National Aeronautics and
Space Administration

tech bytes

AMES' EMERGING TECHNOLO

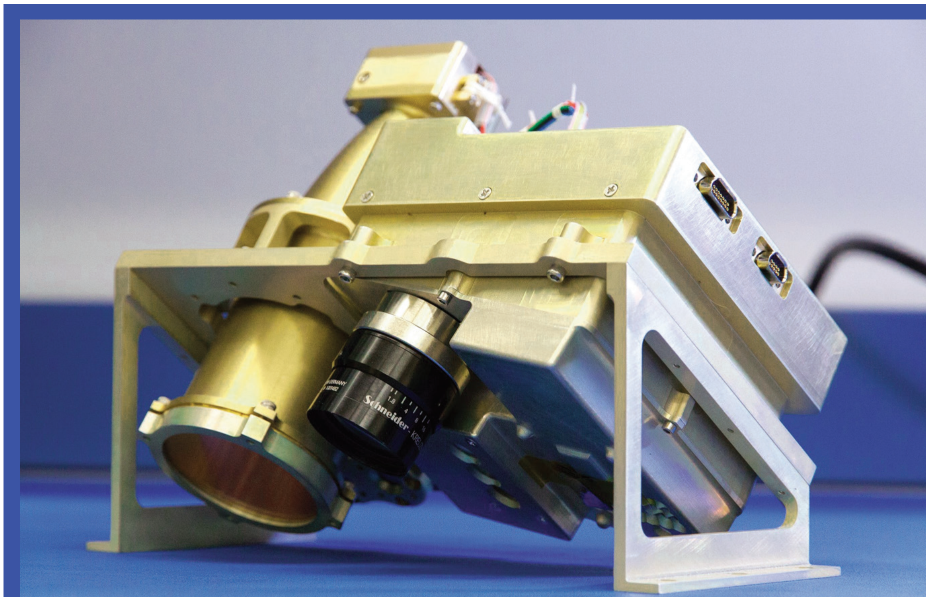
There's water in them-thar craters!

Resource Prospecting on the Moon

Volume 1 • Issue 2 • Winter 2015

In this issue:

The NASA Ames-designed Near Infrared Volatile Spectrometer Subsystem (NIRVSS)



The NIRVSS bracket assembly contains all the observing apertures for the NIRVSS system, including the spectrometers, DOC, LCS, lamp and LEDs. The spectrometers are mounted separately on the rover and are connected to the bracket assembly via fiber optic cables.

Recent discoveries regarding lunar water and other volatiles have led the NASA Human Exploration and Operations Mission Directorate (HEOMD) to select a lunar volatiles prospecting mission for a concept study and potential flight in CY2020. This mission is known as Resource Prospector (RP). RP includes a rover-borne payload that can locate surface and near-subsurface volatiles, excavate and analyze samples of the volatile-bearing regolith, and demonstrate the form, extractability and usefulness of the materials.

Lunar water and other volatiles have a much greater extent of distribution, possible forms, and concentrations than previously believed. To fully understand how viable these volatiles are as a resource, the distribution and form needs to be understood at a "human" scale. Using an analogy from the mining industry, the "ore body" must be better understood at the scales it would be worked before it can be evaluated as a potential architectural element within any evolvable lunar or Mars campaign.

One part of the RP payload designed to locate, or "prospect", for volatiles is the Near InfraRed Volatiles Spectrometer System, or NIRVSS. NIRVSS combines several sensor types in order to identify volatiles, and especially water, on the surface, and also in subsurface materials that are excavated using an auguring drill. The principle sensors used to identify volatiles are two Near Infrared (NIR) spectrometers, which measure reflected NIR light from materials under the rover. One design requirement is that these spectrometers must work both in and out of direct sunlight; thus, NIRVSS has its own lamp providing NIR energy. To be able to provide context for what these spectrometers are viewing, a camera is included as part of NIRVSS. This camera, called the Drill

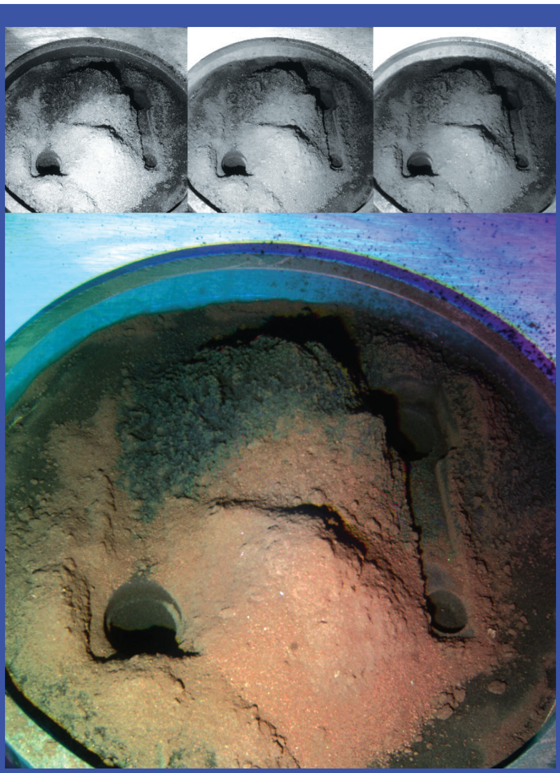
ABOUT THE COVER

The NIRVSS engineering team includes (clockwise from top left): Josh Benton (Mechanical & Thermal Lead), Bruce White (Electrical Engineer), Amanda Cook (I&T Lead), Ted Roush (Instrument Scientist), Erin Fritzler (Instrument Manager). Not shown are: Tony Colaprete (Instrument PI), Josh Forgione (Electrical Lead), Sarah Thompson (Camera Lead), Robert McMurray (Instrument Consultant).

Operations Camera (DOC), can image the scene which the spectrometers are viewing with a spatial resolution as small as 0.1 mm (0.004 inches, approximately the diameter of human hair). To provide the best illumination for these images, a set of eight different colored LEDs are used. By imaging at these different colors, the camera not only provides morphological context but also compositional information.

The last sensor suite in the NIRVSS system is the Longwave Calibration Sensor (LCS). The LCS observes the thermal emission from the scene to provide a measure of the total thermal infrared contribution to the NIR spectrometers, helping to calibrate them and enabling a more accurate measure of the total water and other volatiles measured. The readings from the LCS also record the scene temperature, providing a critical environmental constraint for the presence of water.

The NIRVSS instrument has its beginning with the Lunar CRater Reconnaissance and Sensing Satellite (LCROSS). The NIR spectrometers at the heart of NIRVSS are derivatives of instruments on that mission. Over the last two years NASA Ames has worked with ThermoFisher Scientific (providers of the spectrometer optical engines) and Kennedy Space Center (RP payload management) to develop NIRVSS. The NIRVSS Project follows a rapid-development process in which quick iterations on the design cycle includes the build and test of high-fidelity engineering units. Commercial products are used wherever possible to accelerate this process and point analysis is performed in key areas that can greatly influence design or performance. By following this process, meant to be nimble and reactive, the NIRVSS system has worked through two engineering test units (ETUs) and has started on what is to be the final ETU prior to the flight build. Testing of these ETUs includes mechanical (vibration and shock) and thermal vacuum testing, as well as integration with the RP porotype rover this last summer. ■



Individual wavelength images, using different colored LEDs (top , 410, 740 and 940 nm from left to right),acquired by the NIRVSS Drill Operations Camera can be combined into a single false-color image (bottom).

Left: In the summer of 2015, the RP prototype rover, designed and built by JSC, carried the RP payload, including NIRVSS, in rock-yard testing at JSC.

Right: During 2015 integrated rover, testing the NIRVSS uses its lamp to illuminate drill cuttings from a prepared drill tube. The drill cuttings are brought up from depths of up to 80 cm and brushed into a chute for deposition into the NIRVSS field of view.

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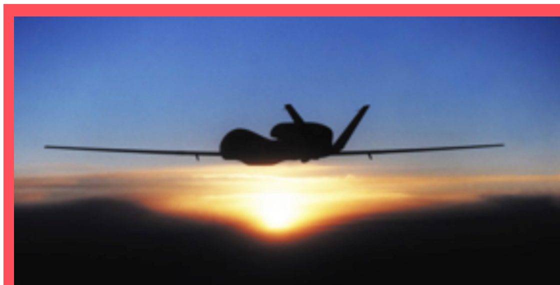
Ames Attacks Aeronautics Salients

This summer, the Agency awarded six teams funding to complete feasibility studies and build prototypes of their proposed approaches, any one of which carries the potential to transform aviation by revolutionizing how we use fuel, affect the environment, and manage the global upsurge in air traffic. Ames won awards for two highly innovative concepts and nearly walked off with a third, which subsequently won a Center Innovation Fund (CIF) award.

The teams had to convince evaluators that their approaches would answer a "big question" related to strategic thrusts such as maximizing efficiency, minimizing environmental impact, or enabling assured autonomy. Ames' teams are concentrating on enabling assured autonomy and maximizing efficiency.



The need for an AOS-type solution is growing. Parimal Kopardekar, who manages the Safe Autonomous System Operations Project, recently stated that within a decade "every home will have a drone. You're going to use a drone to do rooftop inspections. You're going to be able to send a drone to Home Depot to get a screw driver." With that many drones in operation, reliable and safe operating systems will be essential.

Autonomy Operating System (AOS) for UAVs

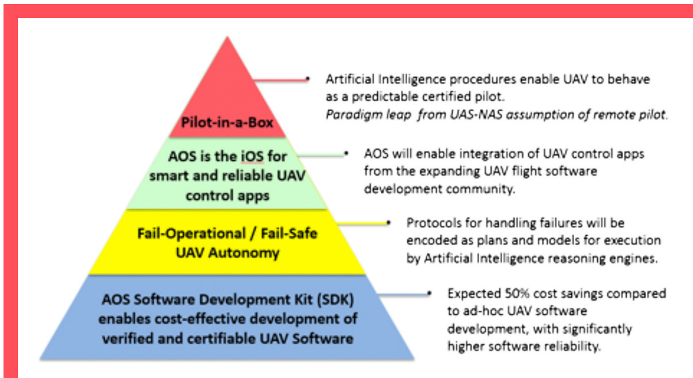
Today's UAVs invariably have remote pilots, a requirement that already represents a limitation on their use. Can UAVs safely and reliably fly as (unpiloted) first-class vehicles in the national air space (NAS)? To do so, they must be able to respond to unforeseen situations as surely and predictably as a certified human pilot. They would need onboard technologies that can handle contingencies safely and autonomously; embedded system intelligence; and autonomy technologies that have undergone enough verification and validation to enable certification. In short – UAVs would have to behave as if they were certified pilots.

The ultimate goal of the project is to produce a "pilot-in-a-box", or the "iOS" for intelligent UAVs. Rather than develop the applications itself, the system will create standards and lay the groundwork and lower the barriers for the for the rapid development of apps by a large, reliably supported developer community whose solutions will apply to a wide range of platforms. If successful, the approach would reduce UAV operations costs, improve their performance, and increase safety.

The team is led by Michael Lowry of the Intelligent Systems Division (ISD), and includes Anupa Bajwa (also ISD), Eric Cooper and Patrick Quach in the Formal Methods Branch at Langley, and professors and students at the University of Cincinnati, the University of Minnesota, and Vanderbilt University.

Mission Adaptive Digital Composite Aerostructure Technologies (MADCAT)

Continuously shape-morphing aircraft wings have been a long-standing goal in engineered flight, dating all the way back to the "wing



AOS builds on and enhances NASA space technology to develop cost-effective, certifiable UAV software; the foundation comes from 2 decades of technology investments in artificial intelligence, the Science Mission Directorate's flight of 22 small satellite missions built on NASA's Core Flight Software (CFS), and the Human Exploration and Operations Mission Directorate's practice of encoding and testing hundreds of astronaut procedures.

Composite Cellular Material Morphing Wing Span Twist Test Section

warping" of the Wright brothers' first successful aircraft. Significant improvements in fuel efficiency across various stages of flight (e.g., take-off and cruise) due to both decreased drag and lighter weight structures help drive today's interest in flexible aircraft.

The team has already demonstrated with physical experiments that wing twist and deflection at local wing sections can improve overall vehicle aerodynamic efficiency. The experiments leveraged recent advances in materials, manufacturing technologies, understanding of aeroelasticity, and flight control systems. They are now setting out to develop a novel aerostructures concept by combining advanced lattice-based cellular composite materials and components with multi-objective flight control systems. These will realize aerodynamically efficient future air vehicles that can adapt their configurations to best perform specific missions. Their goal is to utilize a discrete building block based systems strategy for composite structures ("digital composites") to enable high "stiffness-to-density" ratios for a strong, ultra-light, and flexible material that can adapt to changing flight conditions by altering shape.

Team lead Sean Swei emphasizes that given that over 300 million barrels of jet fuel are used globally every year, even a tiny (1-2%) increase in efficiency would save hundreds of millions of dollars. The building block based construction results in parts that are easily replaceable, so that in addition to in-flight efficiencies, the approach holds potential for revolutionary improvements in the material life cycle efficiency of aircraft structures, allowing low-cost part reuse, repair, maintenance, and reconfiguration. The researchers are already also exploring applications of this aspect of the technology to space technology, as well.

The team includes co-PI Kenny C. Cheung, NASA Space Technology Research Fellows, and partners with the Massachusetts Institute of Technology, the University of California at Santa Cruz, NASA Langley Research Center, University of Alabama, Michigan State University, and Moog, Inc.

Safe Autonomous Flight Environment (SAFE50) for the Notional Last "50 ft" of Operation of "55 lb" Class of UAS

A third Ames team also received high marks but was ultimately not selected by ARMD. However, they subsequently won an FY16 Center Innovation Fund (CIF) award. The Unmanned Aerial Systems (UAS) Traffic Management (UTM) project focuses on the UTM airspace infrastructure and system-wide operations. Within this umbrella, the single most important research need the team identified was the ability of a small weight and power (SWAP) vehicle to land and operate in a complex dynamic environment, especially urban environments.

This is hard because of: (1) environmental uncertainties such as wind and dynamic obstacles; (2) vehicle performance constraints posed by weight, size, and power limits and system failures; (3) demanding precision requirements for navigation and control; (4) an information-rich environment requiring real-time information fusion for decision-making combined with safe trajectory generation and management; and (5) on-board autonomy operation in an infrastructure-free environment.

A key part of the study involves deliberately selected feasibility questions and validating these targeted approaches by flying in realistic environments. The questions are: (1) Can on-board sensors and compact CFD models provide sufficiently accurate and robust wind estimates? (2) How well can dynamic obstacles be characterized using combinations of cameras and LIDARs in real-time? (3) Is on-board

NASA S100- unmanned aircraft. Photo credit: Sebastian Hening.

information fusion for real-time decision-making and safe trajectory generation and management sufficiently robust?

Understanding the feasibility of safely flying small UAS autonomously below 50 feet is a game changer for many civilian applications. "If drones ever fly autonomously where humans are present, safety is the primary concern and this technology will be integral to any solution," says Krishna Krishnakumar, PI. The team also includes J. Melton, C. Ippolito, R. Alena, A. Bencomo, V. Stepanyan, S. Sankararaman, S. L. Han, B. Nikaido, and S. Hening , as co-investigators. P. Kopardekar will act as the project advisor. ■

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Ames Researchers Win STMD Awards

The CCT's office would like to again congratulate Michael Wright and Raj Venkatapathy for earning awards from the Space Technology Mission Directorate (STMD). The awards were handed out by STMD director Steve Jurczyk on September 3. The citations follow.

> Michael Wright

CITATION: *In recognition of superb leadership of the groundbreaking Entry Systems Modeling project*

NOMINATION: *The GCD Entry Systems Modeling (ESM) Project is an anomaly within STMD. ESM really fits somewhere between Early Stage and GCD, and under normal leadership, the project may not have been sustained in a healthy state. However, the project has had exemplary leadership under Michael Wright of Ames Research Center. Mike truly produces Groundbreaking research through his management of the ESM project. As a respected, world-renowned expert in the Aerothermal field, he leads researchers by example, and gets tangible results. The project has produced over 100 technical publications in just over 2 years within STMD. I have personally witnessed Mike's management style, and it is just the right balance of tactical and strategic, detail and concept.*

> Ethiraj Venkatapathy

CITATION: *For exceptional achievement in the development of multiple thermal protection system materials supporting Space Technology Mission Directorate and the Agency.*

NOMINATION:*Under Dr. Venkatapathy's leadership, the TPSM project has developed multiple materials for a wide range of entry environments. The Conformal Ablative Thermal Protection System, the Heatshield for Extreme Entry Environment Technology, and the 3D Multifunctional Ablative Thermal protection System are three distinct materials for specific environments. The CA-TPS material is being used for the Terrestrial Return Vehicle project under the CASIS contract. The HEEET material is being proposed for use in the Discovery 2014 competition. The 3D-MAT material has been infused for testing on the Orion EM2 test flight.*

Instrumentation Workshop Held at Ames

On September 16, 2015, the newly formed NASA Ames Instrumentation Working Group (IWG) and Codes P, A, R, T, S, B, and D sponsored a Center-wide Instrumentation Workshop. From 8 AM to 5 PM, the NASA Ames instrumentation community, as well as the people behind instrument capabilities and facilities at Ames, gathered to present and share their instrument work, ideas & hardware. In total, 50 presentations and 15 posters were presented during the one day workshop, which also featured invited speaker George Komar, from NASA Science Mission Directorate (SMD), addressing technology development opportunities and programs across SMD. In addition, two panel discussions were held at the Workshop: one titled "From Concept to Flight" with four Ames PIs, and a Director's panel with Center management addressing lessons learned and best practices in instrument development and opportunities. In 2005 and 2010, the Center held similar 1-day instrument workshops. This Center-wide workshop aimed to capture the expertise of what organizations are doing (high to mid-TRL development), and plan to do (low-TRL) in the field of instrumentation. Presentations covered diverse areas in instruments for Astrophysics, Astrobiology, Life Sciences, Earth & Planetary Sciences, Aeronautics, and Thermal Systems, as well as cross-cutting instrument technologies. As the true focus or starting point for any mission is the "instrument", Ames wants to position the instrumentation community to be ready to meet NASA's needs. The one-day workshop provided a forum to encourage instrument builders to interact outside their groups, sharing new ideas and developing new partnerships within the Ames community. Going forward, the IWG will organize instrument development and instrument technology-related "lunch & learn" seminar series and talks throughout 2016. ■

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FY2016 Center Innovation Fund (CIF) awards

The FY2016 Center Innovation Fund (CIF) awards announcement was made in mid-September. The purpose of the CIF is to stimulate and encourage creativity, innovation and collaboration within Ames, and between Ames and other NASA Centers in addressing the technology needs of NASA and the Nation. In keeping with those goals, it is no exaggeration to say that this year Ames had some truly excellent proposal. In total, 49 proposals were received, with awards being made to the following 15 innovated, and potentially high-impact concepts:

Ved Chirayath (Code SG)	Multispectral Imaging, Detection and Active Reflectance (MiDAR)
Tony Colaprete (Code SST)	AMES SWIR Camera (SWIRcam): A Spin-Off Of The Ames Imaging Module (AIM)
Matt D'Ortenzio (Code TI)	Critical Event Deconfliction for Interplanetary NanoSat Missions
Kalmanje Krishnakkumar (Code TI)	Safe Autonomous Flight Environment (SAFE50) for the Notional Last "50 ft" of Operation of "55 lb" Class of UAS
Dana Lynch (Code RE)	Development of a Wave Front Control system for space utilizing MEMS Deformable Mirrors
Meyya Meyyappan (Code T)	Low Temperature Atmospheric Pressure Plasma Sterilization Shower
Andre Petukhov (Code TI)	Spectral Mass-Gauging of Unsettled Liquid With Acoustic Waves
Thomas Squire (Code TSM)	Shaped and Seamless Thermal Protection System
Carol Stoker (Code SST)	A Sample Delivery System for Planetary Missions
Patricia Parsons-Wingerter (Code SCR)	Critical 2D-to-3D Transformation of NASA's VESGEN Software for Astronaut Health Countermeasures and Terrestrial Medicine/Ecological Commercialization
Paul Wercinski (Code TSS)	Nano-ADEPT Lifting: Design Development for a Lifting Flight Test Demonstration
Peter Zell (Code PX)	Raising the Technical Readiness of Germanium Immersion Gratingsfor a Space-basedHigh-resolution Infrared Spectrometer

Congratulations to all the winning proposal teams, and thanks to everyone who submitted a proposal.

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A Different Path to Innovation: Space Technology Research Fellows

The NASA Space Technology Mission Directorate (STMD) is dedicated to the development "revolutionary, high-payoff technologies" - and one avenue to that is the NASA Space Technology Research Fellowship (NSTRF) program. For Ames, NSTRF not only raises technology readiness levels and advances the Fellows' research by exposing them to Ames' broad range of knowledge and expertise, it also contributes to the culture of innovation at Ames.

To date, NASA has competitively awarded these prestigious fellowships to 301 students from over 70 U.S. universities across at least 35 states and one U.S. territory. The Fellows receive training grants to conduct research that addresses explicit NASA technology priorities. The first NSTRF class was selected in 2011 and is just starting to graduate, typically with a Ph.D. degree.

The Chief Technologists' Council (CTC) lauded the program, particularly the Fellows' "in-depth engagement…with a NASA (research) collaborator who has extensive expertise in the student's proposal area" and who spends time with the Fellows at designated NASA Centers. The CTC noted that the Fellows "represent the next generation of the nation's leading aerospace researchers, exploring the critical advances in technology for which NASA is renowned."

Perhaps due to its breadth of capabilities, Ames attracts more than its share of Fellows. Over 25 came to Ames this year, most in the summer (8 new Fellows will be coming next year). Over 20 Ames employees, civil service and contractor, are serving as research collaborators (RC).

The RCs are enthusiastic supporters of the program because the Fellows approach problems from nontraditional angles. Vytas SunSpiral says that the program "has been central in enabling our lab to investigate innovative approaches to robotics and controls, and the Fellows have brought their passion and unique skills to help solve complex research challenges."

NSTRF also stimulates a broader community supporting NASA technology development. SunSpiral says "NSTRF has brought the attention of leading research professors to the technologies we are exploring, and we have often been able to tap into the broader creativity and technical insights from the Fellow's home lab" – nontrivial when those labs are of the caliber of Whittaker's robotics program at Carnegie Mellon and Peck's lab at Cornell. And Lynn Rothschild believes the Fellows' time at NASA draws them into our dreams for space.

Some of the Fellows at Ames this year are working in traditional Ames' strengths, such as thermal protection, space biology, cubesats, and robotics (particularly tensegrity). Some are natural outgrowths of Ames' specialties, such as formation flying and novel human-robot interfaces. Still others are working on new fields (to Ames) such as automated construction, digital structures, and countermeasure "skinsuits". In fact, some of the RC's believe that the Fellows can enhance a Center's capabilities in new areas.

A list of the active Fellows assigned to Ames, their RCs, and research projects follows. ■

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Active Fellows

Andrew Sabelhaus	*UC Berkeley*	Approximate Models for Closed-Loop Tajectory Tracking in Underactuated Systems	*Adrian Agogino*
Casey Heidrich	*Georgia Tech*	Technologies to Enable EDL of Smallsat Science and Exploration Payloads	*Brandon Smith*
Adam Koenig	*Stanford University*	Angles-Only Navigation System for Nanosatellite	*Chad Frost*
Joshua Wilson	*Brigham Young University*	Adaptive Control Methods for Soft Robots	*Linda Kobayashi*
Taiyo Wilson	*University of Illinois at Urbana-Champaign*	Continuum-Kinetic Hybrid Framework for Chemically Reacting Flows	*Michael Barnhardt*
Steve McGuire	*U Colorado, Boulder*	Augmented Reality Telepresence for Robotic Exploration	*Stephen Ellis*
Elizabeth Cha	*USC*	Communication of Robot Status to Improve Human-Robot Collaboration	*Terry Fong*
Jennifer Case	*Purdue University*	Control of an Active Sensor Skin for Extreme Terrain Mobility	*Vytas Sunspiral*
Adam Sidor	*Georgia Tech*	Development of Conformal Ablative Thermal Protection Material and Fabrication Process	*Robin Beck*
Przemyslaw Lasota	*Massachusetts Institute of Technology*	Developing an Adaptive Robotic Assistant for Close-Proximity Human-Robot Interaction in Space Environments	*Terry Fong*
Michael Watterson	*U Penn*	Monocular SLAM for Smart SPHERES	*Trey Smith*
Jeffrey Friesen	*UC San Diego*	Modular Joints for Soft Robots	*Vytas Sunspiral*
Simon Vecchioni	*Columbia University*	BioWires: DNA-Based Nanowires for Conductivity-Enhanced, Self-Assembling Nanoelectronics	*Lynn Rothschild*
Joseph Bartels	*Carnegie Mellon University*	Roving in the Permanently Shadowed Regions of Planetary Bodies	*Matt Deans*
Benjamin Jenett	*MIT*	Topological Optimization and Automated Construction for Lightweight Structures	*Kenny Cheung*
Nicholas Cheney	*Cornell University*	Design Automation Algorithm for Soft Robots	*Vytas Sunspiral*
Daniel Cellucci	*Cornell University*	Robotic Assembly of Digital Structures using Deployable Elements	*Kenny Cheung*
Kevin Newman	*University of Arizona*	Achromatic Phase Shifting Mask for High Performance PIAA Coronagraphy	*Rus Belikov*
Jessica Cardenas	*New Jersey Institute of Technology*	hMSCs Cultured on Plant-Derived Tissue Engineering Extracellular Matrix in a Microgravity Environment	*Eduardo Almeida*
Jennifer King	*Carnegie Mellon University*	Re configuring Worlds with Simple Actuation via Physics-Based Nonprehensile Actions	*Vytas SunSpiral*
Electa Baker	*Vanderbilt University*	A Standard of Visualization Abstraction for Human-Robot Interfaces	*Terry Fong*
Anthony Harness	*University of Colorado, Boulder*	Visual Positioning System for the Formation Flying of Suborbital Vehicles and Spacecraft	*Elwood Agasid*
Zakary Littlefield	*Rutgers University*	Robust Path Planning for Space Exploration Rovers	*Xavier Bouyssounouse*
Christopher McBryde	*Georgia Institute of Technology*	Vision Based Object Detection and Navigation for Spacecraft	*Chad Frost*
Lenson Pellouchoud	*Stanford University*	Modeling of Complex Material Systems in Extreme Environments for Space Technology	*John Lawson*
Greydon Foil	*Carnegie Mellon University*	Science Data Understanding for Autonomous Rover Exploration	*Terry Fong*
Matthew Bopp	*Georgia Institute of Technology*	Implementation and Assessment of a Time-Accurate Aeroelastic Model for Analysis of Inflatable Aerodynamic Decelerators	*Michael Barnhardt*
Peter Clarke	*University of Texas at Austin*	A Novel Highly Efficient Scheme for the Boltzmann Equation	*Yen Liu*
Jose Padial	*Stanford University*	Robotic Localization using Shadow Information in Imagery	*Terry Fong*
Aliyeh Mousavi	*Stanford University*	Development of a mechanically versatile bioreactor system as a cellular microgravity countermeasure for regenerative medicine applications	*Tony Ricco*
Kyle Higdon	*U Texas, Austin*	Application of the MCMC Method for the Calibration of DSMC Parameters to NASA EAST Results for Ionizing, Radiating Hypersonic Flows	*Brett Cruden*
Dustin Kendrick	*MIT*	Gravity Loading Countermeasure Skinsuit	
Corwin Olson	*U Texas, Austin*	Modern Estimation Techniques and Optimal Maneuver Targeting for Autonomous Optical Navigation around Small Bodies	*Jeff Mulligan*
Megan Marie Pendleton	*UC Berkeley*	Effects of Ionizing Radiation on Fatigue Properties of Trabecular Bone	*Josh Alwood*
Daniel Szafir	*U Wisconsin, Madison*	Effective Human-Robot Collaborative Work for Critical Missions	*Terry Fong*

TechBytes is published quarterly by the Office of the Center Chief Technologist at NASA Ames Research Center. The publication describes the emerging, potentially transformative technologies that Ames is pursuing to help NASA achieve its mission. For more information about Ames technology, visit the website listed below. If you would like more information about TechBytes, or wish to be placed on the publication's distribution list, contact Jill Bauman, jill.bauman@nasa.gov.