National Aeronautics and
Space Administration

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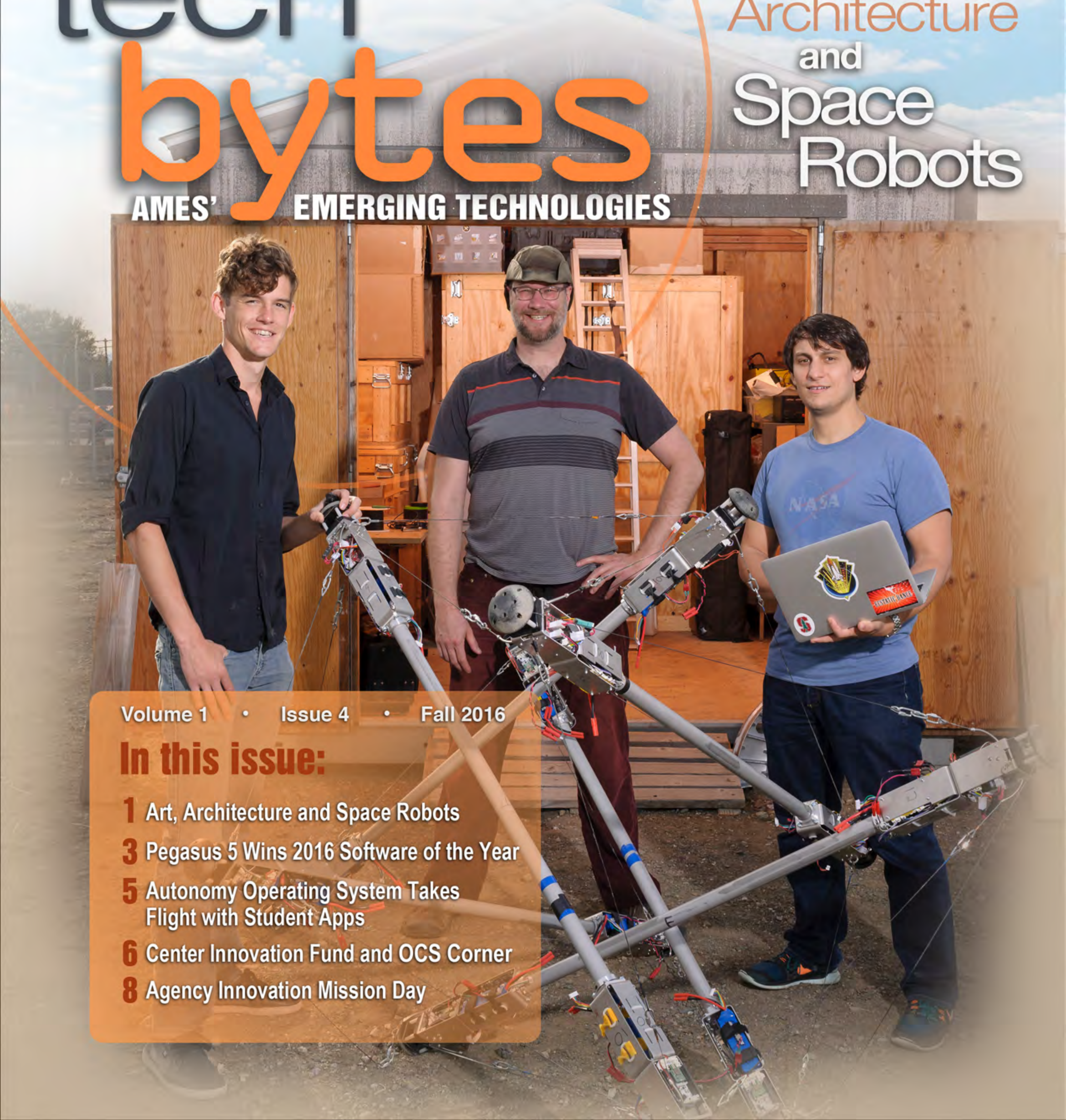
AMES' EMERGING TECHNOLOGIES

Art, Architecture and Space Robots



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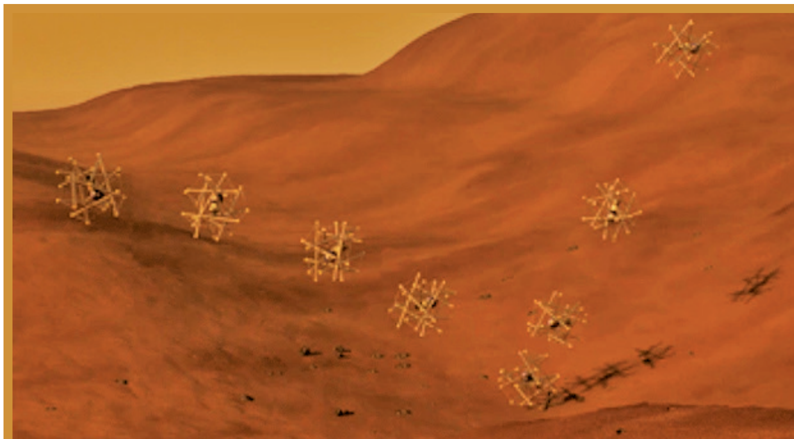
Art, Architecture, and Space Robots



Artist rendering of a Super Ball Bot moving across the surface of Titan. Image Credit: Virtual Technology Laboratory at the University of Idaho and NASA

Art and architecture and space exploration have multiple and close connections (who can forget the architectural elegance of the space vehicles in "2001: A Space Odyssey" or the grace of the U.S.S. Enterprise?). Still, art and architecture are not commonly associated with robots exploring the surfaces of other worlds.

Similarly, biology has provided many and varied methods of locomotion. None even remotely resemble Curiosity rover.

Tensegrity robots link all these elements, a connection enabled by recent advances in machine learning and neuroscience-inspired control theories. It represents a different structural approach, based on how biology primarily designs with tensile materials, minimizing the use of rigid structure like bones. Instead of a rigid frame or skeleton, a tensegrity robot is a continuous tensile network of cables which are in a dynamic balance with individual rigid elements like rods or bones. This results in many unique physical properties, such as variable stiffness and compliance, and the ability to naturally share applied forces and loads throughout all elements of the structure, enabling them to be very robust. Operators can "pre-tense" cabling to stiffen the structure and then soften it to enable different functions. The result is a highly adaptive and responsive robot that can adjust to changing conditions, yet be rigid enough to carry payloads and do work.

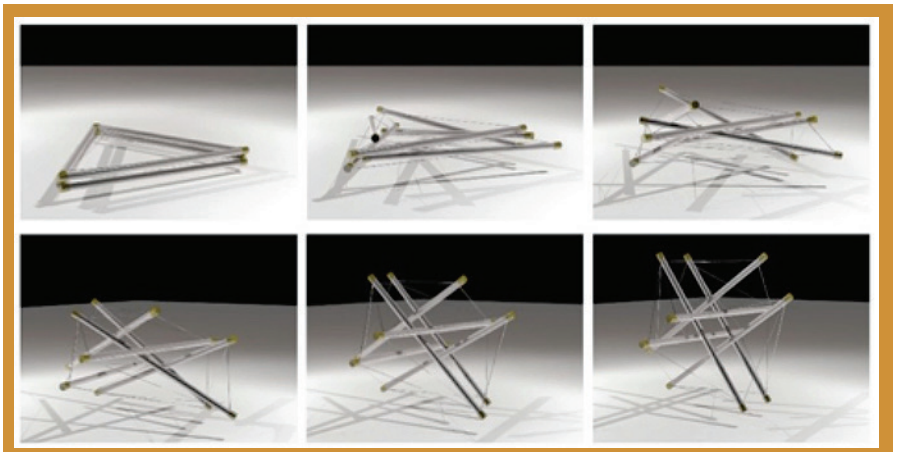
Traditional rovers are rigid structures mechanized to move once they are safely landed. Tensegrity rovers in principle have the capability of serving as a lander that can handle a high-speed landing, and then transform into an explorer that can roll into fragile, risky, or hard-to-reach areas that traditional rovers may not be able to approach. Or the concept can be applied just to landers, or to wings with adaptive systems, and adaptable wheels on traditional rovers.

The fact that tensegrity packages can be folded into very small payloads – but can then expand into much larger structures – has implications for entry, descent and landing, and other large deployable space structures.

However, tensegrity robotics have applications on Earth as well, and NASA has discussed those with other agencies, including the U.S. Geological Survey (USGS) and the Department of Defense (DoD). One can easily envision them dropped by helicopters in designated areas to search for signs of life in urban areas shattered by earthquakes, or map out landscapes littered with improvised explosive devices.

ABOUT THE COVER

Jeffrey Friesen, Vytas Sunspiral, and Massimo Vespignani stand beside the first prototype of SUPERball bot.



The six bar tensegrity probe can be packed into a flat triangle and then deployed to full functional configuration by changing the string lengths with the same actuators which will be used later for mobility. Image Credit: University of Idaho and NASA

There are many possibilities for innovation. Resources like the Pleiades supercomputer are being used to run machine learning within simulated virtual worlds to discover efficient control algorithms and novel morphologies for new types of tensegrity robots. For example, it may be possible to design a legged tensegrity robot that has terrain access capabilities similar to a mountain goat, and the robustness to survive unintended slips and falls, enabling NASA to explore high value science targets, wherever they may be. ■

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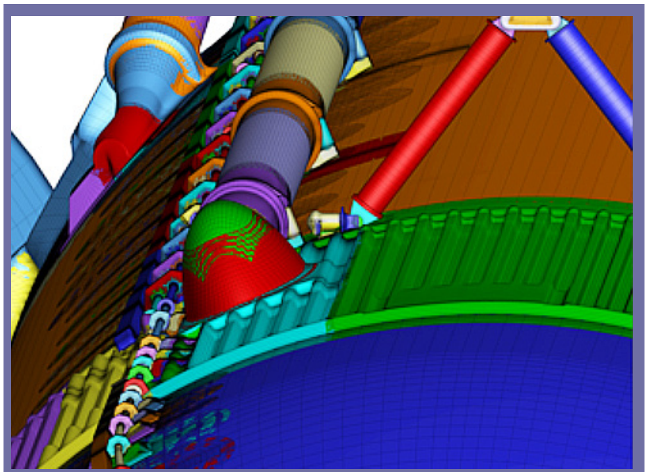
Pegasus 5 Wins 2016 Software of the Year

Aerospace engineers have relied on the Pegasus 5 software in the design of nearly every space vehicle over the last 15 years, including the upcoming Space Launch System, the next-generation Orion human spacecraft, and the space shuttle. Now, Pegasus 5 software, developed at NASA Ames, has been named co-winner of the prestigious NASA Software of the Year award for 2016, sharing honors with the Traffic Aware Planner software from NASA Langley.

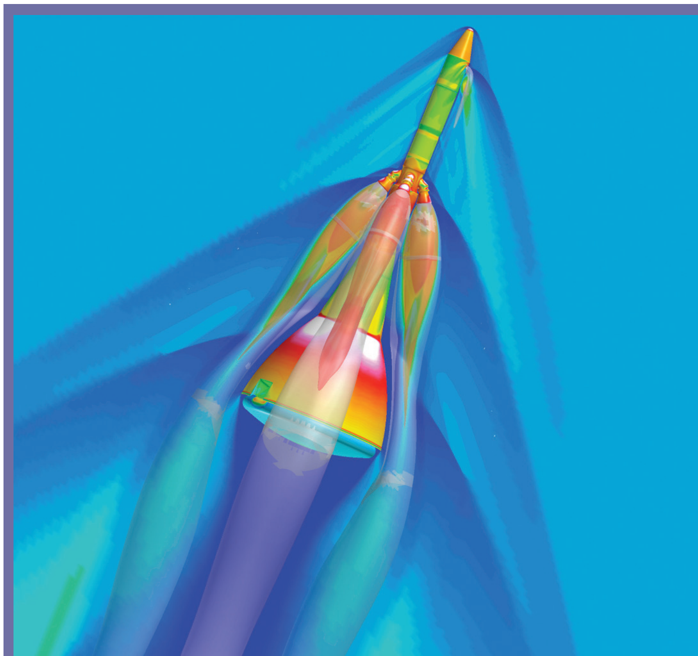


Overset surface grids processed by Pegasus 5 that model the space shuttle's external tank, including its bi-pod attach hardware and liquid oxygen feedline. Image Credit: Stuart Rogers, NASA/Ames

The Pegasus 5 code is used to automatically pre-process complex aerodynamics data when performing computational fluid dynamics (CFD) analysis of an aerospace vehicle. CFD utilizes powerful supercomputers to simulate the air flowing over a vehicle by solving the mathematical equations governing fluid flow. The software uses the overset grid approach, which involves breaking down complex computational domains into smaller regions that can be represented by relatively simple grids.

Pegasus 5 Wins 2016 Software of the Year (continued)

Before Pegasus 5 became available, this process required many weeks of work by an expert CFD researcher—an onerous task prone to user error, especially as simulations and vehicle configurations increased in complexity. Today, Pegasus 5 greatly reduces the amount of work and level of experience required by the user. Because of its seamless, automated integration of overset CFD grids, Pegasus 5 has become a primary tool used in building aerodynamic databases for NASA aeronautics and space programs.



Simulation of the Orion Launch Abort Vehicle using overset grids processed by the Pegasus5 software and the Overset CFD solver. Image Credit: Stuart Rogers, NASA/Ames

Pegasus 5 was developed and written by Norman Suhs, William Dietz, and Stuart Rogers. Suhs and Dietz developed the original version in the late 1990s for the Advanced Subsonics Technology (AST) Program, under a NASA contract with Microcraft, Inc. in Huntsville, Alabama. At the time, Rogers, working for the AST program as a civil servant at Ames, led a team that used Pegasus 5 to perform CFD analysis of a commercial cargo aircraft in a landing, high-lift configuration in a record 50 days, in order to meet a critical program milestone. Since then, Rogers has continued to develop the Pegasus 5 software, adding new capabilities and dramatically improving its efficiency by orders of magnitude through parallelization.

Rogers, who works in the NASA Advanced Supercomputing (NAS) Division's Computational Aerosciences Branch at Ames, maintains the software and oversees its dissemination to over 300 users. Outside NASA, one of the biggest users of the software is The Boeing Company. Boeing has used Pegasus 5 in the analysis and design of many vehicles, including its most fuel-efficient jet airliner to date, the 787 Dreamliner; the third-generation 747; fourth-generation 737; numerous military trainer and transport aircraft; and early Delta expendable launch vehicles. Robert Gregg III, chief aerodynamicist, Boeing Commercial Airplanes, said: "Without PEG5, we would not be able to efficiently design and analyze the wide array of aerospace products that we build at The Boeing Company."

The Pegasus 5 software is also widely used by other aerospace industry companies, including SpaceX, Sierra Nevada Corporation, and Lockheed Martin Space Systems. It has also been released to over 100 professors and students at major universities, including Stanford University, Massachusetts Institute of Technology, John Hopkins University, and the U.S. Air Force Academy.

The Pegasus 5 software is available for release in the U.S. through the NASA software catalogue:

https://software.nasa.gov/software/ARC-15117-1A ■

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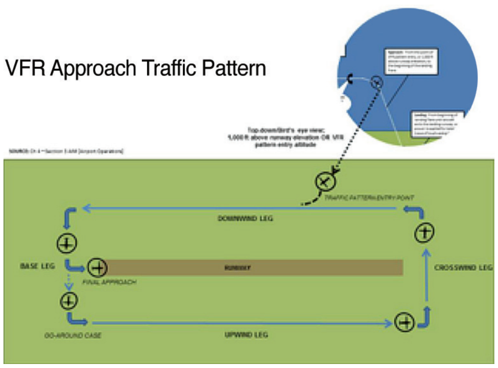
Autonomy Operating System Takes Flight with Student Apps

On August 9, 2016, student interns Jessica Glass and Oeishi Banerjee successfully flew their Aotonomy Operating Sytem (AOS) app VFR (Visual Flight Rules) Approach Terminal Procedures on an X8 quadcopter in front of the 80' by 120' Ames wind tunnel.

This AOS app autonomously navigates an unmanned aerial vehicle (UAV) through basic variations in a standard airport traffic pattern in visual conditions. For this test, a generic airport traffic pattern was simulated by planting flags in the wind tunnel field representing way-points such as base-turn-to-final, standard and extended downwind-to-base turning points, and go-around points. The behavior of this AOS app is described in Jessica's app documentation, and complies with this diagram from the FAA Aeronautical Information Manual:



AOS is an open software platform for building intelligent UAVs. One of the key goals of the AOS project is to demonstrate the feasibility of an IOS smartphone approach for intelligent UAVs: provide the basic infrastructure and core set of key apps, and then foster a vibrant developer community to create a wide range of software apps that make smartphones and potentially UAVs so capable. Truly intelligent UAVs will require an enormous amount of software, so the IOS ecosystem model provides an attractive and economical approach to software development that combines a centrally managed infrastructure developed by a core team with applications developed through an open market. The VFR Approach Terminal Procedures app is the first AOS app developed by engineers outside the core AOS team.

Students Jessica Glass (University of Cincinnati) and Oeishi Banerjee (Cupertino High School) pose with their quadcopter outside the 80'x120' windtunnel.

In ten weeks, Jessica Glass, a University of Cincinnati Aeronautics undergrad, and Oeishi Banerjee, a Cupertino High School Junior, researched the FAA requirements for piloting the VFR traffic pattern, developed and documented a system design, and then implemented the software code. The software was implemented in PLEXIL, a computer language and runtime environment for representing and executing plans and procedures. Plexil was developed by Artificial Intelligence researchers in the Intelligent Systems Division at NASA Ames. ■

The AOS team runs a UAV through a standard airport traffic pattern.

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Center Innovation Fund

While it is fair to say that NASA considers innovation to be an element of every employee's job, the Agency explicitly pursues advancement of low technology-readiness-level (TRL) concepts through the Center Innovation Fund (CIF). CIF seeks to "stimulate and encourage creativity and innovation within the NASA Centers in addressing the technology needs of NASA and the nation." Through the Center Chief Technologists (CCT), each Center leads a call for proposals and a review and selection process supporting emerging technologies. The competitive process is a challenging one, because it generates so many proposals (this year we received nearly 70) advancing excellent and in some cases extremely ingenious, concepts.

This summer, the Ames Research and Technology Council (ARTC), a new advisory committee, reviewed the CIF proposals. It rated them using the following criteria: degree of innovation, including unique contributions to otherwise unmet Agency or national needs; technical merit; and effectiveness of resource planning and utilization. The CIF program at Headquarters, provided a final vetting of all Center selections.

We are very pleased to announce that we have selected 13 CIF proposals to fund. Please join the office in congratulating:

- Rus Belikov (SSA): **Focal plane wavefront estimation for Space Mission Coronagraphs**
- Matthew Deans (TI): **Multifunction 3D Printed Carbon Nanotube Membranes for Tensegrity Robots**
- Rodolphe De Rosee (RE): **Free Space Optical Communications for Nanosats**
- Terry Fong (TI): **Smart Projectiles for Environmental Assessment, Reconnaissance and Sensing (SPEARS)**
- Jonathan Galazka (SCR): **Methane Metabolism by Yeast**
- John Hogan (SCB): **In Situ Yogurt Production for Probiotic and Nutrition Delivery**
- Jessica Koehne (TSS): **Raman Life Detection Instrument Development for Icy Worlds**
- Chris McKay (SSX): **Crucible: A System for Space Synthetic Biology Experiments**
- Nikunj Oza (TI): **Ask-the-Expert: Minimizing Human Review for Big Data Analytics through Active Learning**
- Patricia Parsons-Wingerter (SCR): **Concluding 2D-to-3D Transformation of VESGEN Software for Urgent Astronaut Health Risks during Long-Duration ISS and Mars Exploration Missions**
- Richard Quinn (SST): **Electrochemical Detection of Biological Catalysts as Signatures of Life**
- Lynn Rothschild (SST): **A Robust, Cell-free Production System for On-Demand Protein Synthesis in Space**
- Raj Venkatapathy (TS): **DLR's COMARS+ Sensor Suite for New Frontiers-4 and Discovery Competed Missions**

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OCS Corner

The Office of the Chief Scientist (OCS) is proud to announce the Science Innovation Fund (SIF) and Ames Researcher Award winners.

We have selected 7 proposals to fund via SIF. The SIF invests in highly innovative, exploratory, and high risk - high return scientific research that directly supports advancing the strategic direction of Ames and the Agency. It promotes the vitality of Ames through strategic investments in scientific research, capabilities, and people.

Please join us in congratulating:

- Andre Mattioda, *ICEE (In-situ Carbon Exposure Experiment) Proof of Concept – ICEE PoC*
- Christopher Potter, *New Fusion of NASA Remote Sensing Data to Validate Terrestrial Carbon Cycle Models using Measured Fluxes of Carbonyl Sulfide*
- Diana Gentry, *Coastal California's Fog Aerobiology and Ecology: A Local-Scale Survey of Potential Geochemical Impact*

- David Smith, *Survey of Airborne Microorganisms in Earth's Stratosphere: Acquiring Samples in the Northern and Southern Hemisphere with Ride-Along Flights on NASA Aircraft*
- Brad Bebout, *Biology IS the Technology: Microbial Ecology of Space Food Production*
- Brad Bebout, *Measuring ancient air pressure using fossil bacteria*
- Meyya Meyyappan, *Disinfection of Food Produce using Atmospheric Pressure Cold Plasma*

This year, there were 120 SIF proposals submitted from across the Agency and there was sufficient funding for slightly over 1/3 of those (36%). The average request was for $113K. Because of this, many excellent or good proposals are unable to be funded at this time. We appreciate everyone's interest in this important program and look forward to hearing about the results of these investigations.

This advanced research investment helps make Ames and the Agency more competitive, provides opportunities for risk reduction and increased cost effectiveness, and initiates potentially transformational solutions to the most challenging mission-related problems.

In addition to promoting to new research, Ames gives recognition to employees for their exceptional scientific or engineering research.

Please join us in congratulating the recipients of the 2016 NASA Ames Research Center Researcher Awards.

H. Julian Allen Award

The H. Julian Allen Award was established in 1969 to annually recognize a scientific or engineering paper of outstanding technical merit and significance. The winning author receives an honorarium, a plaque and will give a lecture to the Center.

The 2016 H. Julian Allen Award is awarded to Dr. Anthony Colaprete for his paper "Detection of Water In the LCROSS Ejecta Plume." Science, Volume 330, Issue 463, October 2010, Pages 463-468.

Ames Associate Fellow

The Ames Associate Fellow is an honorary designation that acknowledges distinguished scientific research or outstanding engineering of a non-management related nature. Appointment as Ames Associate Fellow is for a two-year term. The winning researcher receives a personal award, a research stipend, a travel grant and will give a lecture to the Center.

The 2016 Ames Associate Fellows are awarded to Dr. David Blake and Dr. Mark Marley.

- Dr. David Blake is an expert in the field of *in situ* mineralogical analysis and is the principal investigator of CheMin XRD/XRF instrument on Mars Science Laboratory (MSL).

- Dr. Mark S. Marley is an expert in the field of atmospheric science theory and modeling and is recognized, in part, for his work on the interiors of solar system gas giant planets and studies of the dynamic atmospheres of brown dwarf stars.

Ames Early Career Researcher Award

The Ames Early Career Researcher Award recognizes an early career employee that demonstrate exceptional scientific or engineering potential for leadership through outstanding research and the integration of research within the context of the mission of their organizations. The winning researcher receives a personal award and will give a lecture to the Center. The 2016 Early Career Researcher is awarded to Dr. Kenneth C. Cheung.

- Dr. Kenneth C. Cheung conducts research on discrete building-block based materials mechanics and manufacturing, composite digital material analysis and fabrication methods, reconfigurable systems, digital material actuators and rapid prototyping.

Congratulations to all of the 2016 Science Innovation Fund and NASA Ames Research Center Researcher Awards recipients.

Visit the OCS Website for more information:
www.nasa.gov/ames/ocs

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Agency Innovation Mission Day

"We are all innovators." This is the message that participants in the 2016 NASA FIRST (Foundations of Influence, Success and Teamwork) leadership development program seek to promote through the Agency Innovation Mission (AIM) campaign. The 2016 NASA FIRST class is comprised of 40 GS-11's –13's from all centers throughout the Agency. The team established AIM as part of an initiative from Deputy Administrator Dava Newman, to create an Agencywide Innovation Day. The purpose of AIM is to capture and celebrate innovation that is done by ALL NASA employees throughout all career disciplines and organizations. AIM Day, taking place on November 1st, is a "FIRST of its kind" event during which the entire Agency will be connected, learning, and innovating alongside each other. Brandon Smith, Robin De Leon, and Rodolphe De Rosee are the NASA Ames 2016 FIRST team working on the events taking place locally at Ames. The day will include a keynote speech by Dava Newman, pitches from the NASA Innovation Kick Start (NIKS), cross-Center collaboration activities, innovation videos, Human Innovation Training, speakers, a discussion panel, innovation showcasing, and an open house of innovation resources. The team will have a sign-up table during lunch and during the happy hour in the Space Bar on Wednesday, October 19th. AIM Day will be an all-day event taking place in Building 3 on November 1st. More information and resources can be found on the AIM website at: **www.inside.nasa.gov/innovate**.

Agency Innovation Mission (AIM) Day poster. Image Credit: NASA

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Upcoming Innovation and Other Events

Centers of Excellence for Collaborative Innovation: Links to Resources for Government Innovation (**https://www.nasa.gov/offices/COECI/index.html**)

Upcoming APPEL Courses in Creativity and Innovation

(http://appel.nasa.gov)

- Jan 23-25, 2017 Location: AFRC
- May 1-3, 2017 Location: MSFC
- May 16-18, 2017 Location: KSC

Solicitations

Small, Innovative Missions for Planetary Exploration

Solicitation: NNH16ZDA001N-SIMPLEX

- Closing Date: April 28, 2017

Events

- November 1
  Agency Innovation Mission (AIM) Day
  NASA Ames, Building 3
- November 5
  Bay Area Science Festival
  AT&T Park, San Francisco, CA
- November 29 - December 1, 2016
  SBIR/STTR Innovation Summit
  Austin TX
- December 12-16, 2016
  American Geophysical Union 2016,
  San Francisco, CA

Initiatives

NASA iTech Initiative **http://nasaitech.com/#intro**

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