NATIONAL INSTITUTE OF AEROSPACE

2020 Annual Report

Leaders in innovative aerospace research, exemplary education and inspirational outreach

OUR VISION

TO BE A NATIONAL LEADER IN INNOVATIVE AEROSPACE RESEARCH, EXEMPLARY EDUCATION AND INSPIRATIONAL OUTREACH

About Us

The National Institute of Aerospace (NIA) is a 501(c)3 nonprofit research, graduate education, and outreach institute created in 2002 by NASA's Langley Research Center. NIA collaborates with NASA, other government agencies and laboratories, universities and industry to conduct leading-edge research and technology development in aeronautics, atmospheric science and space exploration. In addition, NIA offers a broad, multi-university graduate education program and award-winning educational and public outreach.

Our Mission

- **Lead and conduct** synergistic research with government, academia and industrial partners to stimulate innovation and creativity
- **Deliver** unique, collaborative, and comprehensive graduate and continuing education in science and engineering
- **Inspire** the next generation of aerospace engineers and scientists
- **Develop and commercialize** transformative aerospace technologies

Our Values

- Our people are our strength
- We are dedicated to our stakeholder's success
- We value diversity of background, experience and opinion
- We share one vision and act as one team
- Trust and accountability in all relationships
- We embrace change and reward innovation

Dr. Douglas Stanley
President and Executive Director

2020 has obviously been a devastating year for our Nation and the world. We mourn all of those who have lost their lives or have been placed in hardship by the global COVID-19 pandemic. At NIA, we are blessed to have been minimally impacted during this difficult period. Only a handful of our employees contracted COVID-19, and all of them rapidly returned to health. All of our employees were able to keep their jobs and remain highly productive despite having to work from home for much of the year. We were able to keep our offices and labs open and COVID-free through strict protocols. As you'll see in this report, we continued to have a wide variety of virtual, drive-through, and socially distanced events to promote employee morale. Many of our researchers were even able to redirect their skills as they worked in collaboration with NASA to make major contributions to the design of masks and personal protective equipment. Despite the challenging circumstances, our NIA team was able to continue the innovative research, exemplary education, and inspirational outreach that has characterized NIA since our founding.

In 2020, our researchers received two patents, authored over 100 technical publications, and received a record seven NASA Medals! Dr. Hyun Jung Kim was awarded the prestigious NASA Exceptional Technology Achievement Medal for her work in lightweight, versatile optical components for NASA science missions. John Rawls received the NASA Exceptional Public Service Medal for his sustained and exceptional contributions to NASA's capability to predict aircraft system noise. Drs. Boris Diskin, Hiro Nishikawa, and Yi Liu were honored with the NASA Silver Achievement Medal for their work in improving N95 mask design; and Drs. Sang Hyon Chu and Yi Lin also received the NASA Silver Achievement Medal for their work on better materials for PPE for COVID health care providers. In addition, 20 other NIA employees were recognized with NASA Group Achievement Awards for exceptional team contributions to NASA programs and missions. Dr. Hiro Nishikawa was also named the AIAA Region 1 Engineer of the Year. As you can read in this report, NIA employees and students won 2nd and 3rd place in both the prestigious NASA Langley H.J.E Reid Best Paper Competition and the AIAA Hampton Roads Section Young Professionals Paper Competition. It was a productive year of research despite the global pandemic.

Our unique graduate education program had 36 full-time and 24 part-time graduate students in 2020. Our students can earn degrees from any of our nine member universities and take up to half of their classes from other universities. Our Samuel P. Langley Professors-in-Residence at NIA from our member universities all continued to excel in 2020 by publishing almost 200 peer-reviewed publications and conference papers.

Congratulations to UVA graduate student George Wilkes and his advisor Prof. Mool Gupta for authoring the 2nd place paper in the NASA Langley H.J.E. Reid Best Paper competition!

Finally, our world-class educational and public outreach programs continued to garner new customers, audiences and awards. In 2020, we broadcast 260 episodes of our Innovation Now radio program, which features exciting innovations in aerospace engineering, science and space exploration. This year, its audience increased to over 27 million daily listeners. We also produced and distributed 134 new video episodes for our flagship NASA 360 video series. The program has 5.4 million Facebook followers and reached 84 million people in 2020! With more than 90,000 downloads per month, our NASA eClips program continues to reach classrooms all over the world and won an Emmy Award in 2020. Our RASC-AL, BIG Idea, and Moon to Mars Ice and Prospecting student challenges continued to engage hundreds of university students worldwide in creating concepts and technologies for NASA applications.

We also continued the highly successful NASA iTech program virtually to encourage startup companies to address new technologies and ideas relevant to NASA.

We are looking forward to working with all of our stakeholders in a post-COVID 2021 to provide the highest quality research, education and outreach programs.

About the cover: NIA researcher Jean-Paul Vernier works with teams at NASA and around the globe to help decision-makers understand and assess the risk of natural hazards such as the 2018 Kilauea eruption in Hawaii pictured on our cover. Read about Dr. Vernier's latest research on page 13. Credit: USGS

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NIA Rises to the Challenges of COVID-19

It is no secret that the pandemic caused many organizations to rethink their approaches to safety, health, and productivity in 2020—and NIA was no exception. Around 150 people typically work at NIA's headquarters and lab facilities. To protect them, the institute had some difficult decisions to make in a short amount of time. Fortunately, NIA managed to find a healthy balance between remaining open and remaining safe. The institute owes its success to strict criteria for cleanliness, its staff's innovativeness, and a willingness to adapt in times of uncertainty. The organization's employees' dedication to their work, and more importantly to one another, has allowed NIA to endure the pandemic and stay open and operational.

Photos: (Top) Hand sanitizing station in the National Institute of Aerospace lobby; (Bottom) Rita Aguillard disinfecting the sign-in table.

Photo: NIA partnered with the Virginia Department of Health and the Virginia National Guard (VANG) to offer drive-through COVID-19 testing at NIA's Headquarters facility on June 12, 2020.

Keeping NIA Workers Safe

NIA responded swiftly to its employees' needs as soon as the pandemic hit. Leadership made sure that staff had appropriate equipment and remote connectivity as teleworking became standard practice for most employees. Although most employees chose to work remotely, NIA maintained a skeleton-crew of essential personnel who continued to work on-site to ensure security and cleanliness of NIA facilities and the ability to support both on- and off-site work.

As the worldwide crisis persisted, NIA leadership closely monitored guidance and best practice recommendations from the CDC, OSHA, the Virginia Department of Health, NASA, and others to stay current and keep personnel safe. In addition to sharing these guidelines and the latest updates with staff, NIA's human resources department quickly created and distributed a "Return-to-Work COVID-19 Guide" that answered employees' most common questions, outlined what the institute was doing, what was expected from employees, and the sanitation, health and screening practices put in place to reduce the spread of COVID-19. Diligent adherence to guidelines, such as temperature-taking and hand sanitation stations allowed critical research to continue on pace without interruption. With safety and preventive procedures in place, NIA even found ways to safely make laboratory and office space available to researchers who would typically work on-site at NASA's Langley Research Center as the agency switched to a remote working environment.

Maintaining a Strong Sense of Community and Uplifting Morale

Perhaps the foremost concern that comes with a majority virtual workforce is maintaining a sense of community. How do you prevent workplace morale from plummeting when the work "place" rapidly changes from a communal space to a makeshift office set up in your living room? For NIA, the keys to success were continual communication and an emphasis on community-building activities. According to NIA's director of operations, Cathy Hopkins, the institute maintained "continuous, open, and transparent communication about what we were doing and the knowledge we had available." Leadership committed to quickly and efficiently conveying every step of the institute's COVID-19 response to staff members to alleviate potential confusion and stress. Hopkins credits that intentional focus on communication toward a satisfied and productive virtual workforce.

NIA employees were also able to have a little fun during these trying times, as NIA hosted fun activities online, provided tickets to a holiday drive-thru light show, hosted a socially-distant ice cream social, and much more! "We not only continued having events, we expanded our events to keep people engaged," noted Doug Stanley, NIA's president and executive director. The strong sense of community among NIA employees grew even stronger during the pandemic. According to an annual workplace survey conducted by Best Companies Group, morale among NIA's workforce actually increased in 2020—despite the drastic changes the pandemic brought to the work environment.

Bringing Unique NASA Events into Homes

While many at NIA and NASA worked from home, NIA turned to technological innovation to enable the continuity of NASA's educational and public outreach programs. NIA staff found ways to morph traditionally in-person events, such as the annual Revolutionary Aerospace Systems Concepts – Academic Linkage (RASC-AL) challenge and NASA iTech's Ignite the Night events, into engaging virtual formats.

For some teams, such as NIA's Media and Communications Group, the pandemic provided an opportunity to reach new heights. "While working from home, we reached an unprecedented number of viewers in 2020 and produced a record number of products–all while learning to adapt and evolve our practices," pointed out NIA's media program manager, Scott Bednar. "Whether we're in an office or at home, we're able to meet the new challenges that we face and excel at them."

Learning from the Experience

Rising to meet the challenges of the pandemic was not without some silver lining. The shared embrace of technology among the workforce enabled NIA to move even more swiftly on prior plans to replace antiquated paper-based procedures with automated systems and virtual approval processes. The increased and widespread use of virtual meeting platforms allowed staff to compare and confidently select a uniform cost-effective, efficient and robust solution to work remotely.

NIA plans to take the lessons learned from the COVID-19 pandemic to continue organizational improvements. Reflecting on NIA's COVID-19 response, Dr. Stanley notes that "the adoption of technology, enabled by high-speed internet, is really going to transform the workplace all over the world, and we are certainly going to try to be leaders in that." The institute envisions a post-pandemic era with a workplace that is both online and in-person. Removing worksite barriers from the hiring process increases talent and productivity. "If you can recruit from almost anywhere, you're better able to match the required skills to the capabilities of the U.S. and global workforce," explained Stanley. NIA's dedication to self-improvement will continue to take the organization far in terms of productivity, efficiency and, most importantly–community.

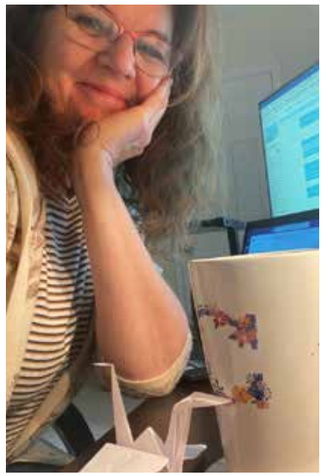


Photo: Holiday drive-through light show. Credit: Nafisah Khan

> "Whether we're in an office or at home, we're able to meet the new challenges that we face and excel at them." Scott Bednar

Photos from some of NIA's virtual challenges: (Top Left) Lori Simonton with her new co-worker, Henrietta; (Bottom Left) Amit Pandit and Jean Paul Vernier and family at the End of Summer Social event; Cathy Hopkins and her paper crane; David Shelton's son, Spencer, on Christmas morning; (Top Right) Keith Jones at the End of Summer Social event; (Bottom Right) Sue Sorlie's morning walk.

NIA Researchers Support NASA's Contributions to National Pandemic Response Team

As NASA leveraged its workforce to respond to the COVID-19 pandemic, the agency tapped into the creativity and capabilities of researchers at National Institute of Aerospace.

Working as members of NASA teams, NIA's Boris Diskin, Hiroaki Nishikawa and Yi Liu drew on their computational fluid dynamics software skills to help the National Pandemic Response Team. Their expertise helped other researchers run computations to enable the design of enhanced, rapidly manufacturable N-95 respirator mask filters. As members of NIA's High Performance Aerospace Computing Center (HiPAC), Diskin, Nishikawa and Liu conduct cutting-edge research in several areas of computational fluid dynamics (CFD), including novel numerical algorithms, multidisciplinary design and optimization, and simulation and modeling of complex turbulent flows. Put simply, they are experts at making CFD software run better and faster. FUN3D is one such software suite used to simulate fluid dynamics extending into the hypersonic regime. On a typical day, NASA, major aerospace companies and educational research institutions use the software to develop and optimize designs for rotorcraft, airplanes, and advanced entry vehicles.

As part of the FUN3D development group at NASA's Langley Research Center, these researchers extended the software's capabilities to much lower airflow speeds. The National Pandemic Response Team wanted to better understand the flow of a human's breath through filters in protective N-95 masks. "FUN3D has recently developed some advanced capabilities to quickly generate grids for complex geometries," says Boris Diskin. "If you want to simulate airflow with masks of a little bit different shape, or filters that affect the geometry of the mask, that's all reflected in grids." Diskin credits Nishikawa and Liu for their prowess in developing algorithms that ensure accurate results from the software–even at much lower Reynold's numbers than NASA typically works with–while also minimizing the required processing time. Ultimately, the data from the optimized FUN3D code helped researchers design filters to last longer and filter out more harmful particles, such as those of the coronavirus.

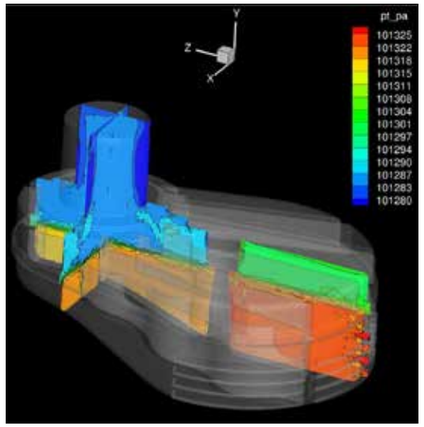


Image: An early conceptual cartridge design and preliminary solution showing roughly the effect of a filter imbedded in the middle of the cartridge. The pictures show estimates of pressure loss through the cartridge and filter. Credits: NASA/ Jan-Renee Carlson

NIA's Sang-Hyon Chu and Yi Lin work within the Advanced Materials and Processing Branch at NASA Langley to develop innovative high-performance materials and processing technologies. They used their materials expertise to identify better ways to decontaminate and sterilize protective equipment used by health care workers to protect against the novel coronavirus. "When you use materials in space, you have to understand how they are going to react; you have to know how they are going to degrade when exposed to harsh temperature extremes, UV light, other types of radiation exposure," says Chu. "What we learn in materials research for aerospace can be applied to evaluate methods of sterilizing or decontaminating protective equipment such as masks, goggles, face shields and gowns."

The NASA Langley team collaborated with many organizations, including the Global Center for Medical Innovations, to share relevant knowledge with a wide variety of innovators, including physicians, researchers and engineers, small startup companies and established leaders in the medical equipment industry. They were intent on solving the most formidable technical challenges of the pandemic.

> "What we learn in materials research for aerospace can be applied to evaluate methods of sterilizing or decontaminating protective equipment such as masks, goggles, face shields and gowns."
>
> Sang-Hyon Chu

As the world looks toward a hopeful future, NIA researchers look beyond the emergency response stage of the COVID-19 pandemic. Chu adds, "We are also paying attention to public facilities, such as airports, schools and other public buildings to help evaluate methods to sterilize surfaces and reduce transmission of the virus effectively."

Whether NIA researchers are looking at tools that lead to improved heat shields for spacecraft or improved face shields for doctors, they know that understanding the materials involved and how they will behave in specific environments impacts performance.

In recognition of their contributions to the National Pandemic Response Team, Boris Diskin, Hiro Nishikawa, Yi Liu, Sang-Hyon Chu and Yi Lin were each honored with a NASA Silver Achievement Medal "for selfless service and dedication in rapidly adapting and applying NASA's talents to help the Nation respond to the COVID-19 pandemic." The medal is awarded by NASA Center Directors for a stellar achievement that supports NASA's core values, when it is deemed to be extraordinarily important and appropriate to recognize such achievement in a timely and personalized manner.

Samuel P. Langley Professor Program

The Samuel P. Langley Professor Program was established by NASA's Langley Research Center to enable an on-site, high-value graduate education program for Langley personnel, as well as graduate students, that would ensure a pipeline of new talent with relevant technical interest and expertise. Langley Professors are selected to be in residence at NIA after establishing themselves as research and thought leaders in fields that are aligned with and complementary to the strategic research directions at NASA's Langley Research Center.

Branch heads and researchers across NASA Langley regularly seek out Langley Professors for collaborative research, or to obtain high-valued research advice and direction. Langley Professors also assist in providing master's and doctoral students to work side-by-side with NASA Langley researchers for extended periods, while addressing their coursework, to perform research on-site at both the National Institute of Aerospace and NASA Langley. Each Langley Professor specializes in a technical discipline that aligns with an element of the research program and interests of NASA's Langley Research Center.

NIA Samuel P. Langley Professors

Dr. James Baeder
University of Maryland

Center for Rotorcraft Aeroacoustics

Computational Aerodynamics and Aeroacoustics

Dr. Mool Gupta
University of Virginia

Center for Photonics, Sensors and Solar Energy

Photonics, Sensors, Solar Energy, and Nanomaterials

Dr. Olivier Bauchau
University of Maryland

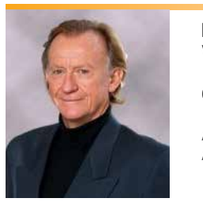
Center for Structural Dynamics

Multibody Dynamics, Rotorcraft Aero-Mechanical Comprehensive Modeling, Structural Dynamics, and Composites Materials and Structures

Dr. Abdollah (Ebbie) Homaifar
North Carolina A&T State University

Autonomous Control and Information Technology Institute

Testing, Evaluation, and Control of Heterogeneous Large-scale Systems of Autonomous Vehicles



Dr. Christopher Fuller
Virginia Tech

Center for Aerospace Acoustics

Acoustics, Active Noise Control, and Acoustic Meta-Materials

Dr. Dimitri Mavris
Georgia Institute of Technology

Aerospace Systems Design Laboratory @NIA

Design of Space Systems, Vehicles and Architectures

Dr. Brian German
Georgia Institute of Technology

Center for Urban and Regional Air Mobility (CURAM)

Aircraft Electric Propulsion, Autonomous Flight, and Emerging Aviation Markets

Dr. Fuh-Gwo Yuan
North Carolina State University

Center for Integrated Systems Health Management

Advanced Smart Materials, Non-Destructive Evaluation, and Integrated Systems Health Management

Samuel P. Langley Distinguished Professor

Christopher Fuller Virginia Tech

Photo: Automatic Reconfigurable Microphone Array Prototype

If you are looking for Dr. Christopher Fuller—or the results of his research—your best tip might be to "look outside." When he's not in the classroom or the lab, you are likely to spot the Virginia Tech professor of Mechanical Engineering surfing. Fuller spent his youth riding waves off Australia's southern coast. He went on to earn bachelor and doctorate degrees in engineering from the University of Adelaide. Since he was appointed as the University's Samuel P. Langley Professor of Engineering at NIA in 2011, the sands of the eastern U.S. coast have been his "home beach." An expert in acoustics, vibration, active noise control, advanced composite materials for noise reduction and beamforming techniques, he's also keen to get acoustics research out of the lab and into applications that make a difference in people's lives.

Prof. Fuller directs the Center for Aerospace Acoustics at NIA, which supports work conducted at both NASA's Langley Research Center and in the commercial aviation sector. He's also found notable success for projects and applications outside of the traditional aerospace industry, such as the automotive and marine industries.

A key focus at the Center for Aerospace Acoustics is acoustic metamaterials. Acoustic metamaterials are described as materials that have properties not readily available in nature. Putting inserts to act as scatterers at specific locations in acoustic materials causes acoustic waves to resonate between those inserts. That resonance causes a phase change, which changes the impedance, causing sound waves in the material to refract and slow down. This allows Fuller to design lightweight and compact noise treatment materials that absorb sound much better than traditional materials while also being cost-effective and scalable to manufacture at useful sizes. These advancements open up a myriad of possibilities for users to place effective sound baffling in places that weren't practical–or sometimes even possible–before. In addition to aerospace applications, Fuller is working with SMD Corp of Arlington, Virginia, to bring the technology to home appliance products.

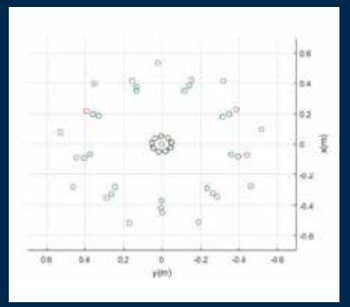


Image: Photogrammetry testing of microphone positions after movement. Blue indicates the initial location, while red indicates the final location for a new point spread function.

Fuller and SMD are also collaborating to develop Active Quiet Bunks for Submarine Crews. The project uses active control and passive treatment elements to effectively cancel and dampen noise to create quiet bunks for submarine crews. It includes an acoustic metamaterial curtain and an active noise-canceling headrest designed to go into the bunks of submarine sailors. Funded by the U.S. Navy's Office of Naval Research (ONR), the technology will soon be tested by the Navy in a Virginia-class submarine at Newport News Shipbuilding.

Another current project supported by ONR, in collaboration with the Naval Sea Systems Command (NAVSEA), involves a **PVDF Wire Sensor for External Measurement of Piping Interior Pressure**. "With normal pressure sensors, you've got to drill a hole in a pipe," explains Fuller. "That can be really invasive, so for certain piping systems, you don't want to do that." This sensor mounts on the outside of the pipe and measures the pressure inside the pipe. Fuller continues to work with SMD Corp as they develop applications of this technology for the Navy and a spinoff into the oil industry.

A spinoff derived from that research is an **Intracranial Pressure Sensor** being developed with researchers at Eastern Virginia Medical School. The technology would be beneficial to medical patients and could help solve a long-time challenge for NASA. It's not uncommon for astronauts who live and work in microgravity to experience swelling from fluids in their cranium. "Instead of just using it to measure the pressure inside of pipes, we can use it to measure the pressure inside of people's heads," explains Fuller. Having a non-invasive and accurate way to monitor edema in real-time is vital for long-duration human exploration.

Fuller's expertise in metamaterials and active noise cancellation is especially beneficial for NASA projects looking into things such as **Active Control of UAM Fan Noise Using Novel Actuator Methods**. Noise is a significant hurdle to widespread implementation of a safe and efficient Urban Air Mobility (UAM) transportation system. Fans or propellers are loud. It is impracticable to control that noise using a liner, and reductions using blade design have pretty much run their course. That's why Fuller and his students are researching new techniques to make active control of UAM noise possible, including virtual error sensors and active control inputs that use novel and practical inputs.

One of the advantages of being a Langley Professor at NIA is connecting his students with opportunities to perform research of direct interest to NASA missions and projects. His students spend extensive time working with NASA to provide high-quality, low-cost research.

Large microphone arrays are used in NASA wind tunnels to image aeroacoustic sources via a technique called beamforming. The microphone array's optimal size and distribution depend upon the noise source, the frequency bandwidth, and the application. Historically, it can take the better part of a day to reconfigure an array for different noise sources and applications. Fuller and his students designed and built an **Automated Beamforming Microphone Array** to reduce costly wind tunnel downtime by automatically reconfiguring the array to a prescribed point spread function in mere minutes.

His students have already built a prototype of the device, and it is slated to be tested in the 14' X 22' wind tunnel at NASA's Langley Research Center as soon as conditions allow. Because it's a senior design project, the budget is quite small - less than $10,000. "So, NASA gets a lot of 'kick for the buck' out of that," Fuller notes. "Plus, the students come down and do a demo at NASA in the wind tunnel, so it's a great experience for them."

Prof. Fuller constantly looks for opportunities to get his students to expand their vision to look beyond the textbooks and envision how they can take what they learn out into the world. "They can always find the equations in a book," he remarks." "I don't get bogged down in really detailed mathematical analysis; I just want to make things work."

Safe and Sound in the Lab

Fuller has directed the Bruel & Kaejer Laboratory for Aerospace Vibration and Acoustics since it opened in 2012. Owned by Virginia Tech and located at NIA's Hampton, Virginia campus, the lab supports education in acoustics and vibration and enables advanced research on analyzing, understanding, and developing innovative solutions for noise and vibration problems in aircraft, rotorcraft, and spacecraft. Access to the state-of-the-art facility has allowed Fuller and his students to continue developing innovative solutions for noise and vibration problems, even as other research facilities in the U.S. were shut down during the COVID-19 pandemic.

MESSAGE FROM VICE PRESIDENT OF RESEARCH

David Throckmorton

During 2020, NIA researchers continued to perform cutting-edge research and technology development to support NASA's Langley Research Center and our other government and commercial aerospace customers. NIA's research staff population continued to grow - evidence of the value our customers receive from the engagement of NIA researchers in the performance of their research and technology development pursuits.

Multiple NIA researchers were recognized for the outstanding quality and impact of their work during 2020.

- NASA Medals (the Agency's highest form of individual recognition) were presented to two NIA researchers: **Hyun Jung Kim** was awarded the NASA Exceptional Technology Achievement Medal, and **John Rawls** was awarded the NASA Exceptional Public Service Medal.

- Five NIA researchers – **Sang Hyon Chu**, **Boris Diskin**, **Yi Lin**, **Yi Liu**, and **Hiroaki Nishikawa** – were awarded the NASA Silver Achievement Medal in recognition of their contributions to the National COVID Pandemic Response Team.

- Some 20 NIA researchers were members of teams that received NASA Group Achievement Awards. These awards recognized significant contributions to the advancement of technology in the areas of high-performance computing, composite structures design and certification, additive manufacturing of rocket engine components; and the conduct of field campaigns to gather in-situ atmospheric data of emissions emanating from volcanic eruptions.

- **Hiroaki Nishikawa** was named Engineer of the Year by Region 1 of the American Institute of Aeronautics and Astronautics (AIAA).

The following pages provide snapshots of a select few of the exciting research contributions of NIA researchers in 2020, as well as a bibliography of technical publications that evolved from the efforts of the NIA research staff.

Research

Research Labs at NIA

As a part of our research strategy, NIA has established Research Centers of Excellence and Labs that bring together experts from NIA, multiple universities, industry, and NASA to perform focused collaborative research activities. These centers and labs are complementary to NASA's research and actively seek funding from outside sources. Langley Professors have their own NIA-based Research Centers and Labs for which they serve as Directors.

- Center for Aerospace Acoustics
- Center for Integrated Systems Health Management
- Center for Photonics, Sensors and Solar Energy
- Center for Planetary Dynamics
- Center for Rotorcraft Aeroacoustics
- Center for Structural Dynamics
- Center for High Performance Computing
- Autonomous Control and Information Technology Institute
- Aerospace Systems Design Laboratory @NIA
- Boron Nitride Nanotube Laboratory

The NASA Exceptional Public Service Medal was awarded to **John W. Rawls**, "For sustained and exceptional contributions to NASA's capability to predict aircraft system noise, including over 40 years of acoustic prediction tool development."

The NASA Exceptional Technology Achievement Medal was awarded to **Hyun Jung Kim,** "For exceptional contributions to the development of light-weight, versatile optical components for NASA science missions."

Battery Prognostics for Multirotor UAS Applications

Edward Hogge, NIA Associate Principal Engineer

Unmanned aircraft systems (UAS) that utilize battery-powered propulsion require a method to assess the actual battery charge state during flight operations. The pilot/operator needs reliable information about the required charge for a proposed mission, the actual charge remaining at any point in the mission, and an accurate estimate of the safe remaining flying time. One approach for obtaining an estimate of a battery's internal State of Charge (SOC) is implementation of an empirical or a chemistry/physics battery model that employs parameters tailored to model an individual battery. The appropriate parameters are determined by off-line laboratory characterization tests of representative batteries coupled with an empirical mathematical fitting process. Flight tests are conducted to assess the performance of onboard battery models as compared to ground-based battery models in tracking the battery charge state and estimating remaining flying time.

The author has developed battery charge-state models to estimate onboard battery SOC for implementation in small, multi-rotor UASs. The battery state is modeled in a filtering framework that is used to propagate the battery state into the future, in a structured way, so as to account for variations in the current and voltage measured by onboard sensors and to account for internal chemical reactions and past usage demand. The battery models use parameters identified from controlled discharge experiments done with special laboratory equipment. The battery's charge capacity, its internal resistance and other parameters are identified through experiments that use programmed load profiles. The current is the controlled input, and the voltage and SOC are the modeled outputs. A prediction of remaining flying time is generated by propagating a number of estimates of the battery charge forward. Think of the spaghetti plot predictions of a hurricane's possible paths approaching the coast for a similar analogy. The most likely path is the average of all such paths. In a similar way, the present battery state is propagated forward using an assumption of the future power demand that will occur over the expected flight plan.

A Monte Carlo estimate of confidence in the prediction of the remaining flying time is accomplished by assessing the measured current component of the power demand required for constant hovering. A distribution of charge values derived from the distribution of motor current values are added to the state variables. The charge state is then used in the model to simulate the discharge – in a loop until a threshold SOC value is reached. The loop count gives an estimate of the remaining flying time and the time to the End of Discharge (EOD). In the example shown in Figure 1, an input distribution histogram of 50-ampere current demand with a ±10 ampere current deviation leads to the indicated prediction for variation in the time to EOD.

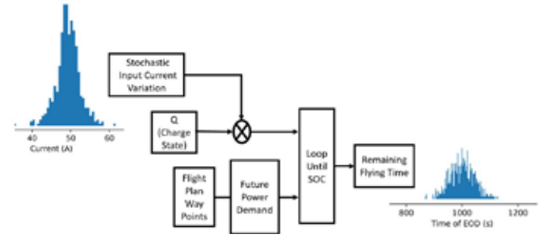


Figure 1 - Monte Carlo estimate of flying time variation

For small multirotor UASs, the onboard battery-charge model software must fit within the computational constraints of an onboard computer that is within the vehicle's payload weight constraints. The battery monitor algorithm must also cooperate with other computational tasks necessary for semi-autonomous operation; and must integrate with the flight software architecture adopted for UAS research. The onboard battery monitor software was developed to meet all of these requirements and is being actively tested on a multi-rotor UAS operated in a simulated urban setting at NASA's Langley Research Center (Figure 2).

Figure 2 -Software evaluation/validation via flight test experiments

The current charge-state models for assessing battery SOC and the prediction of remaining safe flying time will initially serve to advise a human pilot/operator at a ground station. However, as confidence in the predictions is gained, the estimates can be used to inform autonomous mission planning decisions. This research aims to mitigate the battery power interruption risk to an acceptable level of uncertainty for operation in the national airspace. The practical issues that arise in the routine operation of future air taxis in an urban setting will be simulated through flight operation of small multirotor UAS.

SCIFLI Hayabusa 2 Airborne Re-entry Observation Campaign

Robert Conn, NIA Research Scientist

The NASA Scientifically Calibrated In-FLight Imagery (SCIFLI) team, led from NASA's Langley Research Center, is comprised of engineers and scientists that acquire engineering quality image data of spacecraft launches and reentries, parachute and other flight tests. SCIFLI-derived images are acquired from both ground- and aircraft-based imaging systems, and yield "flight-truth" data that enable enhanced interpretation of ground-test results, and/or provide the basis for improvement in computational models. Specifically related to computational fluid dynamic modelling, these data are vitally important for the verification and validation of aerothermodynamic models in order to enable more efficient designs of future launch and re-entry vehicles.

The Japanese Aerospace Exploration Agency's (JAXA) Hayabusa 2 mission was designed to rendezvous with near-Earth asteroid, Ryugu, acquire soil samples from the asteroid, and return those to Earth. The re-entry of the Hayabusa 2 Sample Return Capsule (SRC) provided an opportunity to collect a particularly unique set of flight data, due to the velocity of the re-entering object. Hayabusa 2 SRC was one of the fastest objects made by humans to ever enter the Earth's atmosphere–travelling at over 40 times the speed of sound. In partnership with JAXA, the NASA SCIFLI team was to remotely acquire spectrally-resolved emissions data from the re-entering SRC. An airborne observation was designed to acquire spectra of aerothermodynamic features during the luminous portion of re-entry. These aerothermodynamic features included surface temperature emission, wake chemiluminescence, heat shield ablation, and trajectory reconstruction.

Logistics associated with the Hayabusa 2 imaging campaign were especially complex, as re-entry and recovery were to occur in the Australian outback. Due to the global COVID-19 pandemic, the Australian government had imposed severe restrictions on international travelers entering the country. As a result, upon arrival in Australia, the entire SCIFLI team (comprised of some 30 persons) was required to quarantine for 14 days in a "Medi-Hotel," specifically outfitted for quarantine lodging. During that time, the team's movements were limited to the confines of their hotel rooms.

NASA deployed two Gulfstream-III research aircraft to carry the required instrumentation and sensor operators during the Hayabusa 2 observation. The author served as Simulation Mission Coordinator (SMC) for this campaign, responsible to perform advance mission simulations to define aircraft flight paths and timing to ensure successful data capture. The aircraft had to be at the optimal imaging location, at the optimal time, to enable the instruments to "look" at the exact spot in the sky where the Sample Return Capsule would re-enter. This mission also required the spectrographic instruments to be mounted on specially-designed gimbals. Consequently, flight paths had to be designed that put the sensors at the optimal imaging angle from the spacecraft trajectory at key mission events (like peak radiative and convective heating); and the imaging angles needed to be within gimbal limits, as there were optimal angles for which the gimbals operate at peak performance.

Planning for these observations, which began long before the team's deployment to Australia, required the author's application of mission simulation software to create a virtual version of the observation using vector algebra, physics models, and visualization tools. Spacecraft trajectory data, imaging aircraft flight path data, and configuration of the spectrographic instruments provided input to the simulation software. Azimuth and elevation angles from the imaging aircraft to the spacecraft, and required gimbal angles, were then calculated. This process was performed iteratively until optimal parameters for aircraft positioning were determined. The software also generates simulated imagery of what the spectrograph will see. This imagery is especially useful to the sensor operators, as it shows them which celestial objects are projected to be in the field of view during the observation. During the actual mission, these provided guides for initial pointing of the imagers for determination of where the capsule will come into view relative to the stars in the frame.

The author performed multiple simulations in the days leading up to the actual mission, as SRC entry trajectory data were continually updated and refined. The SCIFLI team successfully captured imagery of the Hayabusa 2 capsule during entry, from first acquisition of signal to loss of signal, with no saturation, from all ten spectrometers utilized during this mission. Additionally, two astrometry cameras produced trajectory data which was provided to the JAXA ground team and used for successful location and recovery of the Sample Return Capsule.

Figure 1 – SCIFLI team, including JAXA colleagues (in green)

Figure 2 – Sample Return Capsule retrieval. Credit: JAXA

Hyperbolic Navier-Stokes Solver on Extremely Complex, Irregular 3-Dimensional Grids

Hiroaki Nishikawa, NIA Research Fellow

Computational fluid dynamics (CFD) is an indispensable tool for engineers and scientists, enabling them to perform experiments and designs in a computer for a wide range of applications, from aerospace engineering (e.g., flow around an aircraft) to medical biology (e.g., blood flow). The first step in a CFD analysis is to generate a computational grid over a domain of interest, where numerical solutions such as pressure values are then determined in each cell (or node) by numerically solving the Navier-Stokes (NS) equations iteratively. As many practical simulations involve complex geometries, such as a domain around a complete aircraft, grids are generally irregular. They will become even more irregular in future automated CFD analyses, where a grid will be automatically generated and adjusted to local solution features.

Unfortunately, current CFD solution methods are not entirely reliable for solving the NS equations efficiently (i.e., with a small number of iterations) and producing accurate simulation results on irregular grids. Modern applications also require higher-order accuracy, but the increase in cost in implementing higher-order methods currently precludes using such methods in practical CFD codes.

The hyperbolic method, originally proposed by the author, has been developed toward the advancement of CFD methods, enabling a seemingly impossible improvement: higher-order accuracy, at a reduced cost, on highly irregular grids. The basic idea is to manipulate the NS equations of mixed hyperbolic-parabolic type into a single first-order hyperbolic system to simplify the construction of high-order schemes, eliminate numerical stiffness for faster iterative convergence, and allow accurate computation of derivative quantities of interest such as viscous stresses and heat fluxes, on fully-irregular unstructured grids. Research in the hyperbolic method has also led to other important algorithmic developments targeted at highly-irregular grids, including improved gradient methods and improved element-centroid formulae.

Current efforts focus on the development of a third-order method for viscous flow simulations. Results demonstrate the seemingly impossible improvement: a third-order hyperbolic scheme yielding a highly-smooth viscous force distribution on irregular grids, for which a conventional second-order method suffers from numerical oscillations. Additionally, a third-order solution is obtained faster than a second-order solution on the same grid. The method has been extended to three dimensions and implemented and demonstrated in NASA's FUN3D code.

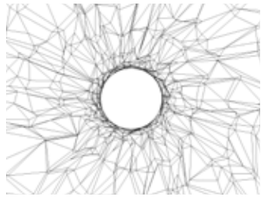


Figure 2 – Irregular tetrahedral grid for a viscous flow over a sphere.

To further improve robustness, new algorithms are being developed, including implicit gradient methods and a more economical high-order scheme up to fifth-order accuracy. The basic concept being the manipulation of the governing equations. The areas of application of the hyperbolic method are expanding to a wide range of scientific-computing communities beyond fluid dynamics: e.g., magnetohydrodynamics, distance-function calculations, plasma simulations, and atmospheric simulations.

An additional effort addresses development of a fully-adaptive space-time hyperbolic NS solver, which solves the two-dimensional NS equations in a three-dimensional domain with coordinates (x,y,t), where t is time. In this method, instead of advancing the solution in time with a small constant time step over a two-dimensional domain, the NS equations are solved just once in a three-dimensional space-time domain to obtain the solution over the entire time. It dramatically simplifies the CFD solution process and results in an extremely fast solver in modern high-performance computing architectures by allowing the large domain to be decomposed and distributed over many computing cores. Automatic grid generation is a key part of the fully adaptive space-time method, and a grid will be highly irregular. It is therefore essential to have a robust and accurate CFD solver. The hyperbolic NS solver is one such method and will be developed toward efficient and accurate space-time simulations. Preliminary results were presented at the 2020 AIAA Aviation Forum: Nishikawa and Padway, "An Adaptive Space-Time Edge-Based Solver for Two-Dimensional Unsteady Inviscid Flows," AIAA Paper 2020-3024, June 2020.

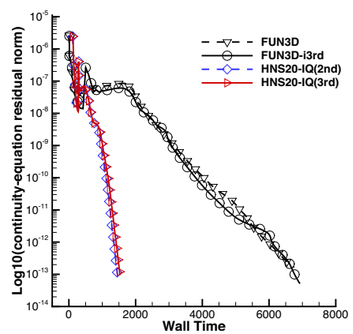


Figure 1 – Faster convergence of the hyperbolic solver for the sphere case.

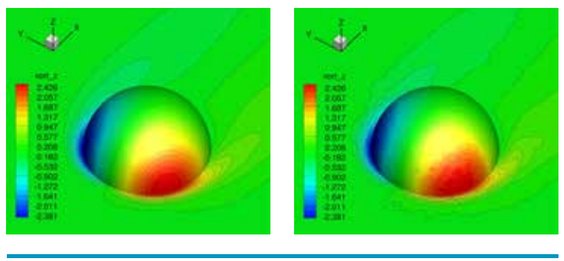


Figure 3 – (Left) Vorticity distribution over the sphere: conventional solver and (Right) the hyperbolic solver.

Ballooning in the Earth's Atmosphere to Understand the Impacts of Pollution, Volcanic Eruptions and Forest Fires on Climate

Jean-Paul Vernier, NIA Senior Research Scientist, and **Amit Pandit**, NIA Research Scientist

As the Earth's surface temperature continues to rise due to anthropogenic activities, climate scientists need to refine model predictions and fully understand how fine particulate matter suspended in the air, also called "aerosols," interact with solar radiation and the formation of clouds. The role of aerosols in Earth's climate represents a significant source of uncertainty for climate prediction. Studying those aerosols is, and will continue to be, a major research endeavor as indicated in the decadal survey prepared in 2017 by the Committee on the Decadal Survey for Earth Science and Applications from Space (ESAS) of the National Academies of Sciences.

While satellite-borne instruments can observe the Earth as a whole on a daily basis, they primarily provide an integrated view of the atmosphere and lack the resolution to see fine-scale processes. Thus, in-situ measurements are key to obtaining data to assess the properties, lifetime, and impacts of aerosols on climate. From lightweight instruments which can be deployed quickly to study transient events such as volcanic eruptions and fires, to larger payloads to gather multiple datasets using more sophisticated instruments, scientists are constantly looking for the best options that will address their science objectives. Scientists at NIA have chosen to study aerosols in the Earth's atmosphere via ballooning with sensors.

In May 2018, as the Kilauea volcano on Hawaii's Big Island began to erupt, with the emergence of lava flooding streets and destroying homes, NIA scientists collaborated with the Universities of Costa Rica, Hawaii, and Colorado to rapidly deploy to Hawaii and make measurements in the volcanic plumes emitted by Kilauea.

The balloon-borne payloads included instruments to measure meteorological parameters, including temperature, pressure, and relative humidity, as well as to infer the optical, physical and chemical properties of aerosols, and the presence and concentration of sulfur dioxide (SO2). These measurements enabled the NIA-led team to gather unprecedented information to study the volcanic plumes. It was discovered that sulfur dioxide can be rapidly converted into aerosols within only a few hours after being emitted, depending on the humidity level – with a humid environment prompting quicker aqueous reactions to form aerosols and deplete SO2.

In fall of 2019, the team launched lightweight balloon payloads from NASA's Langley Research Center to study the properties of a plume injected by the Raikoke volcano, located thousands of miles away on Russia's Kuril Islands. Since the 2014 eruption of the Kelud volcano in Indonesia, whenever and wherever a volcano rumbles around the world, the NIA team, with international collaborators, attempts to rapidly respond to make the balloon measurements needed to produce the most interesting science results. If not, their concentration is studying how pollution affects the Earth's atmosphere, with a focus on the Asian Monsoon.

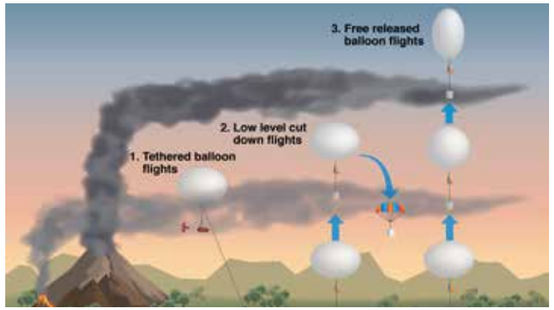


Figure 1 - Balloon activities during the VolKilau campaign to sample volcanic plumes emitted at low altitudes from the fissures and at higher levels from explosive events at the Kilauea summit.

Satellite observations have revealed that a fraction of pollutants emanating from the Earth's surface in the form of aerosols can reach the upper atmosphere, the stratosphere, located 10 miles above the ground. Asia is one of the most polluted regions on the Earth, and pollution from this region is transported by large thunderstorms that form during the Asian Monsoon, the rainy season. Each year since 2014, scientists from NIA have deployed to locations in India to make aerosol measurements to understand how pollution is transported into the stratosphere over India. One of the major findings of this balloon campaign was the discovery of nitrate aerosols near the tropopause. Nitrate aerosols have the potential to modify the properties of ice clouds in the upper atmosphere and amplify their radiative impacts.

Recently, the rising concern of pyrocumulonimbus (PyroCbs) clouds formed as a result of extreme forest fires has also drawn our attention toward making additional measurements. Such measurements are very limited but will be crucial in understanding the impact of PyroCbs on the upper troposphere and lower stratosphere aerosol load and clouds.

With the miniaturization of the atmospheric sensors and satellite communication, balloons have their place for climbing the Earth's atmosphere to make in-situ measurements. NIA scientists continually look for opportunities and partnerships to study aerosols using state-of-the-art technology.

Figure 2 - Flight preparation at the balloon facility of the Tata Institute of Fundamental Research, Hyderabad, India, in July 2019. The main balloon is inflated on the left, while a secondary balloon is used near the main payload to facilitate the launch.

Research Publications

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P. Paredes, **B. S. Venkatachari**, M. Choudhari, F. Li, C.-L. Chang, H. Xiao, and M. Zafar: "Toward Transition Modeling in a Hypersonic Boundary Layer at Flight Conditions." AIAA 2020-0103, *AIAA SciTech Forum and Exposition*, January 2020. https://doi.org/10.2514/6.2020-0103

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1st Runner-Up
Prahladh Iyer, et al: "Analysis of the Equilibrium Wall Model for High-Speed Turbulent Flows," Physical Fluid Reviews, July 2019

2nd Runner-Up
Pedro Paredes, et al: "Nose-Tip Bluntness Effects on Transition at Hypersonic Speeds," Journal of Spacecraft and Rockets, March 2019

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U.S. Patent No. 10,605,783 – March 2020
"System and Method for Progressive Damage Monitoring and Failure Event Prediction in a Composite Structure"

Inventors: J. N. Zalameda, E. R. Burke, **Michael R. Horne**, and E. I. Madaras

U.S. Patent No. 10,745,112 – November 2020
"Method and System for Delaying Laminar-To-Turbulent Transition in High-Speed Boundary Layer Flow"

Inventors: **Pedro Paredes**, Meelan Choudhari, and Fei Li

2020 NASA Langley H.J.E. Reid Award

1st Runner-Up
Harold Haldren, **Mool Gupta**, **et al**: "Swept-Frequency Ultrasonic Phase Evaluation of Adhesive Bonding in Tri-layer Structures." Journal of the Acoustical Society of Ameri-ca, 145, 1609, March 2019

2nd Runner-Up
Hyun Jung Kim: "High Mobility SI GE Growth by using the Molten Target Sputtering (MTS) within Heteroepitaxy Framework." Scientific Reports 9, Article Number 11555, August 2019

2020 Bo Walkley Best Research Publication Award

Saikumar Yeratapally

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Photo: (Top) NIA's Jean-Paul Vernier and colleagues from NASA, France's Centre National de la Recherche Scientifique (CNRS), and India's National Atmospheric Research Laboratory (NARL), prepare for a balloon launch at the Tata Institute of Fundamental Research in India in August 2018 for the "Balloon measurement campaign of the Asian Tropopause Aerosol Layer (BATAL)." The campaign collects data to increase understanding of this seasonal atmospheric phenomenon and its potential impact on ozone and climate.

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Our People

The NIA team has

200+

employees

resident university professors

postdoctoral and graduate students

consultants

research scientists and engineers

education specialists

students

program and operational support staff

Since 2002

91 NIA employees and students have been hired by NASA

30 employees have become permanent U.S. residents

24 employees have become U.S. citizens

90%
of researchers hold graduate level degrees

The majority are doctoral level degrees related to aerospace.

NASA Honor Awards - Group Achievement Awards

Volkilau Team
"For outstanding achievement conducting a rapid deployment during the 2018 Kilauea volcanic eruption to profile emissions from volcanic fissures."
NIA Team Members: **Jean-Paul Vernier** (Team Lead), **Rita Aguillard**, **Carly Bosco**, **Shi Broadwell** and **Bianca Clark**

NASA Langley Transformer of the Year Award
Safeguard for Autonomous Navigation Demonstration (SAND) Team
"For establishing innovative public-private partnerships and rapidly commercialize technologies in support of NASA's transformational goals."
NIA Team Members: **David Bradley** and **Jacob Revesz**

NASA Research and Technology Award
Rapid Analysis and Manufacturing Propulsion Technology (RAMPT) Team
"For outstanding engineering achievements of developing additively manufacturing specialty vendors, bi-metallic rocket engine thrust chamber assemblies, and rocket nozzles."
NIA Team Member: **Sang-Hyon Chu**
(Presented at MSFC Honor Awards Ceremony)

Hiro Nishikawa was named AIAA Region 1 Engineer of the Year
"For innovative, seminal contributions to the theory, implementation, and verification of novel computational approaches to the solution of aerodynamics equations in practical CFD codes"

Continuing Education

NIA has always recognized the importance of continuing and lifelong learning for everyone engaged in technical fields of study. We also understand that the education and training needs of engineers and scientists established in their fields often differ from those of individuals entering the field for the first time. NIA offers a range of short courses, workshops, conferences, seminars, and colloquia to assist those seeking to enhance and expand their knowledge in specialized and emerging areas. Speakers include subject matter experts from NIA, NASA, academia and industry.

The on-site component of the 2020 program was adversely affected by the pandemic. Still, NIA organized, hosted, or assisted with five short courses, workshops or conferences and made well over 200 for-credit courses available through NIA (spring and fall semesters 2020).

Member Institutions

NIA was formed by a consortium of prominent research and education institutions. Today these organizations continue to serve as collaborative partners, provide executive guidance, and offer unique graduate education opportunities, helping to make NIA a leader in innovative aerospace research, education and outreach.

AIAA Foundation Advancing Aerospace · Georgia Tech · Hampton University · North Carolina Agricultural and Technical State University · NC State University · Old Dominion University · University of Maryland · University of Virginia · Virginia Tech · William & Mary Chartered 1693

The Smart Airport and Aviation Partnership (SAAP) was established in late 2019 by way of an i6 Regional Innovation Strategies Grant from the U.S. Economic Development Administration. Aimed at assisting southern New Jersey in building a regional aviation hub, the Partnership is incubating, accelerating and attracting new businesses into a high-tech cluster there. The lead applicant for the grant was the Atlantic County Economic Alliance (ACEA), with NIA as ACEA's managing partner. Carole Mattessich, Esq., is the SAAP Director, working from an office established by the NIA at the National Aviation Research and Technology Park (NARTP), located adjacent to the FAA Technical Center. Mattessich previously helped build an extensive program for aviation-related companies in Cape May County, which joined Atlantic County as central constituent members of SAAP. By bringing all of these parties together, NIA amplified its East Coast reach and its partnership with the FAA Technical Center and economic development partners in southern New Jersey.

With guidance from NIA and partners, leading aviation professionals are working with SAAP on numerous innovative growth strategies, including "flightPlan, the Aviation Accelerator," which successfully graduated its first cohort of seven companies in 2020 and is currently forming its second cohort. SAAP also contributes to the aerospace ecosystem by extending small research grants for aviation-related research consistent with FAA research goals, emphasizing Smart Airport technologies.

smartaviation.nianet.org

SAAP Partners
Atlantic County Economic Alliance (ACEA)
Atlantic County, New Jersey
Cape May County, New Jersey
National Aviation Research and Technology Park (NARTP)
National Institute of Aerospace (NIA)

SAAP Members
Applied Research Associates (ARA)
Atlantic Cape Community College
SJTA/Atlantic City International Airport (ACY)
Delaware River and Bay Authority (DRBA)
New Jersey Economic Development Authority (NJEDA)
Optimal Solutions and Technology (OST)
Rowan University
Stockton University
Dave Sweet (former Boeing executive)
Tech United (formerly New Jersey Tech Council)
Thunderbolt Industries LLC

SAAP Special Advisors
Linda Fowler (Regionerate LLC)
Eric Neiderman (FAA)
Jon Schleifer (FAA)

In 2012, NIA established the Peninsula Technology Incubator, now known as REaKTOR, to foster economic development in Hampton, Virginia, and the Virginia Peninsula. REaKTOR is leading the charge to establish the Hampton Roads region as a leader and national center of excellence for unmanned systems research, development and commercialization.

In 2020, REaKTOR has focused on the creation and development of two projects with one of its companies, Longbow: The Autonomy Research Institute for Societal Enhancement (ARISE) and the Unmanned Systems Research and Technology Center (USRTC).

Autonomy Research Institute for Societal Enhancement (ARISE)
The ARISE project supports REaKTOR's mission to implement an internationally recognized business acceleration program to commercialize technical research, emphasizing aerospace, autonomy, artificial intelligence, and other related technologies. The effort will position Hampton as the epicenter for such research and commercialization to attract jobs and businesses to the City of Hampton.

Unmanned Systems Research and Technology Center (USRTC)
Working with Longbow, REaKTOR will develop the Unmanned Systems Research and Technology Center (USRTC), a for-profit Ft. Monroe-based business. The location offers rare direct access in Hampton Roads to FAA Class G Airspace and the Chesapeake Bay.

ARISE, USRTC and REaKTOR intend to attract national companies looking to set up Autonomous Vehicle Fleet Network Operations Centers and test emerging autonomous technologies. The intent is to provide business development, manufacturing and spin-off technology commercialization services in the USRTC for companies that seek an active and supporting autonomous eco-system with a well-trained workforce.

Psionic
REaKTOR continues to advise Psionic, one of its most successful companies. Psionic is commercializing doppler lidar technology licensed from NASA. Customer-focused evolution of the technology drives their growth. The technology is broadening as new and improved versions of the lidar hardware and software technology advances. Prospective uses include biological identification of swarms (differentiating whether potential threat swarms are drones or birds), autonomous landing of helicopters on pitching decks of ships, and lunar landing navigation.

Advanced Aircraft Company (AAC)
AAC closed its first sale of their flagship technology HAMR UAS. They are rapidly moving HAMR to a production-ready turn-key UAV system.

Visitor Program

NIA's Visitor Program facilitates research collaborations between scientists and engineers at NIA, NASA's Langley Research Center, and researchers, faculty, and graduate students from other institutions. The typical visit is for a semester or summer, but longer or shorter durations can be accommodated. NIA supports this program with concierge services to assist with securing local lodging and transportation, visas for our international guests, access badges for Langley, and office accommodations. Participants usually conclude their stay with presentation of a seminar for our resident faculty, research staff, students and researchers from the Langley community. Travel restrictions resulting from the COVID-19 pandemic severely limited the scope of the Visitor Program 2020. Nevertheless, NIA hosted:

VISITING STUDENTS

David Lusher
University of Southampton
United Kingdom
"OpenSBLI" Framework

VISITING RESEARCHERS

Calum Williams
University of Cambridge
United Kingdom
Develop Tunable Infrared Filters for Space and Science

Emmett Padway
University of Wyoming
United States
Third-Order Hyperbolic Navier-Stokes Solver for Unsteady Simulations with Adaptive Space-Time Unstructured Grids

Graduate Education

NIA's Graduate Program offers master's and doctoral degrees in a range of engineering and science disciplines from our nine member universities: Georgia Tech, Hampton University, North Carolina A&T State University, North Carolina State University, Old Dominion University, University of Maryland, University of Virginia, Virginia Tech, and William & Mary. Programs are available to on-site students, NASA employees, contractors, and others through local instruction and distance-learning facilities. With resident, visiting and adjunct faculty, plus on-site research staff, we have a department-sized academic presence. Students can earn graduate degrees from leading universities, including classes selected from multiple institutions, while performing critical research in a leading national laboratory, working alongside renowned researchers with state-of-the-art facilities.

2020 Graduates

Anum Rauf Barki Ashraf
Virginia Tech, May 2020
Ph.D. in Mechanical Engineering

Dissertation Topic: "A New Paradigm for End-to-End Modeling of Radiometric Instrumentation Systems"

Advisor: Dr. Robert Mahan

Anum is now a Civil Servant in the Climate Science Branch at NASA's Langley Research Center.

Amanda Stark
Old Dominion University, May 2020
M.S. in Mechanical Engineering

Thesis Topic: "Thermal Contact Resistance Measurement and Related Uncertainties"

Advisor: Dr. Robert Ash

Amanda is a Civil Servant in the Structural and Thermal Systems Branch at NASA's Langley Research Center.

Rajendra Bhatt
University of Virginia, May 2020
Ph.D. in Electrical Engineering

Dissertation Topic: "High-Efficiency Solar Thermophotovoltaic Systems Based on Spectrally Selective Emitters"

Advisor: Dr. Mool Gupta

Rajendra is now employed by Science Systems and Applications Inc., working within the Climate Science Branch at NASA's Langley Research Center.

Yanal Issac
Georgia Tech, July 2020
Ph.D. in Aerospace Engineering

Dissertation Topic: "A Quaternion Approach to the Modal Analysis and Reduced-Order Modeling of Three-Dimensional Fluid Systems"

Advisor: Dr. Dimitri Mavris

Yanal is now a Senior System Engineer at Raytheon Missiles and Defense in Tucson, Arizona.

Harold Haldren III
University of Virginia, May 2020
Ph.D. in Electrical Engineering

Dissertation Topic: "Nondestructive Evaluation of Adhesive Bonds by a Novel Ultrasonic Phase Measurement Method"

Advisor: Dr. Mool Gupta

Harold now holds a position as Senior Staff Scientist at Johns Hopkins University Applied Physics Laboratory in Baltimore, Maryland.

Brian Duvall
Old Dominion University, August 2020
Ph.D. in Mechanical Engineering

Dissertation Topic: "Onboard Autonomous Controllability Assessment for Fixed Wing SUAV"

Advisor: Dr. Drew Landman

Brian is now employed as a Civil Servant in the Aeronautics Systems Branch at NASA's Langley Research Center.

Michelle Rodio
Old Dominion University, May 2020
Ph.D. in Mathematics

Dissertation Topic: "Investigating the Feasibility and Stability for Modeling Acoustic Wave Scattering Using a Time-Domain Boundary Integral Equation with Impedance Boundary Condition"

Advisor: Dr. Fang Hu

Michelle is now a Civil Servant in the IT Infrastructure Branch at NASA's Langley Research Center.

Ryan Ernandis
University of Maryland, August 2020
M.S. in Aerospace Engineering

Thesis Topic: "Sampling Based Motion Planning for Minimizing Position Uncertainty with Stewart Platforms"

Advisor: Dr. Michael Otte

Ryan is now employed by Astrobotic Technology Inc., Pittsburgh, Pennsylvania.

Anibel Benjamin Beltran Laredo
Old Dominion University, August 2020
M.S. in Mechanical Engineering

Thesis Topic "Mechanism of Compaction with Wrinkle Formation During Automatic Stitching of Dry Fabrics and the Size Effect of Compression Molded Discontinuous Fiber Reinforced Composites"

Advisor: Dr. Alex Kravchenko

Ben now serves as an Officer in the United States Air Force.

Dilhara Jayasundara
M.S. in Aerospace Engineering
University of Maryland, December 2020

Advisor: Dr. James Baeder

Dilhara is now in the Ph.D. program at the University of Maryland.

Elizabeth "Libby" Urig
University of Virginia, August 2020
M.S. in Materials Science

Advisor: Dr. James Fitz-Gerald

Libby is now in the Ph.D. program in Materials Science at the University of Virginia, working with the Advanced Materials and Processing Branch at NASA's Langley Research Center.

Jose Mondragon
University of Maryland, December 2020
Ph.D. in Aerospace Engineering

Dissertation Topic "Aeroelastic Stability Analysis of a Wing with a Variable Cant Angle Winglet"

Advisor: Dr. James Hubbard

Jose is now employed by Jacobs Engineering, supporting NASA's Langley Research Center.

George Wilkes
University of Virginia, November 2020
Ph.D. in Electrical Engineering

Dissertation Topic "Laser Annealing of Carrier-Selective Layers in High-Efficiency Photovoltaic Devices"

Advisor: Dr. Mool Gupta

George is currently employed by Turner Laser Systems in Fremont, California.

Rounak Mukhopadhyay
North Carolina State University, December 2020
M.S. in Aerospace Engineering

Thesis Topic "Development of Autonomous Truss Modules Utilizing Shape Memory Alloys for Actuation/Sensing Functionalities"

Advisor: Dr. Fuh-Gwo Yuan

Rounak now resides in New Jersey.

Michael Cunningham
University of Maryland, December 2020
Ph.D. in Aerospace Engineering

Dissertation Topic "System Identification of a Multi-rotor Vehicle with Active Feedback Control"

Advisor: Dr. James Hubbard

Michael is now a Research Scientist with Intelligent Automation Inc. in Rockville, Maryland.

Alana Zahn
Old Dominion University, December 2020
M.S. in Aerospace Engineering

Thesis Topic "Finite Element Analysis Investigation of Hybrid Thin-Ply Composites for Improved Performance of Aerospace Structures"
Advisor: Dr. Alex Kravchenko

Alana is now employed by Analytical Mechanics Associates Inc., assigned to NASA's Langley Research Center.

2020 Atmospheric Flight Mechanics (AFM) Best Professional Paper

Rose Weinstein
University of Maryland.

Rose Weinstein and James Hubbard. "Global Aerodynamic Modeling Using Automated Local Model Networks in Real Time" (AIAA 2020-0762).

The **NIA Best Student Paper Award** recognizes and honors outstanding publications by NIA graduate students each year. For 2020, the award goes to:

Rajendra Bhatt
University of Virginia

Rajendra Bhatt and Mool Gupta. "Design and Validation of a High-Efficiency Planar Solar Thermophotovoltaic System using Spectrally Selective Emitter."

Educational Outreach Programs

In 2020, NIA's Educational Outreach Programs team continued to support NASA's Langley Research Center and our nation's Science, Technology, Engineering and Mathematics (STEM) education community with award-winning, inspirational and educational outreach programs, products and services.

NIA's staff improves STEM literacy, advances understanding and opportunities in STEM, increases the participation of underserved populations, and improves teacher competence and confidence in STEM pedagogies. NIA accomplishes this by developing and delivering research-based strategies, programs, and training in collaboration with industry, nonprofits, and federal, state and local governments, who reach audiences in both formal and informal learning environments for learners of all ages.

NIA's educational outreach program increases scientific literacy. It addresses the national concern of attracting and retaining students in STEM disciplines by nurturing their interest through a variety of approaches and mediums throughout their academic careers. Reaching minority and other underserved populations are of particular interest. Capturing students' early fascination in discovery and problem-solving through integrative approaches to STEM and maintaining and feeding that interest throughout their lives is key to this process.

Higher Education Competitions

Managed by NIA, the Breakthrough, Innovative, and Game-Changing (BIG) Idea Challenge is designated as one of six Artemis Student Challenges. The challenge is sponsored by NASA through a unique collaboration between the Space Technology Mission Directorate's Game Changing Development Program and the Office of STEM Engagement's Space Grant Consortium. Directly supporting NASA's Artemis Program, the 2020 Challenge solicited innovations from university teams for sample CLPS-class (Commercial Lunar Payload Services) payloads that would advance exploration objectives for permanently shadowed regions in-and-near the Moon's polar regions. Nearly $1 million was awarded to eight finalist teams to build and conduct robust proof-of-concept testing on their designs. The presentations were broadcast live to the public using NIA's Media and Communications Group's event webcasts on Livestream.

bigidea.nianet.org

NIA continued program management of NASA's Advanced Exploration Systems' annual Revolutionary Aerospace Systems Concepts – Academic Linkage (RASC-AL) Engineering Design Competition for the 12th consecutive year. RASC-AL provides the opportunity for university-level engineering students to design projects based on real NASA engineering challenges while offering NASA access to new research and design ideas by top collegiate talent. Participation included submission of a proposal, technical paper, oral presentation/design review, and a digital poster on one of five themes which asked students to develop new concepts to leverage innovations to improve NASA's ability to operate in space and on distant planetary bodies. Fifteen teams convened to compete at the 2020 RASC-AL Virtual Forum before a panel of NASA and industry experts. NIA brought the student presentations to the public via NIA's Media and Communications Group's event webcasts on Livestream.

rascal.nianet.org

In 2020, NIA conducted the fourth annual RASC-AL Special Edition: Moon to Mars Ice & Prospecting Challenge. Ten finalist university teams were selected to receive up to $10,000 in funding to design and build prototype hardware that could extract water from simulated lunar and Martian subsurface ice, and also be able to accurately assess subsurface density profiles during drilling. Due to COVID-19, the on-site competition was canceled. Competing teams still submitted a proposal, mid-project report, and a final technical report with supporting materials detailing their concept's development, progress, and an explanation for how they would modify their Earth-based system for lunar and Martian environments. A panel of industry and NASA judges reviewed submitted materials for innovations that may apply to NASA's plans for future lunar and Martian in-situ resource utilization.

specialedition.rascal.nianet.org

In 2020, the Federal Aviation Administration (FAA) sponsored the first FAA Challenge: Smart Airport Student Competition to recognize students with the ability to demonstrate innovative thinking focused on improving the efficiency and effectiveness of smart technology in and around the airport environment while enhancing the overall traveling experience. Three finalist teams were selected by a panel of experts to design, build, and test their proposed smart technology to improve traveler's transportation experiences from home, thru the airport environment, and to his/her final destination. Finalist teams submitted a technical paper and demonstrated their concepts at the 2020 FAA Challenge Virtual Forum, which was livestreamed to the general public. The winning team was announced by Shelley Yak, Director of the FAA William J. Hughes Technical Center, and received the $25,000 prize.

faachallenge.nianet.org

Finalist teams presented their research to a panel of NASA and industry subject matter experts at the 2020 BIG Idea Virtual Forum. NASA Administrator Bridenstine presented the Forum's top award during the 2020 Award Ceremony.

K-12 Educational Programs

NIA continues to manage NASA eClips™, a NASA-supported project that brings together exciting video segments and resources with educational best practices to inspire students and increase STEM literacy through the lens of NASA. Initiated in 2008, NASA eClips serves the national K-12 educational community by introducing students to STEM concepts and providing teachers with engaging educational resources and tools that support teaching and learning in classroom and nonformal settings. Resources include video segments for students, student-produced Spotlite videos that address common science misconceptions, dual-language Spotlite videos, Ask SME career connection videos, the Spotlite Design Challenge, and educator guides and interactive Spotlite lessons for teachers and nonformal educators. In response to the COVID-19 pandemic, our team launched NASA eClips at Home to bring science into the homes of students without internet access. Three 26-minute episodes aired on public television station Virginia Public Media (VPM) Plus.

nasaeclips.arc.nasa.gov

NIA-HCS Educator-in-Residence Program

NIA continued a multi-year partnership with Hampton City Schools (HCS) to increase STEM literacy for HCS teachers and students.

In this role, Betsy McAllister, NIA Educator-in-Residence from HCS, implemented ongoing professional development with elementary, middle, and high school teachers, focused on best practices in the STEM classroom and how to use NASA eClips resources. Ms. McAllister collaborated with NASA Science Directorate educators to train HCS 3rd-grade teachers on integrating Elementary GLOBE Earth System and Soil modules into the schools' science and elementary language arts curricula. She collaborates with Sten Oldenwald, Director of STEM Resource Development at NASA's Goddard Space Flight Center, and HCS teachers to engage physical science students in using smartphone sensors for data collection and citizen science projects. McAllister also connected HCS after-school STEM programs with Challenger Center Virtual missions, such as Destination Mars.

In 2020, McAllister partnered with Aerokats and Rovers Education Network (AREN) educators Geoff Bland and Andy Henry to bring AREN projects to the HCS chapter of Brave Hearts, an after-school group of underserved and underrepresented girls. AREN is a NASA-supported project that helps train the next generation of scientists, engineers, and other professionals by using kite-based, low-cost instrumentation systems to gather remotely sensed Earth observations.

The National Capital Chesapeake Chapter of the National Academy of Television Arts & Sciences selected the NASA eClips produced video series, **Carbon, Essential for Life on Earth, Explained by NASA Subject Matter Experts**, as an Emmy Award winner in the Informational/Instructional – Feature/Segment/Series category during the virtual 62nd Emmy Awards Gala in August 2020.

Sharon Bowers and Joan Harper-Neely from NIA's Center for Integrative STEM Education (NIA-CISE) served as the series' Executive Producers. Caleb Stern and Seth Robinson from NIA's Media and Communications Group supported the series as Producers with additional support from other members of NIA's Educational Outreach Programs team.

HU-CARE Science Communication Interns

As part of the NASA MIRO/CARE award, three students from Hampton University's Scripps Howard School of Journalism served as interns in summer 2020 for NIA and Hampton University's Center for Atmospheric Research and Education (HU-CARE). The students provided social media, website, and outreach support for NASA eClips and created a recruitment video for HU's Atmospheric and Planetary Science graduate program.

In Fall 2020, NIA also began managing a team of undergraduate student interns supporting NASA's Applied Science's Disasters Program as science writers. Three of these interns are from Hampton University. NIA mentors the students as they build their work portfolios producing communication materials for the program, including web features, social media content and radio scripts.

Media Communications and Public Outreach

NIA collaborates with government, industry, universities, professional societies, nonprofits and others to develop and implement projects and campaigns that build excitement and support for NASA and the aerospace community.

NIA conducts a robust public outreach program and provides world-class creative services crafted to deliver award-winning campaigns. With internationally recognized work in video, radio, web, live broadcasts, conferences and events, social platforms and mobile applications, NIA provides valuable support for outreach and communications across the entire spectrum of 21st century media.

NASA 360 has more than 5.59 million fans on social media.

FollowNASA360 @NASA360 FollowNASA360

NASA 360 is a suite of premiere NASA outreach programming that brings audiences the latest in NASA science, engineering and aeronautics. From understanding our changing Earth to preparing for the first woman and next man to land on the Moon – productions under the NASA 360 media umbrella include compelling videos in traditional formats, as well as live event coverage, text videos, animations, and promotional trailers that meet client needs and capitalize on current media trends. NASA 360 engages millions of viewers each year through NASA's website and other broadcast platforms such as YouTube and Facebook.

NASA 360 won three Telly Awards in 2020 including:

- **Silver Telly Winner** in Online: Information - NASA Challenges the Public to Convert CO2 into Sugar
- **Bronze Telly Winner** in Online: Other - Farewell Opportunity
- **Bronze Telly Winner** in Social Video: Education & Discovery - Optical Mining

In 2020, products produced by NIA's NASA 360 team include:

Behind the Spacecraft – Perseverance Mars Rover: A nine-episode series introducing viewers to some of the scientists and engineers that are behind the massive nationwide effort of building a Martian rover.

What You Need to Know About: Have questions? We have answers! NASA and NASA 360 partnered to release this nine-episode text-based series that gives viewers an engaging and concise rundown of what they need to know about our home planet and beyond.

Middle School Student Names NASA's Next Mars Rover – NASA 360 filmed and produced a video announcing the name of the Mars Perseverance rover and introducing viewers to the student who submitted the rover's winning name as part of NASA's Name the Rover Contest.

Videos produced by NIA in 2020 had more than 62.6 million views through web and social media platforms.

The NASA 360 team also provided broad support for a host of other NASA-related efforts including:

A Story of Perseverance – Engaged by NASA's Office of the Administrator, NASA 360 was tasked with developing a long-form, documentary-style video chronicling the week leading up to the Mars 2020 launch through the eyes of NASA Administrator Jim Bridenstine.

Mars 2020 Launch Broadcast Support – Working with NASA's Science Mission Directorate, NASA 360 developed a comprehensive package of launch broadcast assets, including custom-built show graphics and a History of Mars Exploration video showcased in each major NASA-hosted broadcast event.

Sentinel-6 Michael Freilich Launch Broadcast Support – In collaboration with NASA's Earth Science Division, NASA 360 developed and repurposed launch broadcast assets in support of the Sentinel-6 Michael Freilich launch.

Co-produced by the NASA 360 team, **NASA Science Live** invites the public to interact with experts live, go behind the scenes, and watch as guests reveal the mysteries of our solar system and beyond. Each episode is broadcast on NASA TV, as well as the agency's Facebook, Twitter and YouTube platforms. In each episode, viewers can submit their questions live for science and engineering experts by using the hashtag #askNASA.

nasa.gov/nasasciencelive

2020 NASA Science Live Episodes

- Earth Day from Home
- Asteroid Close Approach
- On Ice
- Expanding Our views of the Universe
- Science in the Time of Coronavirus
- How to Spot Comet NEOWISE
- Perseverance Mars Rover and the Search for Ancient Life
- Our Next Solar Cycle
- Hispanic Heritage Month
- Our First Attempt to Sample Asteroid Bennu
- Rising Seas
- Lucy in the Sky with Asteroids
- How to See Saturn and Jupiter's Great Conjunction
- You Too Can Do NASA Science

INNOVATION NOW

WHAT CAN YOU DISCOVER IN 90 SECONDS?

innovationnow @innovationradio

Innovation Now brings listeners the stories behind the ideas that shape the future and benefit our lives. Developed in collaboration with NASA's Space Technology Mission Directorate and launched in September 2011, NIA produces and distributes about 260 radio segments annually. The 90-second interstitial is designed to air daily Monday through Friday and is available at no charge to broadcasters. WHRO/WHRV Hampton Roads is the public radio partner supporting online distribution of the program.

Innovation Now reaches more than 27 million listeners worldwide each day. The series is broadcast via public, college and commercial radio stations, and is available for mobile devices through various podcast apps, including NPR One. Innovation Now is discoverable on multiple smart speakers, including Roku, Alexa, and Google Home; and on dozens of streaming platforms, including iTunes, Stitcher, and Player FM.

Innovation Now was a **Silver Telly Winner** in Online: Science & Technology - Faces of Technology: Women of NASA

The complementary video component, "Faces of Technology," takes viewers inside NASA Centers to give them an immersive glimpse of the people developing some of the NASA technologies featured in the podcasts. These 1-minute videos are distributed through social media and on the Innovation Now website. Targeted videos were released to support Women's History Month, Black History Month, and National Disability Employment Awareness Month. Select videos are produced in both English and Spanish formats. In response to pandemic travel restrictions during 2020, NIA expanded the series to include, "Faces of Technology at Home." Through a series of virtual interviews, NIA was able to continue quality production while featuring NASA researchers who were continuing their technology development remotely as well.

innovationnow.us

NASA Home & City

A **2019 Headquarters Honor Award for Team Excellence** was presented to NIA's **Scott Bednar**, **Rebecca Jaramillo**, **Seth Robinson**, **Matthew Schara**, **David Shelton**, **Harla Sherwood**, **Caleb Stern** and **Jessica Wilde** for their work on NASA Home and City.

The team was also honored with a **Communication Arts 2020 Interactive Annual Award** for their work on the interactive NASA website.

homeandcity.nasa.gov

livestream.com/viewnow

2020 Livestream Event Webcasts

- AIAA Sci Tech 2020
- FAA Smart Airport Student Competition
- 2020 NASA Innovative Advanced Concepts Symposium
- 2020 RASC-AL Virtual Forum

NASA iTech

NASA iTech is a unique program to find innovative ideas that address critical problems here on Earth and hold great potential to solve critical technology challenges in future space exploration. Those ideas may come from small or large businesses, academia, other government organizations – or others who may not have previously had a forum to present their solutions to NASA leadership or its industry partners.

Two NASA iTech Cycles were held in 2020, each culminating in a virtual forum.

The focus areas for Cycle I were Artificial Intelligence (AI) and Machine Learning, Biotechnology, System Autonomy, Advanced Manufacturing, and X-Factor Innovations. Amalgamated Vision, Mojo Vision, and Otolith Labs were selected as winners at the Cycle I Forum.

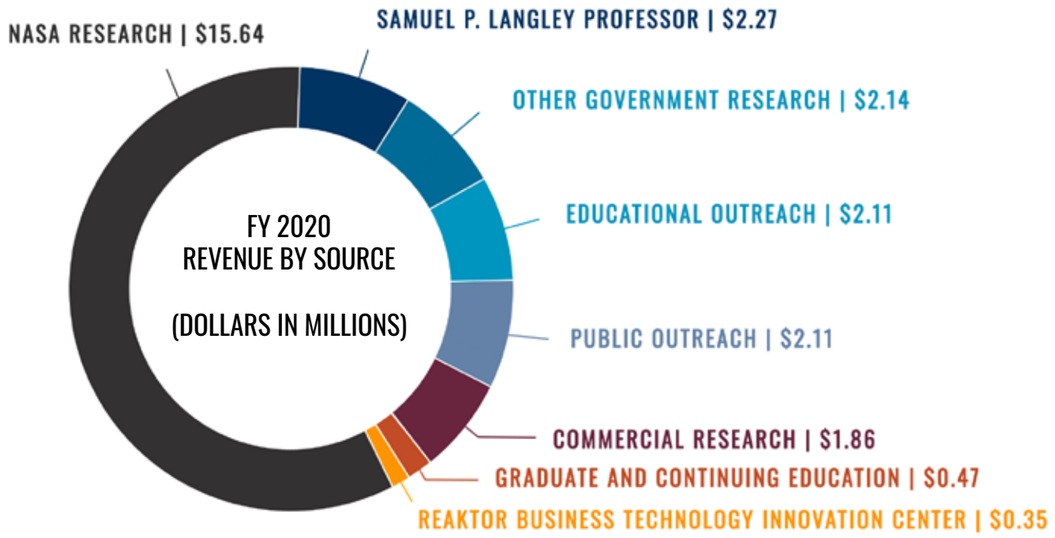
The focus areas for Cycle II were Power Generation/Energy, Integrated Photonics, Advanced Engineered Materials, Miniaturized Systems, and X-Factor Innovations; and the winners selected were AutonomIQ, HyPoint Inc., and Rapair Medical Devices.

Six Ignite the Night events were also held in 2020. These regional and virtual events provide a select group of startups the opportunity to "fast pitch" their ideas on stage to an esteemed panel of NASA's Center Chief Technologists, industry experts and investors.

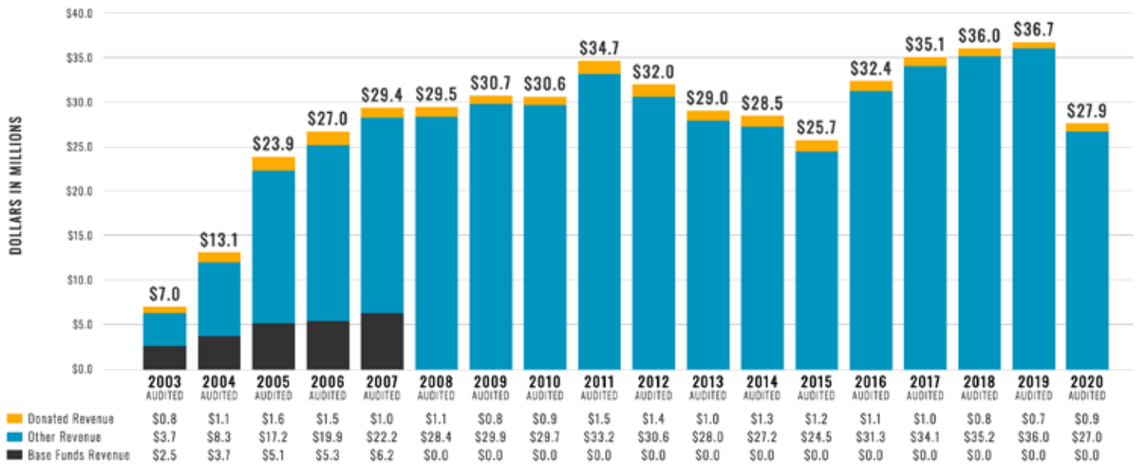
Event Webcasts

The NIA Media Communications Group provides live web broadcast and public engagement support for conferences, events and workshops. These broadcasts broaden public exposure to some of the most exciting new developments at NASA and in the aerospace industry and stimulate an interest in science, engineering and technology relevant to aerospace. As events moved to virtual platforms, NIA broadcast capabilities evolved to allow audiences to actively participate in these forums.

Financials



NIA TOTAL REVENUE BY YEAR



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National Institute of Aerospace
100 Exploration Way
Hampton, VA 23666
(757) 325-6700

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