and technology programs and directions. In effect, the NTL promotes and enables NASA to increase its creative capacity by leveraging innovative solutions to complex problems.

In recent years, solutions produced under the auspices of the NTL supported a variety of NASA needs, including mitigation of certain space or planetary environmental conditions, software development, chemical detection, and graphic design and document layout. For example, NASA ran two challenges on the Topcoder platform, which specializes in software and coding challenges, to improve computer vision for the Robonaut 2 project. The challenges resulted in algorithms to provide the basis for computer vision and accelerate project development. The Dust Mitigation Technologies Challenge helped NASA explore innovations created by many terrestrial industries such as mining, food, and cosmetics that have created unique dust mitigation capabilities. The resulting solutions supported NASA's need to protect the health of astronauts traveling to the lunar surface, ensure accuracy of instrument readings, prevent vision/optical system obscuration, and prevent or mitigate equipment failure.

Through partnerships with other organizations, the NTL challenges are helping NASA to advance its goals in tandem with other non-NASA, societal goals. NASA teamed with the Robert Wood Johnson Foundation to conduct the Earth & Space Air Prize, a multi-phase challenge to design and demonstrate small, affordable, and easily maintained aerosol sensors. NASA sought a technology to acheive the needed sensitivity, longevity, and ability to operate in a reduced-gravity environment while the Robert Wood Johnson Foundation desired a similar sensor capability for city air monitoring. The challenge awarded $250,000 and resulted in the development of two high-accuracy, low-maintenance prototype air quality sensors that are undergoing further development and testing. The NTL also supported the Next-Generation Animal Tracking Challenge, a collaboration of NASA's Human Exploration and Operations Mission Directorate and the Department of Interior's Bureau of Ocean Energy Management (BOEM). This challenge sought ideas for using CubeSats for remote surface-tracking capabilities. NASA would apply these capabilities to future lunar or Mars missions, while BOEM wanted to follow animal position and path movement in U.S. waters. Receiving numerous ideas and concepts, this challenge provided a solid foundation from which to begin creating a design and proof of concept. In addition, NASA has collaborated for several years with the Houston Cinema Art Society on CineSpace, a short film competition using NASA imagery. Enabling creative relationships at the intersection of art and science, the competition has yielded dozens of inspiring films, the best of which are screened at the annual Houston Cinema Arts Festival.

Participants have reaped benefits by engaging in the NTL challenges and crowdsourcing projects. Opportunities for skill-building and community engagement, for example, motivated Lauren Fell, a quantum cognition graduate student, to participate in multiple NTL challenges. Having matured her expertise in CAD modeling, 3D printing, robotics, and storyboarding, Fell says: "The most valuable benefit of participating in these challenges has been the skills I have gained through completing them. It's been great to feel involved in some of the projects NASA is undertaking. Having the opportunity to contribute in some small part to space exploration is a real dream."

Lauren Fell stands with a collection of her challenge solutions. Photo: Lauren Fell.

NASA International Space Apps Challenge

29K Participants in 2019

225 Worldwide Locations in 2019

71 Countries Represented in 2019

Goal: To inspire local communities to come together, think intensely, and create solutions to important problems.

Free and Open NASA Data: Tell Us What You Can Do With It

The International Space Apps Challenges introduces problem-solvers worldwide to NASA's free and open data. By using NASA data to solve challenges, Space Apps teams learn about NASA's data and share in the creation and application of the knowledge that results.

NASA created the International Space Apps Challenge in 2012 as a way to encourage people all over the world to use NASA's huge storehouse of open data gathered over several decades. People leverage these data to build innovative solutions that can contribute to their own communities as well as provide insight or new thinking for NASA's mission-related challenges. Formulated with the intent to build an innovation community around Earth- and space-related challenges, Space Apps has become the world's largest global annual 48-hour hackathon event. Hackathons are physical or virtual competitive environments designed to produce functioning solutions within a very short amount of time—the kind of situation that tends to promote out-of-the-box thinking.

NASA gathers subject matter experts, cleans up datasets, and issues the challenges. Individual communities worldwide serve as local event hosts by raising funds, securing venues, and managing logistics, outreach, and local volunteers. Space Apps grew from 25 locations in 2012 to 225 locations in 71 countries with over 29,000 global participants in 2019.

Space Apps does not offer cash prizes but rather provides participants an opportunity to innovate around Agency open data and open source code. In a sense, NASA offers data for free and challenges people all over the world to play with it and display their talent to the Agency. The results can go a long way toward helping NASA with its mission and strengthening communities here on Earth.

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"I'm excited today that there are going to be so many people that are new to coding just stepping out, having fun and learning to be creative and using technology as a tool."

— Kimberly Bryant
Founder of Black Girls Code at Space Apps 2016, Pasadena, CA

"We are excited to join teams all around the world to solve NASA challenges, as it is through such teamwork and collaboration that we will again reach the Moon by 2024."

— Lisa Watson-Morgan, Program Manager, NASA Human Landing System

KBR intern Cory Haralson (far right) and his team StarStruck are global winners on the 2019 NASA Space Apps Challenge. Photo: NASA

Best Use of Data: AEDES PROJECT

Manila, Philippines

The solution that best makes data accessible, or leverages it to a unique application.

The AEDES PROJECT developed an automated information portal that correlates dengue cases and deaths with real-time data from climate, google searches, and satellite maps, giving an advance indicator of when dengue will emerge and potential dengue hotspot locations.

Best Use of Hardware: Cafeína

Salvador, Brazil

The solution that exemplifies the most innovative use of hardware.

Cafeina developed Ocean Ride, a microplastic collection system that works as a dockable object on any boat and can be a fixed platform strategically positioned in the areas of sea currents where there is a large flow of microplastics.

Best Mission Concept: c.a.w.s.t.o.n.

London, United Kingdom

The solution with the most plausible solution concept and design.

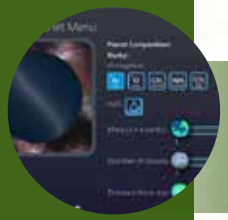
Team c.a.w.s.t.o.n. developed phoeNEX, which uses a combination of NASA's Landsat 8 data and Fire Information for Resource Management System (FIRMS) data to geographically locate and track fires.

Galactic Impact: Massa

São Paulo, Brazil

The solution with the most potential to improve life on Earth or in the universe.

Massa's solution is Poseidon, an application programming interface (API) that can be consulted by governments and third parties to detect ocean oil spills by analyzing satellite imagery using artificial intelligence and deep learning model.

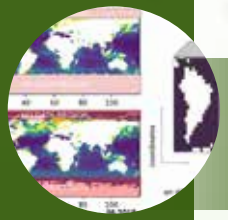


Most Inspirational: StarStruck

Huntsville, USA

The solution that captures our hearts.

Team StarStruck developed Plan-It, a game that allows the player to create their own solar system with unique and intriguing planets. The goal is to interest people in astrophysics and provide an easy way to get into the study of space.



Best Use of Science: The Great Bloom Theory

Poznan, Poland

The solution that makes the best and most valid use of science and/or the scientific method.

The Great Bloom Theory developed a machine learning solution designed to predict harmful algal blooms in a way that would facilitate the discovery of the interplay between known factors. This prediction model could inform more efficient prevention methods applied locally.

An Outlet for Innovation Where None Existed Before

Space Apps inspires collaboration, creativity, and critical thinking in a fast-paced environment, bringing together diverse skills and experiences into teams that help generate unexpected, creative, and compelling solutions to problems. The graphic to the left shows the top solutions developed in 2019 out of 2,067 proposed. While some solutions have a global reach, such as Team Massa's Poseidon app to monitor the oceans for oil spills, others were intended by the participants for use in their own communities. The Philippines-based team AEDES Team developed software leveraging NASA data to improve public health response against dengue in the Philippines. Meanwhile, London-based team c.a.w.s.t.o.n. created phoeNEX, a community driven firefighting and fire mitigation application for use on mobile devices. In 2020, NASA conducted a special edition of Space Apps centered on the COVID-19 pandemic, which led to the development of thousands of applications to improve understanding and ameliorate the impacts of the global crisis.

In addition to yielding thousands of societally relevant uses of NASA data, Space Apps creates an enormous community of individuals and teams willing to support this yearly initiative. This community includes not only software developers, but also artists, designers, storytellers, policy strategists, and hardware specialists. Space Apps organizers make a concerted effort to support participants in their pursuits. For example, Space Apps has offered "data boot camps" to familiarize new participants, particularly women and girls, with how to work with NASA data. Participants in these NASA activities have reported time and again that their involvement has given them enjoyment, satisfaction, or a feeling of empowerment for making contributions to Earth and space exploration.

NASA is now making a focused effort to pair winning project teams with a mentor with subject matter expertise. This mentor will help identify opportunities for the team, making introductions to useful resources and influential people. In this way, NASA can assist winners in finding a "home" for their ideas without any exchange of funds from NASA itself. Space Apps also trains its local leads to perform a similar function, helping to accelerate and incubate local projects after the hackathon. Successful projects go on to attract investment from local governments and companies, and local leads acquire planning and networking skills that lead to their own job opportunities and entrepreneurship.

Further, Space Apps provides opportunities for community engagement and development. In addition to incentivizing innovation and driving collaboration in Earth and space science and technology, Space Apps offers its local leads countless opportunities to network and grow their capacities as organizers, entrepreneurs, and community leaders. Some founded their own business accelerators; others find opportunities in science and technology education. Concomitantly, Space Apps also serves a diplomatic function, with its community of local leads often heavily engaged with U.S. embassies and diplomatic posts around the world. NASA engages the U.S. Department of State every year to ensure that opportunities are extended through posts around the world that take an interest in Space Apps.

Students participate in a Space Apps challenge focused on Earth and space (2018). Photo: NASA.

STEM Student Challenges

Leveraging Young Minds in Finding Solutions

STEM student challenges serve the dual aim of attracting, engaging, and educating American pre-college and higher education students and educators as well as providing NASA with fresh sources of innovation.

NASA is committed to engaging students across the United States from elementary through college levels to join us on our journey of exploration and discovery. NASA's STEM engagement activities are designed to attract, engage, and educate students as well as support educators. Activities to this end include internships and fellowships, research and development opportunities, challenges and competitions, pre-college and higher education STEM learning experiences, educator and faculty support, and institutional investments. Students are invited to work alongside NASA engineers, scientists, and technologists; participate in experiential learning opportunities; engage in exhibits and activities in museums and out-of-school programs; and benefit from NASA investments in faculty, teachers, and institutions all over the nation.

In addition, NASA scientists, engineers, and education specialists recognize the value that student-focused challenges and contests can bring to both students and the Agency. Competitions are motivating and drive students to act individually or work in teams to solve tough NASA-related problems, Students are called on to apply and sharpen their STEM skills and inspiring them to pursue STEM careers at NASA or elsewhere. At the same time, the Agency's student-focused challenges and contests can inspire potential novel solutions to tough problems.

233

Number of Teams in 2019

Goal: To create unique opportunities for students, build a diverse future STEM workforce, and strengthen public understanding.

"Twenty-three university teams submitted full proposals describing their Mars Greenhouse designs for the 2019 Big Idea Challenge and five teams were selected to present their proposals to a panel of experts. All the students involved gained a real understanding of the challenges of space exploration and key systems engineering skills. Through the internships provided to the winning students, NASA gained what is probably the most credible Mars greenhouse design yet developed."

— Kevin Kempton, Panel Chair, 2019 Big Idea Challenge

Students competing in the BIG Idea Challenge demonstrate their photobioreactor concept for the Sustainable Integration of Regenerative Outer-space Nature and Agriculture (SIRONA) Mars Greenhouse Design. Photo: NASA.

Student Launch

Student Launch is a research based, competitive, experiential exploration activity. It strives to provide relevant, cost-effective research and development of rocket propulsion systems.

Human Exploration Rover Challenge

The annual competition challenges high school and college students worldwide to create a vehicle designed to traverse the simulated surface of another world.

Breakthrough, Innovative and Game-changing (BIG) Idea Challenge

Student teams from Space Grant affiliated colleges and universities are challenged to design lunar payloads that demonstrate systems needed for exploration and science in the Moon's polar regions.

Robotic Mining Competition (RMC): Lunabotics

RMC teams present their robot and design philosophy; submit a paper explaining how they developed the robot, and perform outreach to under-served, under-represented students in grades 6-12 in their communities Building a robot for a simulated lunar mission is the final event.

Micro-G NExT

Micro-g Neutral Buoyancy Experiment Design Teams (Micro-g NExT) encourages undergraduate students to design, build and test a tool or device that addresses an authentic, current space exploration challenge.

Spacesuit User Interface Technologies for Students (SUITS)

SUITS Design Challenge requires student teams to design and create spacesuit information displays within an augmented reality (AR) environment.

First Nations Launch (FNL)

This competition is an opportunity for students attending a Tribal College or University, or who are members of an active American Indian Science and Engineering Society collegiate chapter to design, build, and fly a high-powered rocket.

Future Engineers Challenges

Through a series of "Future Engineers" 3D Space Challenges students focus on solving real-world space exploration problems and submit 3D model designs for 3D printable objects for an astronaut to theoretically use in space.

Mars Ice Challenge: RASC-AL Special Edition

The challenge inspires students to explore and demonstrate methods to identify different layers using system telemetry, and ultimately extract water from lunar or Martian ice deposits.

Inspiring a Future Generation of STEM Professionals

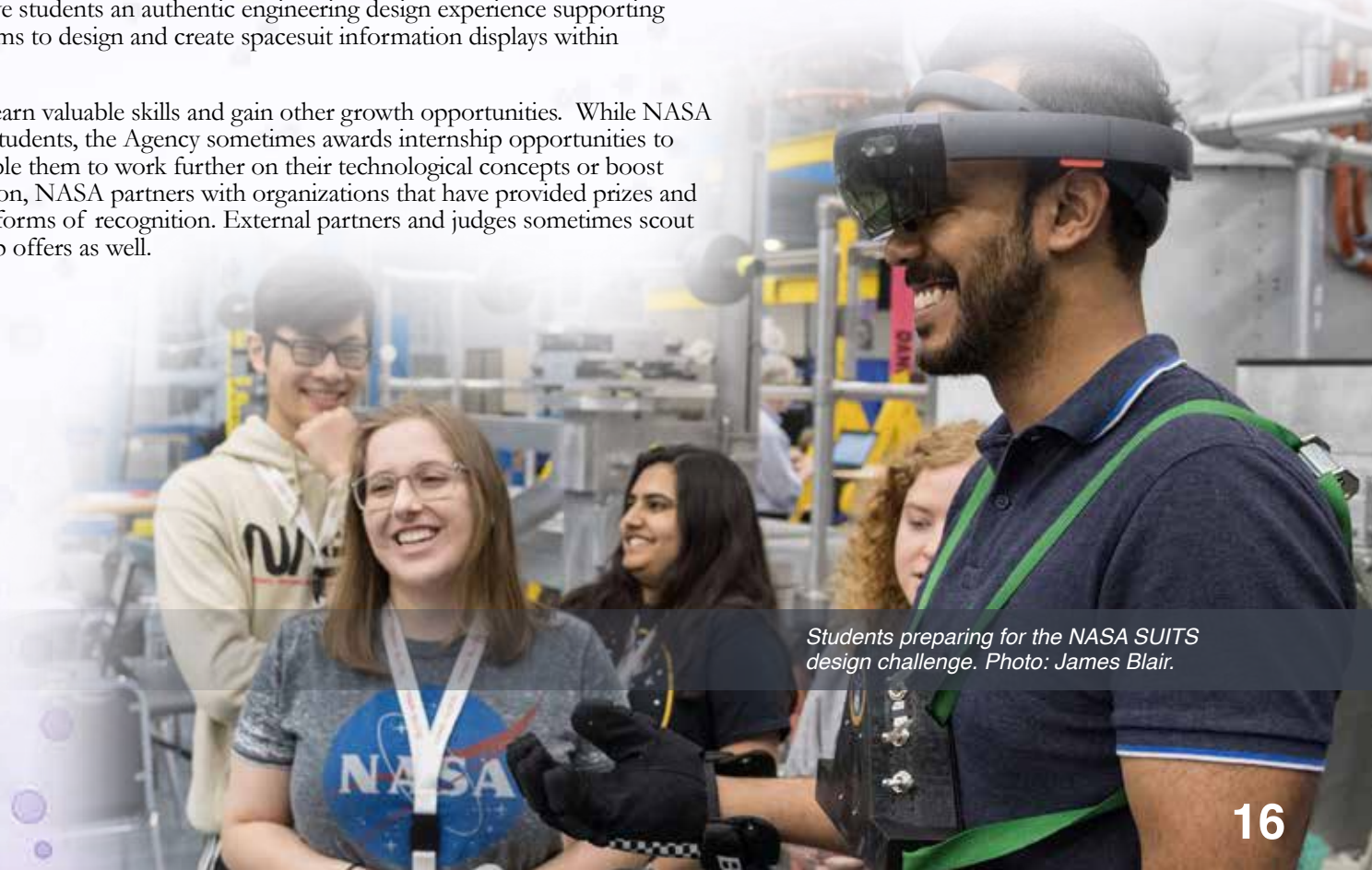
NASA's student-focused challenges and contests have drawn on the ingenuity and enthusiasm of students from elementary to college levels to design innovative solutions related to NASA-specific scientific and technical needs, while also developing critical skillsets that apply to the future of the country. For example, through a cooperative agreement, the Breakthrough, Innovative, and Game-changing (BIG) Idea Challenge provides NASA's Game Changing Development program the opportunity to engage talented university students in developing ideas and concepts for technology to improve future space missions. In addition, the Student Launch competition incorporated both a rocket design and development component and an autonomous rover or drone deployment. Several of NASA's student-focused competitions have centered on knowledge and technologies needed to support the Artemis lunar missions.

These and many other challenges provide NASA with fresh solutions to tough problems. NASA's Micro-g Neutral Buoyancy Experiment Design Teams (Micro-g NExT) challenges undergraduate students to design, build, and test a tool or device to address an authentic, current space exploration challenge. For example, a student team from Lone Star College-Cy Fair in Cypress, Texas, created a novel zip-tie cutter used by astronauts during a spacewalk on the International Space Station in 2019. NASA's Spacesuit User Interface Technologies for Students (SUITS) gave students an authentic engineering design experience supporting NASA's Artemis mission, requiring teams to design and create spacesuit information displays within augmented reality environments.

Through their participation, students learn valuable skills and gain other growth opportunities. While NASA does not typically offer cash prizes to students, the Agency sometimes awards internship opportunities to students who win competitions to enable them to work further on their technological concepts or boost future professional prospects. In addition, NASA partners with organizations that have provided prizes and in-kind support of trophies and other forms of recognition. External partners and judges sometimes scout for talent and extend student internship offers as well.

"The work of our students surpassed all expectations. Through our participation in this challenge, we have realized the value of providing an end-to-end design experience to students in the first two years of their engineering study."

— Jared Cammon, Professor of Engineering Technology at Lonestar College, Cypress Center



Students preparing for the NASA SUITS design challenge. Photo: James Blair.

Citizen Science

Members of the Public Making Real Scientific Advances

Citizen science gives the public opportunities to learn the process of science first-hand, collaborate with NASA scientists, and make meaningful scientific contributions.

NASA's citizen science projects are collaborations between scientists and interested members of the public. Through these collaborations, volunteers—known as citizen scientists—conduct cutting-edge science.

Citizen science is important to NASA's exploration missions. NASA's citizen science activities are composed of 22 ongoing projects and participation from over 100 scientists. The research they perform furthers the agency's scientific goals by analyzing and augmenting NASA's vast, unique data sets. From studies of our planet's biodiversity to exploring the sun, comets, and planets outside of our solar system, our citizen science activities involve members of the public in a wide range of investigations in space science and beyond. NASA-funded projects have engaged over a million volunteers from around the world and resulted in thousands of scientific discoveries and numerous scientific publications.

Citizen scientists provide unique skills, perspectives, and insights to NASA research that the Agency does not have in house. They collect data from far reaches of the globe, observing penguins, clouds, and aurorae. They contribute their own expertise in data science, small telescopes, even artwork. Some volunteers participate for only a few minutes. Others devote years to a project, delving deep into the professional literature, working shoulder to shoulder with the professional scientists, and even crafting their own research tools and questions. More than 138 volunteers have become co-authors on peer-reviewed scientific publications as a result of their work on NASA citizen science.

Goal: To give the public opportunities to learn the process of science through first-hand experience, collaborate with NASA scientists, and make scientific contributions.

"My favorite projects are those that engage and challenge, projects where citizens can make significant contributions and the community can be proud of its accomplishments."

— Chris Ratzlaff, Alberta Aurora Chasers

A small sampling of NASA's citizen scientists and the scientists they collaborate with (clockwise from upper left): Citizen scientist Chris Ratzlaff, astrophysicist Dr. Marc Kuchner, citizen scientist Jonathan Holden, astrophysicist Dr. Steven Silverberg, astrophysicist Dr. Nora Eisner, citizen scientist Augusto McAngus Ardizzone, citizen scientist Katharina Doll, and atmospheric scientist D. Marile Colon Robles in the center.

Citizen science has helped NASA discover:

54,000
Circumstellar disks

400,000
Martian seasonal fan structures

18,000
Mosquito breeding sites

1,500
Brown dwarfs

"Internet and smart phones make it possible for volunteers and professionals to conduct scientific research—all working together on the same science project, from around the world."

—Dr. Marc Kuchner, Citizen Science Officer for NASA's Science Mission Directorate

Expanding Scientific Research through Citizen Collaboration

The complexity of scientific research and data requirements has driven some NASA scientists to look to public participation as a means to advance their research projects. NASA's space telescopes, planetary exploration spacecraft, and Earth-observing satellites provide powerful capabilities for understanding our planet and universe through the enormous volumes of data they produce daily. Mission science teams, however, receive far more data than they can process and analyze on their own. In some cases, computer algorithms are not sufficient for detecting the kinds of patterns scientists seek in spacecraft imagery; therefore, direct human involvement remains essential. Other scientists may apply for grants to analyze collected data, but even so the amount of data available to be mined can exceed resources available within the Agency. To address this shortcoming, some scientists have tapped the community of citizen scientists who can help process large volumes of data, welcoming the public to make astronomical or environmental observations to augment or validate measurements made by spacecraft on orbit. These approaches have yielded a bounty of new discoveries.

Citizen scientists from around the world have combed through huge volumes of imagery to help identify 400,000 fan features on the Martian surface, created each spring when cold jets of gas erupt from beneath a surface layer of carbon dioxide ice, subsequently blown by winds to form long fan shapes. These discoveries contribute to our understanding of how Mars works. They have also discovered 54,000 circumstellar disks using images obtained by NASA's Wide Field Infrared Survey Explorer (WISE) mission, as well as 1,500 brown dwarfs, which are difficult to observe in the voids between the stars. Both data sets will help in our understanding of how our solar system and, by extension, our home planet formed billions of years ago. In addition, NASA-funded citizen science projects have found the oldest white dwarf with a disk (Backyard Worlds: Planet 9), the oldest planet-forming disk (Disk Detective), and a new kind of aurora (Aurorasaurus).

Earth system science has also benefited from observations and data analysis by citizen scientists, with results that directly impact our understanding of our ecosystem and our role in it. Using the GLOBE Observer app sponsored by NASA, citizen scientists have uncovered over 18,000 mosquito-breeding sites, capturing data useful for tracking mosquito-borne diseases. These ground observations complement data gathered by NASA Earth observing satellites. The GLOBE Observer app enables citizen scientists to easily collect ground observations of cloud formations, land cover, and the distribution of trees.

The proliferation of smart mobile devices and a growing interest among the public to contribute to our understanding of our home planet has effectively augmented NASA's cadre of scientists, amplifying their capability to rapidly identify trends and recommend solutions to environmental problems that may be detected.

Lauren Farmer, a citizen scientist in Canberra, Australia, collects Earth science data through the GLOBE Observer Program. During the last Arctic summer, she helped obtain the program's most northerly observation at the geographic North Pole. (Photo: Lauren Farmer)

NASA@WORK

120 Challenges since 2010

87% Successful solutions

53% Technical challenges

47% Non-technical challenges

Goal: To foster collaboration across the entire NASA community through interactive challenges and problem solving.

NASA@WORK

Going Above and Beyond

NASA@WORK is an internal, Agency-wide platform that provides NASA employees an unconventional and inventive way to share knowledge and advance projects.

Operated by NASA's CoECI, NASA@WORK is an internal, no-fee platform that allows NASA employees to connect with each other to find solutions to problems. With a civil servant and contractor workforce of tens of thousands spread out over ten field centers, NASA has a great deal of resident knowledge and talent that can be leveraged to solve problems. However, it can be difficult for individual employees to know who can help provide expertise or ideas to address a need they have. Employees can issue challenges or calls for ideas to their colleagues via the NASA@WORK platform to receive insights and promote interactive discussion. Those who provide winning ideas (as identified by the idea seeker) receive recognition. Because NASA@WORK competitions are easy and free to employees to conduct, they are often a first step toward gathering knowledge in advance of conducting a public competition.

"The NASA@WORK program does more than just crowd-source solutions, it gives the solution-seekers a different take on their own work."

— James (Jake) Mireles
KBRwyle Business Data Analyst, NASA JSC

"This platform is a great way to develop motivation for change by collaborating with fellow employees into one shared vision of "One NASA." It gives a rare opportunity to contribute to projects from different Centers that would not be possible otherwise."

— NASA Shared Service Center Communication Specialist Venetia Gonzales

Small Challenges, Big Impacts for the Agency

CoECI has supported more than 120 challenges and calls for ideas on the NASA@WORK platform, resulting in low-cost, high-efficiency solutions that have improved NASA's ability to support its mission.

As the COVID-19 pandemic started to spread, NASA engaged its workforce through NASA@WORK to help find ways to mitigate the impact of COVID-19 and support the search for a cure. Through NASA@WORK, engineers at NASA's Jet Propulsion Laboratory (JPL) designed a new, high-pressure ventilator tailored specifically to treat COVID-19 patients. NASA's Armstrong Flight Research Center (AFRC) and its industry partners developed an oxygen helmet to treat COVID-19 patients exhibiting minor symptoms and minimize the need for those patients to use ventilators. NASA civil servants continue to work on solutions to the global pandemic via NASA@WORK.

In 2019, Husna Aziz, Project Coordinator at NASA's Office of the Chief Technologist (OCT), engaged the Agency workforce using NASA@WORK to promote the 2020 Technology Taxonomy, which standardizes technology communication across the Agency. OCT asked NASA employees to develop a short video that describes their work with a technology that falls under an area of the 2020 Technology Taxonomy. NASA leadership served as judges and voted on their favorite videos. Three teams were selected as winners for their use of creativity, clear identification of the problem and solution, and clear identification of NASA taxonomy.

NASA engineer Mike Buttigieg (facing page) works on the helmet, which was successfully tested by doctors at Antelope Valley Hospital in California. Dr. Melanie Pickett at Kennedy Space Center (left) and Dr. Alex Schepelmann at Glenn Research Center (above) were among those who participated in the winning videos.

NASA Solve

Public Participation in NASA's Work

The NASA Solve website shares opportunities for members of the public to collaborate with NASA via challenges, prize competitions, and crowdsourcing and citizen science projects.

Goal: To provide an entry point to an array of NASA projects that are open for public participation.

NASA has historically sought solutions to challenging research questions and engineering problems by looking within the ranks of its own workforce, the U.S. aerospace industry, academic institutions, and certain other non-governmental organizations. These entities remain critically important to NASA's ability to fulfill its mission successfully. But the Agency recognizes that its work in space and aeronautics continues to be of great interest to the public and that good ideas can come from anywhere. NASA Solve (www.nasa.gov/solve) aggregates and provides a single entry point on the NASA web portal for the public to access NASA-supported opportunities to contribute to the Agency's R&D and other mission-related activities. In harnessing the public's interest and ingenuity, the activities featured on NASA Solve seek to make space exploration and other avenues of NASA R&D an endeavor of and by people everywhere.

NASA Solve provides listings for challenges and prize competitions, hackathons, and crowdsourced and citizen science projects. Each project listing provides information about who can participate, any awards available, and a link to register or learn more about the project. NASA Solve gets the word out about new opportunities through social media (@NASASolve), a periodic newsletter to which members of the public can subscribe via the website, and appearances at major public events and STEM-related festivals.

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International Space Apps

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www.spaceappschallenge.org

STEM Student Challenges

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Citizen Science

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