2019
ANNUAL
REPORT

NATIONAL INSTITUTE OF AEROSPACE

Leaders 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 VISION

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

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PRESIDENT'S MESSAGE

This year's annual report features our innovative research, exemplary education, and inspirational outreach that has characterized NIA since our founding. In 2019, we once again had the highest revenues in our history! We continued our expansion in Southern New Jersey supporting the Federal Aviation Administration's William J. Hughes Technical Center with research and outreach activities, as well as establishing the Smart Airport and Aviation Partnership with $1.7 million in funding from the U.S. Economic Development Administration and local government and industry partners.

In 2019, our researchers submitted 20 new invention disclosures, received six patents, and authored 100 technical publications. Dr. Jin Ho Kang received the prestigious NASA Exceptional Technology Achievement Medal for his work on spacecraft materials. Dr. Hiro Nishikawa was named the AIAA Hampton Roads Section (HRS) Engineer of the Year, and Dr. Tyler Hudson was named the HRS Young Engineer of the Year. This is the fifth time in the past 14 years that an NIA researcher has been selected as the Engineer of the Year, and the fourth time an NIA researcher has been selected as the Young Engineer of the Year! In addition, Dr. Hiro Nishikawa authored the AIAA Best Paper of the Year in Computational Fluid Dynamics, Dr. Swee Balachandran co-authored the AIAA Best Paper of the Year in Aircraft Operations, and the AIAA Best Paper of the Year in Multidisciplinary Design Optimization was co-authored by Drs. Li Wang and Boris Diskin of NIA, together with NIA Distinguished Langley Professor from the University of Maryland, Dr. Olivier Bauchau. That's three nationally recognized Best Papers in the same year!

Our Center for High-Performance Aerospace Computing (HiPAC) under the leadership of NIA Senior Research Fellow, Dr. Boris Diskin, engaged in a record 31 different research projects with $6.4 million in funding, in collaboration with 11 different universities and seven industry partners. HiPAC also hosted 19 Computational Fluid Dynamic seminars, bringing the total to 123, all recorded and hosted on our website as a free service for the user community.

This report also includes a section on our Peninsula Technology Incubator and REaKTOR unmanned systems business accelerator, which are assisting companies commercializing aerospace-related technologies. It raised over $10 million in private capital to enable the growth of these early-stage companies and recently won a $50,000 grant to assist women-owned businesses.

Our unique graduate education program had 33 full-time and 27 part-time graduate students in 2019. Our students can earn degrees from any of our nine member universities and take up to half of their classes from other universities. We also sponsored 28 seminars at NIA and NASA presented by distinguished faculty and researchers from all over the world, as well as two workshops and three short courses.

Our Samuel P. Langley Professors-in-Residence at NIA from our member universities all continued to excel in 2019 by publishing almost 200 peer-reviewed publications and conference papers. Seven of the eight are Fellows in their respective professional societies. We were pleased to welcome a new Langley Professor from North Carolina A&T State University: Dr. Abdollah "Ebbie" Homaifar, Director of the Autonomous Control and Information Technology (ACIT) Institute. This report features his research in trusted autonomy for unmanned systems.

Finally, our world-class educational and public outreach programs continued to garner new customers, audiences and awards. In 2019, we broadcast 261 episodes of our Innovation Now radio program, which features exciting innovations in aerospace. This year, its audience increased to more than 20 million daily listeners. We also produced and distributed 86 new video episodes for our flagship NASA 360 video series. The program increased Facebook followers to 5.44 million and reached 51.3 million people in 2019! With more than 90,000 downloads per month, our NASA eClips program continues to reach classrooms. 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 coordinating the highly successful NASA iTech program to encourage startup companies to address new technologies and ideas relevant to NASA—raising over $500 million in private capital to date.

I look forward to working with each of our stakeholders in 2020 as we continue creating a unique research, education and outreach capability to support our many customers.

Dr. Douglas Stanley
President and Executive Director

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 future strategic research directions at NASA's Langley Research Center.

Branch heads and researchers within NASA Langley's Research Directorate regularly seek 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 performing their coursework and research on-site at both the National Institute of Aerospace and NASA Langley. Each Langley Professor specializes in a technical discipline that aligns with the research program and interests of NASA's Langley Research Center.

NIA SAMUEL P. LANGLEY PROFESSORS

James Baeder
University of Maryland

Center for Rotorcraft Aeroacoustics

Computational Aerodynamics and Aeroacoustics

Olivier Bauchau
University of Maryland

Center for Structural Dynamics

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

Christopher Fuller
Virginia Tech

Center for Aerospace Acoustics

Acoustics, Active Noise Control, and Acoustic Meta-Materials

Mool Gupta
University of Virginia

Center for Photonics, Sensors and Solar Energy

Photonics, Sensors, Solar Energy, and Nanomaterials

Professor Mool Gupta, University of Virginia Samuel P. Langley Distinguished Professor at NIA was named an IEEE Fellow, with special recognition of his contributions to laser material interactions.

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

Dimitri Mavris
Georgia Institute of Technology

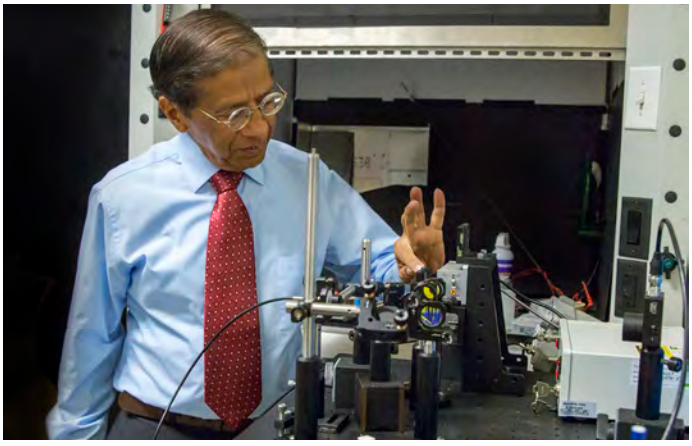
Aerospace Systems Design Laboratory @NIA

Design of Space Systems, Vehicles and Architectures

Fuh-Gwo Yuan
North Carolina State University

Center for Integrated Systems Health Management

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



Dr. Mool Gupta with an optic fiber-based hybrid spectroscope he developed. Image Credit: NASA/David C. Bowman

SAMUEL P. LANGLEY DISTINGUISHED PROFESSOR
ABDOLLAH "EBBIE" HOMAIFAR, NORTH CAROLINA A&T STATE UNIVERSITY

Dr. Abdollah "Ebbie" Homaifar is the Samuel P. Langley Professor for North Carolina A&T State University at the National Institute of Aerospace, as well as the Duke Energy Eminent professor in the Department of Electrical and Computer Engineering at N.C. A&T. He is the Director of the Autonomous Control and Information Technology (ACIT) Institute, which he established in 2015, as well as the Director of the Testing, Evaluation and Control of Heterogeneous Large-Scale Systems of Autonomous Vehicles (TECHLAV) at N.C. A&T.

For more than three decades, Professor Homaifar has built a symbiotic support structure to train future engineers and leaders in the field. He has advised and provided coursework to more than 300 graduate students and 1000 undergraduate students, many of whom were the students of collaborators from various departments and colleges. As of 2019, more than 26 Ph.D. and 90 M.S. students have graduated under his guidance. One of the main contributors to the creation of N.C. A&T's Ph.D. program in electrical and computer engineering, Professor Homaifar has developed and taught 11 graduate and undergraduate courses. Professor Homaifar has also generated more than $40 million in sponsored research dollars as P.I. and Co-P.I. over the past three decades, including more than $6 million in grants in the past three years and an additional $5.3 million contract in the past two years that had a TRL-3 technology prerequisite (requiring demonstrated proof-of-concept).

Professor Homaifar's current global research projects include machine learning, approximate reasoning, soft computing, evolutionary computations, stochastic control and estimation, modeling and control of systems of systems, robotics, unmanned aerial vehicles (UAVs), testing and evaluation of autonomous vehicles, optimization and signal processing. Because of the results and impact of these projects, Professor Homaifar received the STEM Scientist of the Year Award at the 2018 Black Engineer of the Year Awards STEM Global Competitiveness Conference in Washington, DC. This award honored his lifetime achievements in science and engineering accomplishments, his teaching and services impacting numerous students' lives, and his years of adding considerably to the multiethnic, multicultural, and multinational workforce. Due to his continual industry-changing work at N.C. A&T, in December 2019, the North Carolina Department of Transportation (NCDOT) chose a research team at North Carolina A&T State University to establish the N.C. Transportation Center of Excellence in Connected and Autonomous Vehicle Technology (NC-CAV), a project the agency is funding with a $1 million grant.

As the leader of several major multi-institutional research projects, Professor Homaifar established a university-wide institute in 2016 and two research centers. These centers bring together top researchers to address grand challenges and investigate problems of significant national interest. His primary focus is on autonomous vehicle control, testing, and evaluation of large systems of systems. TECHLAV is a high visibility center entrusted with the development of assured autonomy technology that will enable the future vision of U.S. national defense and U.S. transportation solutions.

Professor Homaifar has written more than 350 technical publications, including book chapters and journal and conference papers. He also serves as an associate editor for the Journal of Intelligent Automation and Soft Computing and as a reviewer for the IEEE Transactions on Fuzzy Systems, Man Machines and Cybernetics, and Neural Networks.

Dr. Homaifar received B.S. and M.S. degrees in electrical engineering from the State University of New York at Stony Brook and holds a Ph.D. in electrical engineering from the University of Alabama. He is a member of the IEEE Control Society, Sigma Xi, Tau Beta Pi and Eta Kapa Nu.

In December 2019, the North Carolina Department of Transportation (NCDOT) chose a research team at North Carolina A&T State University to establish the **NC Transportation Center of Excellence in Connected and Autonomous Vehicle Technology (NC-CAV)**, a project the agency is funding with a $1 million grant.

The grant supports a three-year multi-disciplinary effort that will include work led by Professor Homaifar to explore emerging applications of Connected Autonomous Vehicles (CAVs) and develop and deploy CAVs and Unmanned Aerial Vehicles (UAVs) for advancing transportation systems. N.C. A&T will partner with the City of Greensboro, North Carolina in this effort to build a road between the university and downtown exclusively for autonomous vehicles.

The **Testing, Evaluation, and Control of Heterogeneous Large-Scale Systems of Autonomous Vehicles (TECHLAV)**, directed by Professor Homaifar, is a Department of Defense Center of Excellence in Autonomy, led by North Carolina A&T State University in collaboration with the University of Texas at San Antonio and the Southwestern Indian Polytechnic Institute. The Center conducts notable integrated multidisciplinary research and education on Large Scale Autonomous Systems of Vehicles (LSASV).

The TECHLAV Center involves three research thrusts.

- Thrust 1 develops scalable methodologies to improve modeling, analysis, localization, navigation and control of LSASVs.
- Thrust 2 develops systematic techniques to enhance the reliability and efficacy of the control structure and the communication backbone for LSASVs.
- Thrust 3 develops and provides technologies and tools for the testing, evaluation, validation and verification of LSASVs.

RESEARCH

MESSAGE FROM VICE PRESIDENT OF RESEARCH

David Throckmorton

During 2019, NIA researchers continued to perform cutting-edge research and technology development in support of NASA's Langley Research Center and other government and commercial aerospace customers. The Research Department staff continued to grow in 2019 – 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 in 2019 for the outstanding quality and impact of their work.

NASA awarded NIA Associate Principal Engineer Jin Ho Kang the NASA Exceptional Technology Achievement Medal, the agency's highest form of individual recognition.

The American Institute of Aeronautics and Astronautics (AIAA) recognized NIA researchers for "Best Papers of the Year" presented at AIAA venues in the topic areas of Aircraft Operations, Computational Fluid Dynamics, and Multidisciplinary Design Optimization.

Fifteen NIA researchers were members of teams that received NASA Group Achievement Awards or the XCELLENCE award of the Association for Unmanned Vehicle Systems International (AUVSI). These awards recognize significant contributions that enhance scientific understanding of the transport of aerosols in the atmosphere, and development of software to ensure safe operations of autonomous vehicles in flight, among other topics.

For the second year in a row, the Hampton Roads Section of the American Institute of Aeronautics and Astronautics recognized an NIA employee as its Engineer of the Year. The 2019 awardee was NIA Associate Research Fellow Hiroaki Nishikawa.

The following pages provide a snapshot of some of the exciting research contributions of NIA researchers in 2019, as well as a bibliography of technical publications resulting from the efforts of NIA's research staff.

Dr. Boris Diskin, Director of NIA's Center for High Performance Aerospace Computing (HiPAC) was selected to become an NIA Senior Research Fellow. Selection for this level of recognition constitutes NIA's highest honor and is emblematic of extraordinary technical excellence demonstrated over a long and sustained period of time. Dr. Diskin is the first employee in the 17-year history of NIA to be recognized with this distinction.

The Hampton Roads Section of the American Institute of Aeronautics and Astronautics selected **Dr. Hiroaki Nishikawa**, NIA Associate Research Fellow, to receive its 2019 Engineer of the Year award. Dr. Nishikawa was recognized for his "innovative, seminal contributions to the theory, implementation, and verification of novel computational approaches to the solution of aerodynamic equations in practical CFD codes."

RESEARCH CENTERS AND 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 & Solar Energy
- Center for Planetary Dynamics
- Center for Rotorcraft Aeroacoustics
- Center for Structural Dynamics
- Center for High Performance Aerospace Computing
- Autonomous Control and Information Technology Institute
- Aerospace Systems Design Laboratory @NIA
- Boron Nitride Nanotube Laboratory

AN INTEGRATED COMPUTATIONAL MATERIALS ENGINEERING (ICME) FRAMEWORK TO INVESTIGATE THE EFFECTS-OF-DEFECTS ON THE FATIGUE PERFORMANCE OF ADDITIVELY MANUFACTURED (AM) MATERIALS

Saikumar Yeratapally, NIA Research Engineer

The development of advanced aerospace materials has historically been an empirical and iterative process. Because of this, developing new materials, certifying them as safe, and deploying them into service often took many years, even decades. The advent of additive manufacturing (AM) introduced the ability to design and optimize materials for specific, desired functionality. AM makes the "bottoms-up" design of materials possible and allows designers to tailor a composite's location-specific microstructure by controlling process parameters. AM creates opportunities for integrated material and product design. Still, timely certification of new materials for aerospace applications remains challenging.

A typical AM processing technique, laser powder-bed fusion (LPBF), has a large process-parameter space. In other words, there are many "knobs to tune," such as laser power, laser speed, layer thickness, spot size and build direction. Powder-based AM processes are also subject to the formation of multiple process-specific defects. Potential defects include irregular lack-of-fusion (LoF) pores that result from low laser power and/or high laser-speed processing; regular/smooth keyhole pores that result from high laser energy density; and near-spherical entrapped gas pores that form due to trapped gas in powder particles. The types of defects, their density, and the local stress state, directly affect the performance of as-built components.

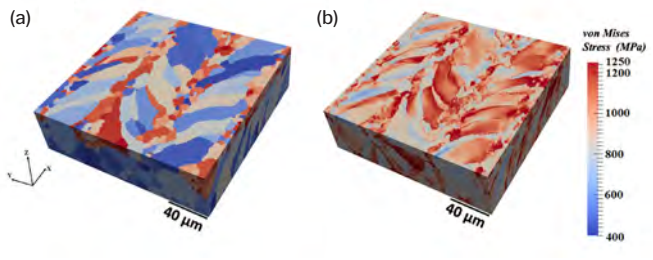


Figure 1 - (a) LPBF process-specific microstructure produced from SPPARKS for a combination of process parameters, (b) Heterogeneous stress field as calculated by ScIFEN, when the microstructure is subjected to a peak strain of 1%.

It is far too time-consuming to produce several specimens using various combinations of process parameters, and then conduct nondestructive evaluation (for defect quantification) and mechanical testing (for property characterization) on each sample to identify optimal process parameters. A digital transformation of the design, tailoring, and certification of AM materials will remove these barriers. This digital transformation is the objective of the Materials Genome Initiative. This multi-agency initiative aims to reduce the time required for materials design, development, and certification by a factor of two.

An integrated computational materials engineering (ICME) framework that integrates AM process modeling simulations with predictive performance models will help narrow the process parameter-space. By using this framework, process engineers will significantly cut the time they spend exploring the process parameter space, and limit the production of components that exhibit sub-optimal performance.

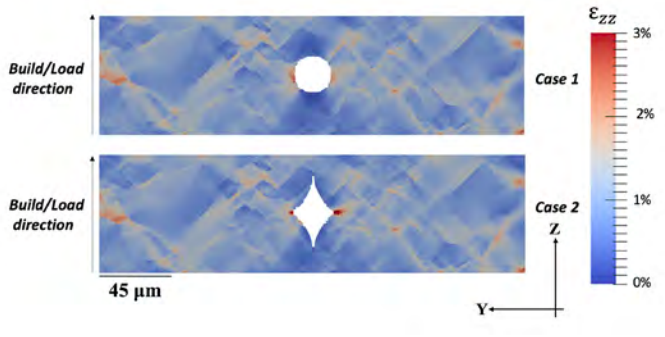


Figure 2 - Strain fields surrounding an idealized near-spherical keyhole pore (Case 1) and an idealized LoF pore (Case 2) embedded within the same parent microstructure. Peak strain applied in both the cases is 0.5%

Ongoing research at NIA focuses on developing an ICME framework that links AM process parameters to the heterogeneous microstructure, and links the microstructure to the properties of the materials. The framework automates coupling between SPPARKS (an open-source LPBF process simulation package from Sandia National Laboratories), and ScIFEN (a finite element solver developed at NASA's Langley Research Center to predict mechanical properties). Figure 1 shows an overview of the ICME framework. The framework also allows researchers to understand how material defects within specimens produced using AM processes can affect the fatigue properties of those specimens. Figure 2 shows a case study that uses the ICME framework to study the effect of defect geometries on the strain localization in the vicinity of two types of idealized defects. Development of the framework with a digital platform for the concurrent design, optimization, and certification of materials, systems and manufacturing processes aligns well with NASA's Vision 2040: A Roadmap for Integrated, Multiscale Modeling and Simulation of Materials and Systems.

DEVELOPMENT OF A HIGH-SPEED, MULTI-PHYSICS, MULTI-DIAGNOSTIC, LASER-BASED MEASUREMENT SYSTEM FOR NON-INTRUSIVE WIND TUNNEL MEASUREMENTS

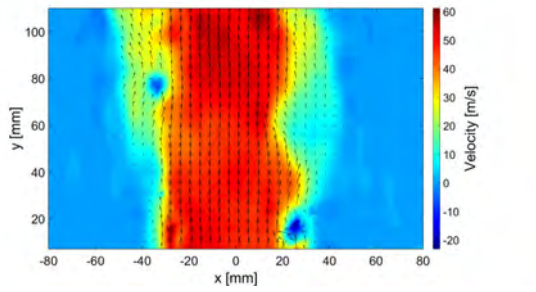
Ross A. Burns and **Tim W. Fahringer, Jr.**, NIA Research Engineers

In the past two decades, ground-based test facilities have dramatically increased the use of laser-based techniques to permit non-intrusive, off-body measurements of flow-field parameters. Such techniques apply to a broad range of aerodynamic regimes from low-subsonic to hypersonic, non-reacting and reacting flows. However, laser operating parameters, such as output wavelength, repetition rate and linewidth, constrain the range of flow regimes where it is possible to make measurements with an individual laser. Using a single diagnostic technique to measure a specific flow parameter can lead to biases based on the physics of the diagnostic. For example, if a velocity measurement tracks particles immersed in the flow, the difference between the particles' velocity and the velocity of the fluid leads to a bias error in the measurement. If, instead, the velocity is measured with multiple approaches, say one particle-based and another molecular-based, we can decrease the uncertainty of the overall measurement.

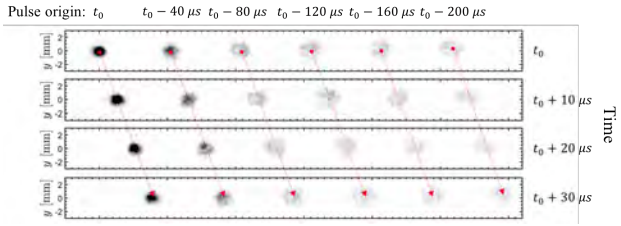
In partnership with collaborators at NASA's Langley Research Center, NIA researchers have developed a novel and versatile approach to laser-based diagnostics. They have advanced a high-speed diagnostics platform that is capable of implementing multiple diagnostic techniques simultaneously measuring the same flow quantities using multiple physical processes. The nucleus of this system is a laser that produces a burst of high-energy pulses at repetition rates from 10 kHz to 2 MHz. It is reconfigurable to allow frequency doubling, tripling or quadrupling, and it allows for variable pulse widths ranging from 10 picoseconds to 100s of nanoseconds. The measurement system also includes multiple high-speed cameras for data acquisition, and performance measurement systems to monitor the laser frequency and variability. With these elements, this single system can be configured to perform a host of laser diagnostics, including particle image velocimetry (PIV), Doppler global velocimetry (DGV), Rayleigh scattering, Planar laser-induced fluorescence (PLIF), Picosecond-laser electronic-excitation tagging (PLEET), among a host of others. The system makes it possible to measure multiple relevant flow quantities, including velocity, temperature, density and composition.

This new system also offers the potential to measure flow quantities across most flow regimes using several different physics. Figure 1 presents measurements from three flow regimes using three distinct physical processes, all using the same laser system. Figure 1(a) depicts an instantaneous vector field of a low-speed jet obtained using PIV, a technique that uses statistical correlation to estimate displacements between subsequent images. Figure 1(b) shows a sample data set taken in a transonic flow acquired using the PLEET technique, which uses photoionization of nitrogen gas to measure flow displacements directly. Lastly, Figure 1(c) shows a velocity field measured across an oblique shockwave in a supersonic flow using the cross-correlation DGV technique, which infers velocity through the measurement of a Doppler shift in the observed laser frequency. The ability to perform so many different techniques with minimal changes to the experimental configuration makes it easy to tailor this platform to the needs of specific experiments.

(a)



(b)



(c)

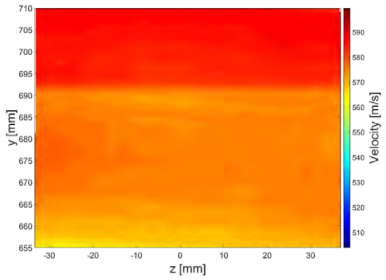
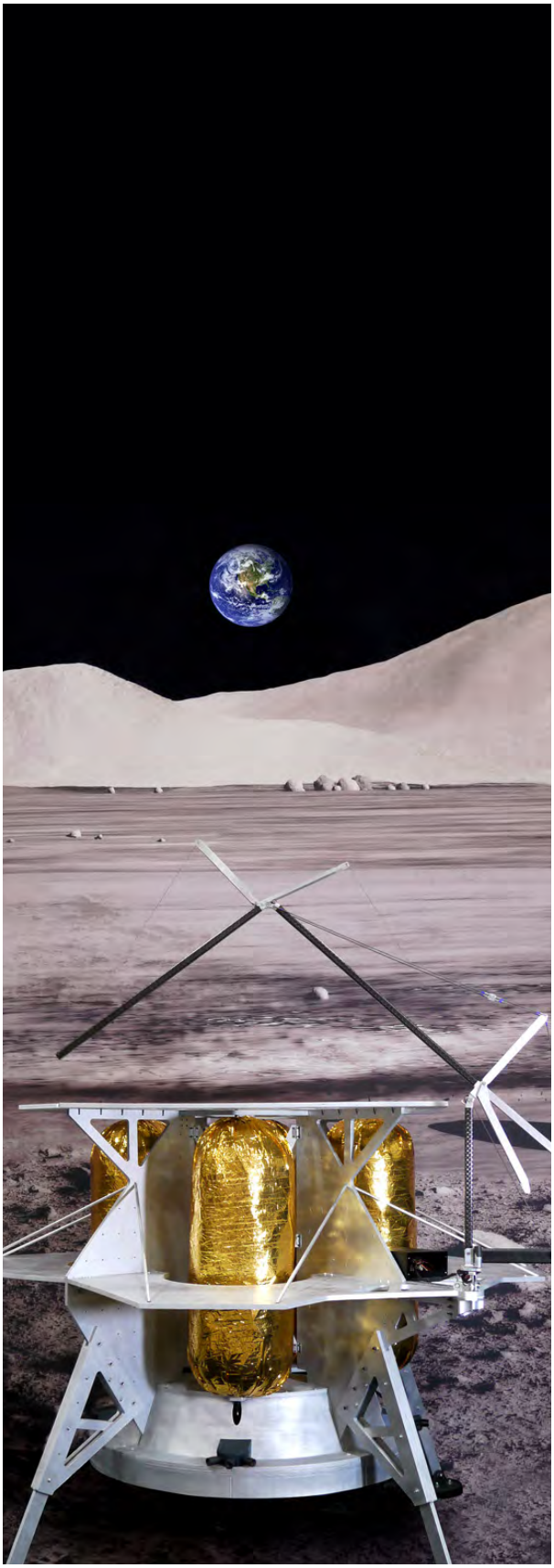


Figure 1 – Sample results from the multi-diagnostics platform in different flow regimes. (a) Sample PIV vector field from a low-speed jet, (b) sample high-speed images of PLEET velocimetry of a Mach 0.85 flow showing the measured displacements, and (c) velocity field across an oblique shock wave using cross-correlation DGV.

LIGHTWEIGHT SURFACE MANIPULATION SYSTEM (LSMS) FOR PAYLOAD OFF-LOADING ON THE LUNAR SURFACE

Iok M. Wong, NIA Research Engineer



NASA's Artemis Program seeks to return American astronauts to the Moon to establish a sustainable human presence and perform crucial scientific research that will lead to eventual human missions to Mars. The program envisions the use of commercially developed lunar landing vehicles to deliver payloads of scientific instruments and other cargo to the lunar surface. The task of off-loading cargo and deploying instruments will require a payload lifting system. Before initiation of the Artemis program, researchers at NASA's Langley Research Center developed and tested a Lightweight Surface Manipulation System (LSMS) to make these capabilities possible. However, that concept requires an upgrade for it to effectively integrate with the new human and cargo landers that are in development by commercial industry partners.

This research focuses on miniaturizing the LSMS to fit on small cargo landers for use on missions to the Moon as early as 2022. Development of the LSMS-mini (Figure 1) includes a self-deployment system (SDS), and a self-leveling system (SLS). The SDS allows the LSMS-mini to deploy itself into the mass lifting configuration. The SLS allows for LSMS-mini operations even when the lander has come to rest at an inclined angle of up to 15 degrees. Several new miniaturized tools for the LSMS-mini are also in development. These tools include lifting end effectors capable of picking up payloads at an inclined angle, a payload charging port for recharging payloads such as rovers, and a quick tool-exchange interface, among others.

The development of these new systems also brings new challenges when considering manufacturing simplicity and commercialization. With commercial industry participants leading the lander effort for cargo (and possibly for human landers as well) the systems need to be commercially viable. Parts need to be readily available (i.e., not unique and one-of-a-kind). They also need to be relatively easy to manufacture with scalability, adaptability and minimal operational overhead.

Advanced versions of some common tools have been invented with this commercially-driven approach in mind. For example, a traditional leveling system needs at least two motors—each with control electronics to drive the two-degree-of-freedom, X, and Y rotation needed to level an object to the ground. In contrast, the self-leveling system for the LSMS-mini features an innovative design that requires only one motor to achieve the same results. This design enables the reduction of necessary control electronics by more than 40%, significantly reducing power draw and manufacturing cost.

A flight-like engineering development unit of the LSMS-mini is being built. Testing of the LSMS-mini will advance its technology readiness for evolving lander designs. Additional testing will investigate multi-unit operations, where two or more units will operate collaboratively. New sensing systems and software will give each unit the ability to recognize and communicate with others. More control and autonomy research will support the Artemis Program on a wide range of lunar surface activities.

Figure 1 (left) - LSMS-mini operates on a lunar lander mock-up

RUNTIME VERIFICATION OF AUTONOMOUS VEHICLES

Dr. Ivan Perez, NIA Research Scientist

Safety-critical systems, those in which a failure can result in injury or death of a human, require extremely high levels of assurance and reliability. For civil aviation applications, for example, the probability of failure per hour of operation must be less than 1 in 10^9.

Formal verification techniques are one method for achieving high-level assurance. Formal verification is based on proving the correct behavior of a system by building a mathematically rigorous model of that system and then analytically verifying the system's operational properties. By using a formal proof, one can assert that a property will hold not just for one input or in one test scenario, but for a whole range of inputs and situations. A formal proof makes it possible to verify a system's properties more thoroughly than via empirical testing. This is particularly useful as the number of possible inputs and scenarios grows; if the model of the system is accurate, a proof is as good as having tested all possible combinations, and its value is incalculable.

Although there have been considerable advances in creating industrial-scale formal methods, it is not yet practical to apply them to entire systems due to their exceedingly high complexity. That complexity is only expected to grow with the popularity of machine learning and artificial intelligence. However, Runtime Verification (RV) is a technique that has the potential to facilitate the safe operation of safety-critical systems that are too complex to formally verify or fully test. In RV, the desirable behavior of a vehicle during a mission is captured in a collection of mathematical properties. The system is then monitored during execution to detect when those properties are violated during the mission and respond accordingly.

A Runtime Verification framework, known as Copilot, has been developed as a result of a collaboration between the NIA and Galois, Inc. Copilot generates software code that can be executed safely and with minimal resources on nearly any computer or embedded system. These attributes make it ideal for application to Unmanned Aerial Vehicles (UAVs), where weight, power and timing constraints are significant. Figure 1 depicts the process flow for development and application of the Runtime Verification Framework.

Copilot has been used to specify and verify some of the properties required for the safe operation of UAVs; and has been evaluated in actual flight test environments (Figure 2), as opposed to simulations. However, as these systems become more complex, it becomes more difficult for human engineers to describe precisely what properties should hold during flights. Current work has focused on extending Copilot and similar systems to facilitate describing more sophisticated properties in a way that is clear, understandable and precise. These extensions have been used to specify the correct behavior of swarms of UAVs that must cooperate with each other to carry out a mission. Artificial errors have been injected in simulations to verify the correct behavior of the swarm under stress. Additional research is exploring how to integrate Copilot with some of the systems used by NASA to create UAV applications, such as NASA's Core Flight System (cFS) and the ICAROUS (Independent and Configurable Architecture for Reliable Operations of Unmanned Systems) sense and avoid software suite.

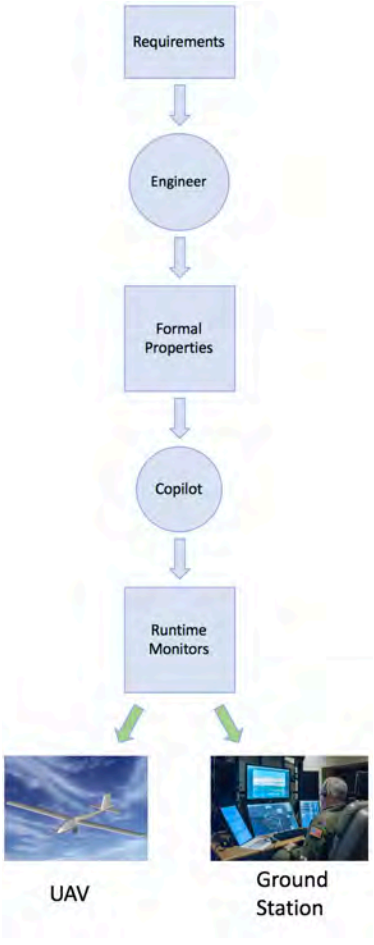


Figure 1 (above) - Engineers formalize system requirements using the Copilot language. This framework then generates software runtime monitors that verify the safe operation both from the vehicle itself and from the ground station.

Figure 2 (below) - Copilot has been used to formalize requirements of UAV missions and monitor their safe operation during flight tests carried out in collaboration with NASA's Langley Research Center.

RESEARCH PUBLICATIONS

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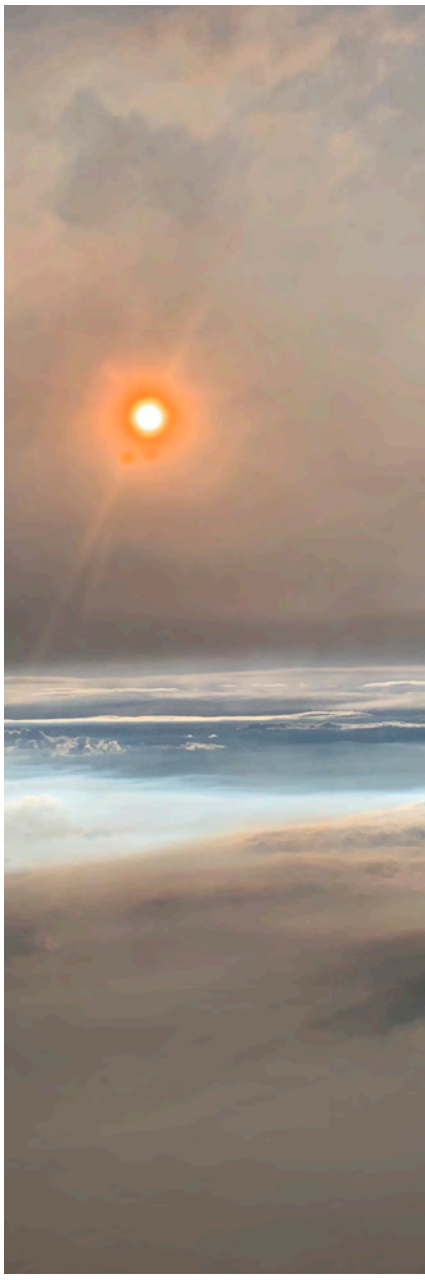
S.R. Zavada, G. Sauti, K.L. Gordon, J.G. Smith, and E.J. Siochi: "Thermally Induced Healing of Electrically Insulating Ethylene–Octene Copolymers," Industrial & Engineering Chemistry Research, Vol. 58 (43), 19899-19908, October 2019, doi.org/10.1021/acs.iecr.9b03575

Yamakov, V. I., and Glaessgen, E. H.: "AladynPi – Adaptive Neural Network Molecular Dynamics Simulation Code with Physically Informed Potential: Computational Materials Mini-Application," NASA/TM-2019-220431, December 2019.

HUMAN FACTORS

J. Hanson, M. Clowdsley, and S. Thibeault: "Human Factors Ground Test Assessment and Protocol Development for Space Radiation Protection Concepts," *Human Factors and Ergonomics Society Annual Meeting*, Vol. 63(1), 1782-1786, November 2019, doi:10.1177/1071181319631243

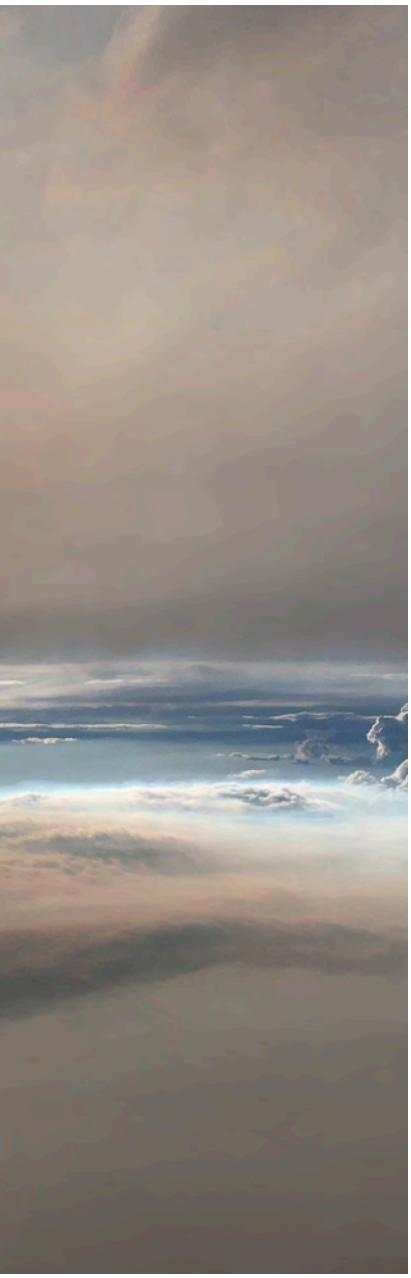
Dr. Jin Ho Kang, NIA Associate Principal Engineer, received the NASA Exceptional Technology Achievement Medal for "exceptional technology contributions to improve the space environment survivability, dimension stability, and stowage configuration of aerospace materials."



NANOTECHNOLOGY

J. Peeples, **S.-H. Chu**, J. P. O'Neil, M. Janabi, B. Wieland, and M. Stokely: "Boron Nitride Nanotube Cyclotron Targets for Recoil Escape Production of Carbon-11," *Instruments*, 3(1), 8, January 2019, doi:10.3390/instruments3010008

D. M. Marincel, M. Adnan, J. Ma, E. A. Bengio, M. A. Trafford, O. Kleinerman, D. Kosynkin, **S.-H. Chu**, C. Park, S. J. A. Hocker, C. Fay, S. Arepalli, A. A. Martí, Y. Talmon, and M. Pasquali: "Scalable Purification of Boron Nitride Nanotubes via Wet Thermal Etching," *Chemistry of Materials*, 31(5), 520-1527, February 2019, doi:10.1021/acs.chemmater.8b03785



A. Duzik, H-U Ko, **H. J. Kim**, J. Kim, J. H. Kim, S. H. Choi, and R. G. Bryant: "Fabrication Method, Characteristics and Applications of Cellulose Nano Fiber (CNF) Film," NASA/TM-2019-220268, April 2019.

D. Lee, **F.-G. Yuan**, C. Fay, **S.-H. Chu**, and C. Park: "Piezoelectric Characterization of Boron Nitride Nanotube-Polyurethane Composites," *Micro-and Nanotechnology Sensors, Systems, and Applications XI, International Society for Optics and Photonics*, 10982, 1098233, May 2019, doi:10.1117/12.2513999

Y. Jia, T. Ajayi, J. Morales, M. A. R. Chowdhury, G. Sauti, **S.-H. Chu**, C. Park, and C. Xu: "Thermal Properties of Polymer-derived Ceramic Reinforced with Boron Nitride Nanotubes," *Journal of the American Ceramic Society*, July 2019, doi.org/10.1111/jace.16670

G. Sauti, C. Park, J. W. Lee, H. H. Luong, and **S.-H. Chu**: "NtGCM User's Manual: 1.1 (High Pressure High Temperature Laser-based) Nanotube Growth Chamber Monitor," NASA/TM-2019-220395, August 2019.

SENSORS, OPTICS, AND MEASUREMENT SYSTEMS

A. N. Watkins, K. Z. Goodman, and **S. M. Peak**: "Transition Detection at Cryogenic Temperatures Using a Carbon-Based Resistive Heating Layer Coupled with Temperature Sensitive Paint," AIAA Paper 2019-2191, *AIAA SciTech Forum and Exposition*, January 2019, doi:10.2514/6.2019-2191

M. A. André, **R. A. Burns**, P. M. Danehy, S. R. Cadell, B. G. Woods, and P. M. Bardet: "Velocimetry during depressurized conduction cooldown events in the HTTF," *Nuclear Engineering and Design*, Vol. 341, 406-414, January 2019, doi:10.1016/j.nuceng des.2018.11.026

Photo (left) - As part of a joint campaign led by NASA and the National Oceanic and Atmospheric Administration, Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ), NIA researchers are tracking smoke from fires to improve air quality forecasting. Image credit: Dr. David Peterson, Naval Research Laboratory.

The Association for Unmanned Vehicles Systems International (AUVSI) presented its AUVSI XCELLENCE award -- 2nd Place in the Category of Detect and Avoid Solutions – to NIA Research Engineer **Dr. Swee Balachandran**, recognizing research performed by a team which included NIA Research Scientist **Marco Feliú**, and NIA Research Engineers **Brendan Duffy**, **Andrew Peters** and **Kyle Smalling**.

A paper co-authored by NIA Research Engineer **Dr. Swee Balachandran**, was recognized as the Best Paper presented at AIAA Conferences in 2018 in the area of Aircraft Operations. NIA Research Engineers **Kyle Smalling** and **Nick Rymer** supported the research presented in the paper.

D. T. Reese, **R. A. Burns**, P. M. Danehy, E. J. Walker, and W. K. Goad: "Implementation of a pulsed-laser measurement system in the National Transonic Facility," AIAA Paper 2019-3380, *AIAA Aviation Forum and Exposition*, June 2019, doi:10.2514/6.2019-3380

T. W. Fahringer, **R. A. Burns**, P. M. Danehy, P. M. Bardet, and J. Felver: "Pulse-burst Cross-correlation Doppler Global Velocimetry," AIAA Paper 2019-3384, *AIAA Aviation Forum and Exposition*, June 2019, doi:10.2514/6.2019-3384

P. Danehy, B. Wisser, **T. Fahringer**, C. Winski, B. Falman, and S. Shea: "Laser Light Sheet Flow Visualization of the Space Launch System Booster Separation Test," AIAA Paper 2019-3507, *AIAA Aviation Forum and Exposition*, June 2019, doi:10.2514/6.2019-3505

UNMANNED SYSTEMS

M. Consiglio, **B. Duffy**, **S. Balachandran**, L. Glaab, and C. Muñoz: "Sense and Avoid Characterization of the Independent Configurable Architecture for Reliable Operations of Unmanned Systems," *13th USA/Europe Air Traffic Management Research and Development Seminar (ATM2019)*, ATM-2019-50, June 2019.

B. Duffy, and L. Glaab: "Variable-Power ADS-B for UAS," *38th Digital Avionics Systems Conference (DASC 2019)*, September 2019.

A. J. Moore, M. Schubert, T. Fang, J. Smith, and **N. Rymer**: "Bounding Methods for Heterogeneous Lidar-derived Navigational Geofences," NASA/TM-2019-22399, September 2019.

2019 BO WALKLEY BEST RESEARCH PUBLICATION AWARD

Dr. Pedro Paredes
"Nonmodal Growth of Traveling Waves on Blunt Cones at Hypersonic Speeds"

by **Pedro Paredes**, Meelan M. Choudhari and Fei Li (NASA's Langley Research Center), Joseph Jewell (Purdue University), and Roger Kimmel (U.S. Air Force Research Laboratory), AIAA Journal, Vol 57, No. 11, November 2019.

OUR PEOPLE

The NIA team has

200+

employees

resident university professors

postdoctoral and graduate students

consultants

research scientists and engineers

education specialists

program and operational support staff

91%
of researchers hold graduate level degrees

The majority are doctoral level degrees related to aerospace.

83 NIA employees and students have been hired by NASA

29 employees have become permanent U.S. residents

Since 2002

22 employees have become U.S. citizens

MARTIN L. DREWS MEMORIAL SCHOLARSHIP

This scholarship is awarded each year to a student engaged in research related to the exploration of space.

The 2019 Martin L. Drews Memorial Scholarship was awarded to

Manuel J. Diaz
Ph.D. Candidate
Georgia Institute of Technology

Manuel Diaz is the first two-time winner of the scholarship, having also received it in 2018.

NASA GROUP ACHIEVEMENT AWARDS PRESENTED TO

Jean-Paul Vernier, **Hongyu Liu** and **Rita Aguillard**
The Balloon Measurement Campaigns of the Asian Tropopause Aerosol Layer (BATAL) Team

Hongyu Liu and **Bo Zhang**
North Atlantic Aerosols and Marine Ecosystems Study (NAAMES) Team

Clay Hubbs
NASA / Alaska Airlines / Industry Traffic Aware Strategic Aircrew Request (TASAR) Team

Emily Gargulinski and **Zak Johns**
Ozone Water Land Environmental Transition Study (OWLETS) Team

David Bradley
SAFE2DITCH (crash management system) Team

CONTINUING EDUCATION

NIA has always recognized the importance of continuing and lifelong learning for all individuals 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. To assist those seeking to enhance and expand their knowledge in specialized and emerging areas, NIA offers short courses, workshops, conferences, seminars and colloquia. Invited speakers include subject matter experts from NIA, NASA, academia and industry.

In 2019, NIA offered 25 seminars, organized, hosted, or assisted with seven short courses, workshops or conferences and made more than 200 for-credit courses available through NIA (spring and fall semesters 2019), including a multi-university course in Small Satellite Design. NIA also organized a session at AIAA Aviation 2019, where five graduate student papers were presented.

MEMBER INSTITUTIONS

NIA was formed by a consortium of prominent research and education institutions. Today these groups 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
NC State University
North Carolina Agricultural and Technical State University
Old Dominion University
University of Maryland
University of Virginia
Virginia Tech
William & Mary — Chartered 1693

SAAP
Smart Airport and Aviation Partnership

The Smart Airport and Aviation Partnership (SAAP) was established in August 2019 through a Regional Innovation Strategies Grant from the U.S. Economic Development Administration. The partnership will transform Southern New Jersey's aerospace ecosystem by incubating, accelerating, and attracting new businesses into a high-tech cluster. Companies in the cluster will leverage "smart" infrastructure and Internet-of-Things technologies for airport and aviation applications in collaboration with the Federal Aviation Administration (FAA) and airports in both Atlantic County and Cape May County. The lead applicant was the Atlantic County Economic Alliance, and NIA is ACEA's lead partner under the grant.

Carole M. Mattessich, Esq. was named SAAP Program Director, bringing an intimate knowledge of the Southern New Jersey business community to the program. Mattessich previously worked to create an extensive program for aviation-related companies in Cape May County.

With guidance from NIA and partners, leading aviation professionals will work with SAAP on numerous innovative growth strategies, including "flightPlan, an Aviation Accelerator" with the first cohort in 2020. Graduates will pitch their ventures at a regional "Innovation Forum" and will be eligible to apply for grants for performing FAA-approved research during 2020.

smartaviation.nianet.org

SAAP Partners
Atlantic County Economic Alliance (ACEA)
Atlantic County, New Jersey
Cape May County, New Jersey
National Institute of Aerospace (NIA)

SAAP Members
Applied Research Associates (ARA)
SJTA/Atlantic City International Airport (ACY)
Delaware River & Bay Authority (DRBA)
National Aviation Research & Technology Park (NARTP)
New Jersey Economic Development Authority (NJEDA)
New Jersey Tech Council
Optimal Solutions & Technology (OST)
Stockton University
Dave Sweet (former Boeing executive)
Thunderbolt Industries LLC

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

REaKTOR
BUSINESS TECHNOLOGY INNOVATION CENTER

In 2012, NIA established the Peninsula Technology Incubator, now known as REaKTOR, to foster economic development in the city of Hampton, Virginia and the Virginia Peninsula. REakTOR is actively involved in establishing the Hampton Roads region as not only a community leader but as a national center of excellence for unmanned charge to plan and develop a UAS/UTM Research and Test Facility at Fort Monroe, in Hampton, Virginia.

Citing REaKTOR's focus as their primary motivation, Longbow, LLC moved here from Memphis, Tennessee in 2019. Industry leaders, agencies and institutions supporting this research publicly include NASA, SBA, Hampton University, ODU, Verizon and L3 communications.

TECHNOLOGY SHOWCASE EVENT

REaKTOR helped founders explore the market side of their business through a Business Technology Innovation Center technology showcase held at NIA. The showcase helped entrepreneurs learn how to communicate clearly and concisely to investors as well as targeted audiences for marketing.

The showcase produced outstanding results with investors approaching two of the seven presenting companies to provide seed capital. Investors offered fractional C-Level services to three companies and capital, sales, marketing, and distribution services to one company. REaKTOR's next Technology Showcase is planned for late spring 2020.

CAPITAL ATTRACTION

Two investor groups have established active relationships with REaKTOR. Several high net worth individual entrepreneurs with a combined $120 million in exits are part of REaKTOR's capital investment pool.

Prodigy Capital Group recently invited REaKTOR into its select Prodigy Incubation Network. Prodigy is completing a raise of $100 million seed capital fund exclusively earmarked for companies participating in the Prodigy Incubation Network. The new fund will use Prodigy's unique and well-vetted business valuation model and offer the group considerable latitude to fund companies using this model.

The REaKTOR Business Technology Innovation Center is one of 60 nationwide winners of the Small Business Administrations' Growth Accelerator Fund Competition. REaKTOR is using the $50k award to develop several programs focused on women entrepreneurs and to provide proposal and technical assistance for women-owned businesses seeking research grants.

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 NASA's Langley Research Center, office accommodations and compensation. Participants usually conclude their stay with a seminar for our resident faculty, research staff, students and researchers from the Langley community. In 2019, NIA hosted 24 visiting students, researchers and professors.

VISITING STUDENTS

Sudarshanan Bharadwaj
University of Texas at Austin
United States
Shielded Learning Techniques for Urban Air Mobility (UAM) Traffic Management

Jordan Fisher
Purdue University
United States
Diagnostic Techniques for Velocimetry, Species Concentration and Temperature Measurement in Flowing Gaseous Systems

Justin He
Virginia Tech
United States
Al-Based Metal Matrix Composite Tubular Wires for Additive Manufacturing

Eric Hoffman
Virginia Tech
United States
Robotics Algorithms for Integrating a Standoff Ultra-Compact Raman (SUCR) Spectrometer onto a Rover Platform

Phillip Jang
Cornell University
United States
Dependency Analysis Using Semi-Definite Programming

Christopher Manderino
University of Pittsburg
United States
Software Assurance and Formal Methods

Clark Pederson
University of Texas
United States
Boundary Layer Transition Control Device Optimization for Second Mode Transition in Hypersonic Flows

Javier Puig Navarro
University of Illinois
United States
The Ab-Initio Problem in the National Airspace

Mike Smyser
Purdue University
United States
Optical Diagnostics

Nathan Walkenhorst
Virginia Tech
United States
Robotics Algorithms for Integrating a Standoff Ultra-Compact Raman (SUCR) Spectrometer onto a Rover Platform

VISITING RESEARCHERS

Frédéric Alauzet
Mississippi State University
United States
Meshing, Mesh Adaptation, CFD

Pierre Calmon
CEA, Saclay
France
Nondestructive Testing at CEA in France

Jared Crean
Rensselaer Polytechnic Institute
United States
Nonlinearly Stable High-Order Methods for Hyperbolic Partial Differential Equations

Krzysztof Fidkowski
University of Michigan
United States
Error Estimation and Adaption with Application to Turbulent Flows

Philip Hall
Monash University
Australia
Distributed Vortex-Wave Interaction Arrays and Turbulent Shear Flows

Stefan Heinz
University of Wyoming
United States
New Hybrid Methods for Wall-Modeled Large-Eddy Simulations (WMLES)

Myung Jong Kim
Korea Institute of Science and Technology (KIST)
South Korea
4U Composite Materials and their Radiation Shielding Properties

Oana Marin
Argonne National Laboratory
United States
HPCI PETSc Training

Olivier Mesnil
CEA, Saclay
France
Nondestructive Testing at CEA in France

Jan Nordstrom
Mathematics Linköping University
Sweden
Linearly and Nonlinearly Stable Equations and Fully Implicit Matrix Equations

Jonathan Rogers
Georgia Tech
United States
Guidance, Navigation, Control

Ralf Rudnik
German Aerospace Center
Germany
Validation of NASA High Lift Common Research Model (HL-CRM) and Boundary Layer Ingestion Studies

Barry Smith
Argonne National Laboratory
United States
HPCI PETSc Training

Yuxiang Zhou
Technical University of Kaiserslautern
Germany
Aerodynamic and Aeroacoustic Prediction and Validation for a Propeller Configuration of Interest for Embraer S. A.

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, University of Maryland, North Carolina A&T State University, North Carolina State University, Old Dominion University, 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 from multiple institutions, while performing critical research in a leading national laboratory, working alongside renowned researchers with state-of-the-art facilities.

2019 GRADUATES

Justin Green
University of Virginia in May 2019
Ph.D. in Mechanical and Aerospace Engineering

His dissertation topic was "Onboard Autonomous Trajectory Planner." His advisor was Dr. Robert Lindbergh. NASA's Langley Research Center now employs Justin in the Atmospheric Flight and Entry Systems Branch.

Shane Seaman
Virginia Tech in May 2019
Ph.D. in Materials Science and Engineering

His dissertation topic was "Material-Related Effects on the Structural-Thermal-Optical Performance of a Thermally-Tunable Narrowband Interferometric Spectral Filter." His advisor was Dr. Randy Heflin. Shane is now a civil servant in the Electromagnetics and Sensors Branch at NASA's Langley Research Center.

Jasme Lee
North Carolina State University in May 2019
M.S. in Mathematics

Her thesis topic was "Dose-Response Modeling of Quiet Sonic Boom Community Response Survey Data." Her advisor was Dr. Alyson Wilson. Jasme is now a research staff member at NIA.

Matthew Galles
Old Dominion University in August 2019
M.S. in Aerospace Engineering

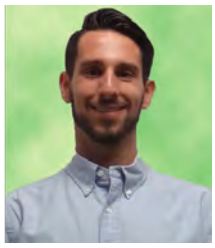
His thesis topic was "Reducing Noise Impact of Unmanned Aerial Vehicles by Flight Control System Augmentation." His advisor was Dr. Brett Newman. Matt was a Pathways student and is continuing as a Research Engineer in the Aeroacoustics Branch at NASA's Langley Research Center.

Cameron Neill
Old Dominion University in May 2019
M.S. in Aerospace Engineering

His thesis topic was "Comparison of Support Methods for Static Aerodynamic Testing and Validation of a Magnetic Suspension and Balance System." His thesis advisor was Dr. Colin P. Britcher. Williams International in Detroit, Michigan, now employs Cameron.

Adrian Wos
Old Dominion University in May 2019
M.E. in Mechanical Engineering

His project title was "Coupling Noise Generation by CFD and Noise Propagation by CAA." His advisor was Dr. Oktay Baysal. Adrian currently works for the Department of Defense, Naval Development Acquisition Program.



Matthew Julian
University of Virginia in August 2019
Ph.D. in Electrical and Computer Engineering

His dissertation topic was "High-Efficiency Photon Sieves and Applications." His advisor was Dr. Mool Gupta. Matt is now a Staff Physicist / Senior Consultant with Booz Allen Consulting.

Matthew Bailey
Virginia Tech in December 2019
Ph.D. in Aerospace Engineering

His dissertation topic was "An Extended Calibration and Validation of a Slotted-Wall Transonic Wall-Interference Correction Method for the National Transonic Facility." His advisor was Dr. William Devenport. Matthew is now employed as an Operations Manager at NASA's Langley Research Center.

Huan-Yu (Tony) Chang
North Carolina State University
in December 2019
Ph.D. in Mechanical Engineering

His dissertation topic was "Damage Visualization of Scattered Ultrasonic Wavefield via Integrated High-Speed Camera System." His advisor was Dr. Fuh-Gwo Yuan. Tony is currently employed as a Test Engineer by Western Digital in San Jose, California.

Joaquin Neto Dias
University of Maryland in December 2019
Ph.D. in Aerospace Engineering

His dissertation topic was "Active Spanwise Lift Control: A Distributed Parameter Approach." His advisor was Dr. James E. Hubbard. Joaquin has returned to his appointment as a Flight Test Engineer with the Brazilian Air Force.

Bryan Koscielny
University of Virginia in December 2019
M.S. in Materials Science

His thesis topic was "The Effect of the Inter-Layer Time Interval on Selective Laser Melted Inconel 718." His advisor was Dr. Jim Fitz-Gerald. Bryan is now a member of NIA's research staff.

Yu-Sheng (Sam) Chang
North Carolina State University
in December 2019
Ph.D. in Mechanical Engineering

His dissertation topic was "Damage Detection and Localization Under Ambient Environment via Green's Function Reconstruction." His advisor was Dr. Fuh-Gwo Yuan. Sam is now employed as a Research Engineer by Foxconn Inc. in Milwaukee, Wisconsin.

Kai Xie
University of Virginia in December 2019
Ph.D. in Electrical Engineering

His dissertation was "Laser Sintered Nanograin SiGe Thermoelectric Thin Film Devices." His advisor was Dr. Mool Gupta. Kai is now a Seismic Imaging Analyst at CGG in Houston, Texas.

Debajyoti Basu Sarkar
Hampton University in August 2019
M.S. in Planetary Sciences

His thesis topic was "Lithospheric Stress Regimes on Heat-Pipe Planets." His advisor was Dr. William B. Moore. Deb is now enrolled in a Ph.D. program in Planetary Sciences at Hampton University.

Kylie Lovato
Hampton University in August 2019
M.S. in Planetary Sciences

Her thesis topic was "Proton/Hydrogen Aurora for Early and Current Mars." Her advisor was Dr. William B. Moore.

Nadew Kibret
North Carolina A&T University
in December 2019
Ph.D. in Electrical Engineering

His dissertation topic was "A Formal Systems Engineering Methodology for Cyber Physical Systems: The Verifiable Design Process." His advisor was Dr. William Edmonson. Nadew is now employed as a Research Assistant (funded by DARPA) at N.C. A&T.

Cecelia Mulvaney
University of Virginia in December 2019
M.S. in Materials Science

Her thesis topic was "Electron Beam Freeform Fabrication of Aluminum: Investigating Properties and Cracking of Alloys 2219 and 7075." Her advisor was Dr. Jim Fitz-Gerald. Cecelia is now enrolled in a Ph.D. program, also in Materials Science at the University of Virginia.

The **NIA Best Student Paper Award** recognizes and honors outstanding publications by NIA graduate students each year.

George C. Wilkes
University of Virginia

"Laser Annealing of TiO2 Electron-Transporting Layer in Perovskite Solar Cells," **George C. Wilkes**, Xiaoyu Deng, Joshua Choi, and Mool C. Gupta; ACS Applied Materials and Interfaces, 10 (2018), 41312–41317; doi: 10.1021/acsami.8b13740

EDUCATIONAL PROGRAMS AND OUTREACH

In 2019, NIA's Educational Programs and Outreach 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

RASC-AL
Revolutionary Aerospace Systems Concepts Academic Linkage

NIA continued program management of NASA's Advanced Exploration Systems' annual **Revolutionary Aerospace Systems Concepts – Academic Linkage (RASC-AL)** Engineering Competition for the 11th 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 a two-tiered down-select proposal process, technical paper, oral presentation/design review, and poster presentation on one of four themes related to NASA's ability to access and explore destinations in cislunar space via the lunar orbiting space station, "Gateway," which is in development as part of the agency's Artemis program. Fourteen teams convened in Florida to compete at the RASC-AL Forum before a panel of NASA and industry experts. NIA brought the student presentations to the public via live online video.

rascal.nianet.org

NIA executed the third annual **RASC-AL Special Edition** competition, introducing a lunar component and renaming the challenge the "Moon to Mars Ice & Prospecting Challenge." The challenge asked engineering students to design and build prototype hardware that can extract water from simulated lunar and Martian subsurface ice and also be able to accurately assess subsurface density profiles during drilling. Nine teams traveled to NASA's Langley Research Center to demonstrate their systems' approaches to in situ resource utilization (ISRU) for future human missions to the Moon, Mars, or both. Teams also presented their explanations for how they would modify their Earth-based system for lunar and Martian environments to a panel of NASA and industry experts. Judges scored the teams on water extraction, drilling telemetry, technical papers and a technical poster session.

specialedition.rascal.nianet.org

Moon to Mars Ice & Prospecting teams, using lessons learned from the first two years of the competition, adapted their prototypes to harvest **380% more water** than last year. The lessons and key technical knowledge learned from this challenge serve as an integral contribution to NASA's collaborative body of knowledge for ISRU.

The 2019 Moon to Mars Ice & Prospecting Challenge garnered **85.8 million** social media and online impressions.

BIG IDEA CHALLENGE

The 2019 **BIG Idea Challenge**, sponsored by NASA's Game Changing Development (GCD) Program, solicited innovations on the design, installation, and sustainable operation of a Marsboreal Greenhouse that complemented the unique design of the Mars Ice Home concept. Finalist teams traveled to NASA's Langley Research Center to participate in a two-day BIG Idea Forum, where they presented their research to a panel of NASA and industry subject matter experts. The student's presentations were broadcast live to the public on the web, and members of the top winning teams were offered internships at NASA's Langley Research Center.

bigidea.nianet.org

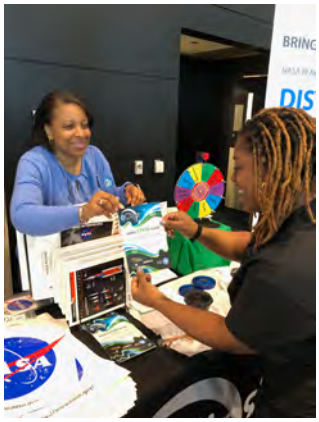
K-12 EDUCATIONAL PROGRAMS

During 2019, NIA continued managing the multimedia educational program, NASA eClips 4D, which was selected by NASA's Science Mission Directorate to address the ongoing needs of America's formal and informal K-12 educators. The program Designs, Develops, Disseminates and Discovers (4D) new strategies to empower STEM education.

NASA eClips 4D provides educational resources relevant to the formal K-12 classroom. It can also increase understanding of NASA science content for lifelong learners, informal audiences and the public. Science content for new activities draws from all four divisions of NASA's Science Mission Directorate as well as cross-divisional topics. The content in many of these latest resources addresses national student misconceptions in science.

NASA eClips partners and collaborators include Arlington Public Schools (APS), Hampton City School (HCS), Newport News Public Schools (NNPS), The GLOBE Program, Promethean, Nearpod, the Virginia Latino Higher Education Network (VALHEN), the International Technology and Engineering Educators Association (ITEEA), and Virginia Children's Engineering Council (VCEC). The team also worked closely with many cross-collaborators through the Science Activation Collective, including the Challenger Learning Center, NASA Earth to Sky, NASA Museum Alliance, National Informal STEM Education Network (NISE), the NASA Science Visualization Studio, Arizona State University and My NASA Data.

nasaeclips.arc.nasa.gov



Joan Harper-Neely shares NASA eClips resources with a student at the Henrico County STEAM Symposium.

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. Betsy McAllister, NIA Educator-in-Residence (EIR) from HCS, implemented ongoing professional development with elementary, middle, and high school teachers, focusing on best practices in the STEM classroom and how to use NASA eClips resources.

Leveraging the EIR position, Ms. McAllister infused STEM pedagogies and NASA eClips resources into HCS and Virginia Department of Education (VDOE) curriculum to help teachers make authentic STEM practices integral to the HCS and VDOE student experience. Ms. McAllister developed meaningful partnerships between NIA and HCS Academies.

The collaboration continued to support the Academies of Hampton through a second-year NIA partnership with Bethel High School's Media, Arts and Design (MAD) Academy. Students in the summer extended learning program developed Spotlite videos for the NASA eClips website.

NIA also shared expertise with HCS teachers through work with HCS instructional leaders, HCS STEM Magnet Schools, and the HCS Out of School Time Program's summer STREAM Experience and Design Challenge. As part of her residency, Ms. McAllister also supported numerous educational outreach events at the request of HCS and NASA Langley's Office of STEM Engagement.

STEM Education Specialist, **Joan Harper-Neely** was honored as an "Emerging Leader" by the ITEEA at its 81st Annual Conference in Kansas City, Missouri. The March 2019 issue of the organization's flagship journal, Technology and Engineering Teacher, also featured Harper-Neely as one of ITEEA's "2019 Leaders to Watch."

Students and teachers from Bethel High School's MAD Academy presented their NASA Spotlite videos and met with NIA's Media Communications Group at NIA headquarters.

FIFTH COHORT OF HU-CARE SCIENCE COMMUNICATION INTERNS JOIN NIA EDUCATION AND OUTREACH

As part of the NASA Minority University Research and Education Project (MUREP) Institutional Research Opportunity (MIRO)/CARE award, Kayla Holmes, Samya Epps, and Jordyn Edwards from Hampton University's Scripps Howard School of Journalism served as interns in 2019 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.

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's multi-layered support and world-class creative services are crafted to deliver award-winning campaigns. With internationally recognized work in radio, web, live broadcasts, conferences and events, NIA provides valuable support for marketing and media, outreach and communications.

Videos produced by NIA in 2019 had more than **10.6 million views** through web and social media platforms.

APOLLO'S 50TH ANNIVERSARY

NIA joined NASA's Langley Research Center to celebrate the 50th Anniversary of Apollo. NIA's support included program promotion and an exhibit at the celebration in July 2019. NIA also marked the 50th Anniversary of Apollo with NASA Headquarters at a unique National Air and Space Museum-coordinated event on the National Mall in Washington, D.C. The core of NASA's Space Technology Mission Directorate's "Explore" exhibit was the NASA Home and City website, developed in collaboration with NIA.

NIA also worked with NASA and commissioned Houston-based artist, David Maldonado to create a mural for the anniversary celebration. The public joined in painting the mural on July 20 and the completed painting was displayed on tour at NASA centers across the U.S.

NASA 360 is a premiere NASA outreach program that brings audiences the latest in NASA science, engineering and aeronautics. From understanding our changing Earth to preparing the first woman and next man to land on the moon – videos and productions in the NASA 360 media suite 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 has more than **5.65 million fans** on social media.

FollowNASA360

@NASA360

FollowNASA360

In 2019, 1.9 million online viewers watched episodes co-produced by NIA's NASA 360 team, including:

- To the Moon, and Beyond
- Going Interstellar
- Our Weird Home
- Storms Across the Solar System
- NASA's Next Solar System Explorer
- 50 Years of Apollo
- A World of Fires
- A Telescope Like a Time Machine
- Galaxy of Horrors
- Black Hole 101
- New Discoveries from Our Mission to Touch the Sun
- OSIRIS-REx: X Marks the Spot

NASA HOME & CITY 3.0

NIA, working with NASA's Space Technology Mission Directorate, recently updated the popular NASA Home and City website. The interactive website visually explains how space exploration impacts our daily lives through technology transfer that is often invisible, yet critical to activities in health and medicine, transportation, public safety, environment, agriculture, home and recreation.

homeandcity.nasa.gov

NIA's team of **Scott Bednar**, **Rebecca Jaramillo**, **Seth Robinson**, **Matthew Schara**, **David Shelton**, **Harla Sherwood**, **Caleb Stern** and **Jessica Wilde**; supported by subcontractors Woodpile Studios, Bully! and Mission Media; and in collaboration with NASA's Space Technology Mission Directorate, were recognized with a 2019 Headquarters Honor Award for Team Excellence. The American Advertising Awards recognized the same team with regional and NATIONAL silver ADDY awards.

NIA's Media Communications Group won **2019 International Davey Awards** for productions created for NASA's Planetary Science Division, NASA's Innovative Advanced Concepts program, NASA's Centennial Challenges program, and NASA's Space Technology Mission Directorate. The prestigious award honors the achievements of teams from smaller companies.

WHAT CAN YOU DISCOVER IN 90 SECONDS?

innovationnow

@innovationradio

FeedSpot, an online distributor with ~2 million registered users selected Innovation Now as one of the **top 30 podcasts** you must subscribe to in 2019.

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 their industry partners.

Two NASA iTech Cycles were held in 2019, each culminating in a weeklong forum. The Cycle I Forum was held in Mountain View, California. The winners selected were (in alphabetic order): Aris MD from Wilmington, Delaware; Enduralock LLC from Lenexa, Kansas; and Momentus Inc. from Santa Clara, California.

The 2019 NASA iTech Cycle II Forum was held in Las Cruces, New Mexico. The winners selected were: Alertgy from Melbourne, Florida; Everix Inc. from Orlando, Florida; and OXOS Medical Inc. from Atlanta, Georgia.

Three Ignite the Night events were also held in 2019. These regional 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. Ignite the Night events were held in Austin, Texas; Colorado Springs, Colorado; and Orlando, Florida.

The 70 NASA iTech finalist companies have reported **$500 million raised** in private investment dollars since the program began.

INNOVATION NOW

INNOVATION NOW brings listeners the stories behind the ideas that shape the future and benefit our lives. Developed in collaboration with NASA's Langley Research Center 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, for broadcast during programs such as National Public Radio's "All Things Considered." WHRO/WHRV Hampton Roads is the public radio partner supporting online distribution of the program.

Innovation Now reaches more than 19 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 continues to be offered at no charge through internet on-demand radio services such as Stitcher and PlayerFM, and on media content providers like iTunes. During 2019, the program became discoverable on numerous cable TV platforms.

To meet the needs of an expanding visual audience, NIA continues to produce simple videos to complement selected podcasts so viewers can watch the stories come alive. Another video component, "Faces of Technology," takes viewers inside NASA Centers to give them an immersive glimpse of the people developing NASA technologies. Supporting podcasts for the videos give listeners more information about the technologies. These videos are distributed through social media and on the Innovation Now website. Targeted videos were released to support Women's History Month, Earth Day, and National Disability Employment Awareness Month.

innovationnow.us

NASA SCIENCE LIVE

NASA invites the public to interact with experts live each month, 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 for science and engineering experts by using the hashtag #AskNASA or by leaving a comment live in the chat section.

nasa.gov/nasasciencelive

2019 NASA Science Live Episodes

- 50 Years of Apollo
- Going Interstellar
- To the Moon and Beyond
- Our Weird Home
- A World of Fires
- Storms Across the Solar System
- Special Edition – NASA's Newest Solar System Exploration Mission

EVENT WEBCASTS

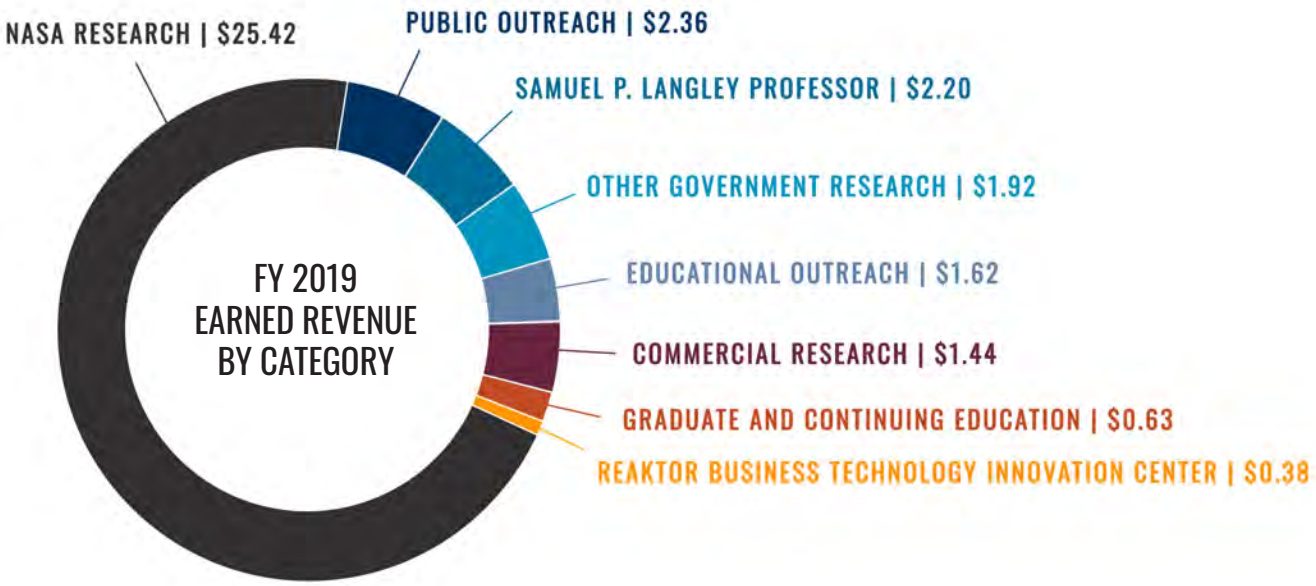
The NIA Media Communications Group provides live web broadcast and public engagement support for conferences, events and workshops. These broadcasts broaden public exposure to some of the most exciting new developments in the aerospace industry and stimulate an interest in science, engineering and technology relevant to NASA.

livestream.com/viewnow

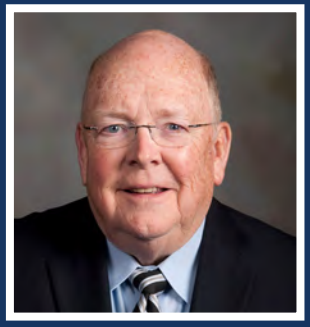
2019 Livestream Event Webcasts

- AIAA SciTech Forum
- AIAA Aviation Forum
- AIAA Propulsion and Energy Forum
- Bill Nye and Friends vs. the Asteroids
- 50th Lunar Planetary Science Conference
- NASA's Moon to Mars Ice & Prospecting Challenge
- Humans to Mars 2019
- AbSciCon 2019
- 2019 NIAC Symposium
- NASA's 3D Printed-Habitat Challenge
- RASC-AL Forum 2019
- BIG Idea Challenge
- NASA iTech Winners Announced (Cycles I and II)

FINANCIALS



NIA TOTAL REVENUE BY YEAR



IN MEMORIAM

Walter F. O'Brien Jr., the J. Bernard Jones Professor of Mechanical Engineering at Virginia Tech, passed away July 25, 2019, surrounded by his family. He was in many ways the "Father of NIA," having led the original proposal to establish the Institute and having served on NIA's Technical Advisory Committee since NIA's inception. Walt's vision for NIA and his contributions to our mission cannot be overstated. We honored his service by dedicating a laboratory to him in our Research and Innovation Laboratories. He will be greatly missed.

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NATIONAL
INSTITUTE OF
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100 Exploration Way
Hampton, VA 23666
(757) 325-6700
www.nianet.org