National Aeronautics and
Space Administration

tech bytes

AMES' EMERGING TECHNOLOGIES

Humans and Robots Exploring Other Worlds ...Together

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tech bytes

The Ames Office of the Center Chief Technologist (OCCT) is pleased to welcome you to the debut issue of ***TechBytes***. The purpose of this quarterly newsletter is to inform you of emerging, and potentially transformative, technologies at Ames, and how they're helping NASA to achieve its mission. In addition, TechBytes is a forum to recognize innovators within the Ames community, encourage collaboration and find solutions to problems within and outside the Center, and break down barriers to innovation that often seem like formidable roadblocks outside individual control. We encourage you to pass along this issue to your colleagues. An electronic version of this Ames TechBytes is available at: http://www.nasa.gov/centers/ames/cct/

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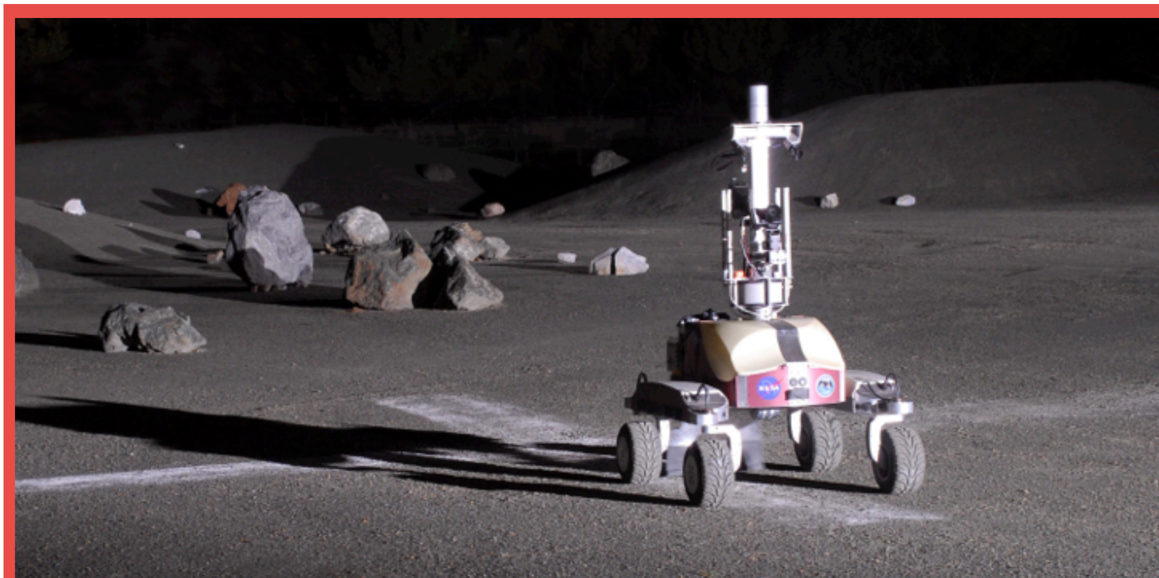

The K10 rover in the Ames Research Center's specially built "Roverscape."

Humans and Robots: Exploring Other Worlds...Together

Just as remotely operated vehicles help humans explore the depths of the ocean from above, NASA has begun studying how a similar approach may one day help astronauts explore other worlds. The Intelligent Robotics Group at NASA Ames, directed by Terry Fong, is developing the technology for "Surface Telerobotics" exploration in which an astronaut in an orbiting spacecraft, or positioned at a suitable Lagrange point, can remotely operate a robot on a planetary surface. In the future, astronauts orbiting other planetary bodies, such as Mars, asteroids or the moon, could use this approach to perform work on the surface using robotic avatars. This capability could significantly enhance the ability of humans and robots to explore together, performing tasks that may involve high-speed mobility, short mission durations, focused or dexterous tasks with short-time

ABOUT THE COVER

Terry Fong of the Intelligent Robotics Group at NASA Ames preforms remote operation tests of the K10 planetary rover at the Ames Roverscape site. Photo Credit: Dominic Hart decision-making, reduced autonomy or redundancy on the surface asset, and/or contingency modes/failure analysis through crew interaction.

The Human Exploration Telerobotics Project, managed by Dr. Fong, conducted testing of the first fully-interactive remote operation of a planetary rover by an astronaut in space, achieving a number of firsts for NASA in the field of human-robotic exploration. During the test, Expedition 36 Flight Engineer Chris Cassidy remotely operated the K10 planetary rover in the Roverscape – an outdoor robotic test area the size of two football fields located at NASA Ames – on Earth's surface, hundreds of miles below his post aboard the International Space Station. For more than three hours, Cassidy used the robot to perform a survey of the Roverscape's rocky, lunar-like terrain and began deploying a simulated Kapton film-based radio antenna.

The capability of using a remotly controlled rover to deploy mission critical equipment like a surface radio antenna will enable such missions as the Orion L2 Farside mission (L2fm), a concept was developed by Dr. Jack Burns of the Lunar University Network for Astrophysics Research (LUNAR) at the University of Colorado, Boulder. It is a potential follow-on mission to the Dark Ages Radio Explorer (DARE) mission, an Ames proposal recently submitted to the Small Explorer (SMEX) program, led by Dr. Burns and managed at Ames. Like L2fm, DARE will identify when the first stars, black holes and galaxies formed in the early Universe and their characteristics. L2fm and DARE have the potential to open an entirely unexplored early epoch of the Universe (the "Cosmic Dawn") and break the field of cosmology wide-open for further long-term experimentation. Remotely controlled telerobotics, like that being developed by Dr. Fong and his team at Ames, are paving the way for such revolutionary science. ■

Chris Cassidy on board ISS remotely controlling the K10 rover at Ames.

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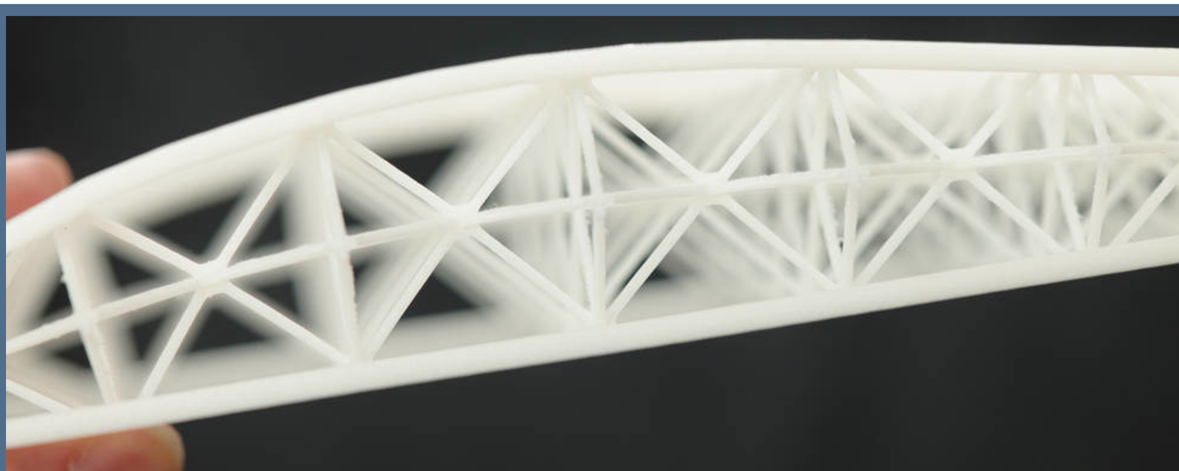
The K10 rover deploying a simulated Kapton film-based radio antenna, like that concieved for the Orion 12 Farside mission.

SpaceShop: The Importance of Prototyping I

Tucked away on the second floor of N220 is a facility that promises to transform how innovators at Ames turn concepts into working prototypes. The SpaceShop, established in 2012, is working with researchers and other innovators across Ames. What the facility offers them is the ability to optimize designs and rapidly and inexpensively prototype them – especially, but not only, novel technologies.



3-D printed airfoil.

SpaceShop manager Alex Mazhari emphasizes that "the whole Center could be using this stuff. They really have to integrate it into their design process." The capabilities the facility has to offer – including laser cutting, 3D printing and scanning, vinyl cutting, molding and casting, silk-screening, and CNC milling – are demonstrated during 90-minute training sessions offered every workday during core hours. Products can range from engraved plaques to actual components for existing projects or prototypes designed to help "sell" a concept and get it funded.

All of Ames' technical directorates have used the SpaceShop to varying degrees. Mazhari says Code T particularly has become a frequent customer. Code T's FrankenEye is a perfect example of what the SpaceShop can accomplish. The FrankenEye concept explores a unique opportunity to exploit smaller, expendable unmanned aerial systems (UAS) to build modular, scalable aircraft systems with improved performance leveraging 3D printing and rapid manufacturing techniques. A virtual library of aircraft parts is used for exponentially increasing the design space for prototyping and testing. This approach enables reduced development time of new aircraft configurations optimized for specific mission requirements by as much as an order of magnitude by repurposing existing components and open architectures, thus significantly reducing project development costs. For example, the SpaceShop has printed nose cones and airfoils milled sound insulation foam, and developed modular flaps sized to meet FrankenEye's varying payload requirements. The flaps initially cost $10-15 per component; the cost eventually dropped to 30-40 cents. They took hours to make where production of comparable prototypes outside the Shop would have taken weeks. The Shop has saved the FrankenEye thousands of dollars and significant amounts of time.

The Tensegrity project has also made good use of the prototyping capabilities of the SpaceShop. Tensegrity represents a novel approach to robotics, in that it replaces the traditional concept of a vehicle on wheels with an actively controlled tendon-robot powered much like a biological organism with bone and muscle. Supported by the NASA Innovative Advanced Concepts (NIAC) program, the tensegrity robots are such a cutting edge and new approach to robotics that best engineering practices are still being developed through rapid prototyping and experimentation. The Shop has helped the project build its first prototype robot, and continues to help prototype new components and assemblies, such as the rod “end caps” which house the actuators and sensors and act somewhat like feet on the current robot. Given the high level of experimentation and rapidly evolving designs, the project benefits from hands-on manufacturing which can be immediately field-tested, and quickly iterated with modifications as needed. The team tests initial components even as the rest of job is being manufactured. Rapidly manufactured parts are essentially fit checks and holders, typically not for final structural components. Working with the SpaceShop has also been great for quick additions and other rapid modifications to meet project deadlines. The first prototype of the superball was completely built in the SpaceShop (printing and milling), and the initial prototypes of rover CNC were milled on the shopbot.

Code R engineers used the SpaceShop to support their work for Wetlabs. They designed components such as syringe mounts and an innovative “centrifuge on a drill” – novel approach to a biomedical problem that could not have succeeded without multiple rapid, inexpensive iterations. Youssef Mohamedaly and Peter Tong believe they saved money as well as time using SpaceShop. Rather than design parts using software, sending the parts to a vendor, and waiting for the delivery of the part, they were able to manufacture the parts themselves in a morning, change the design as needed, and make a new version in two hours. Because they prototyped and addressed design issues, they say, their final parts all fit and performed perfectly.

Alex Mazhari taking John Holdren, senior advisor to President Barack Obama for science and technology, on a tour through Ames' Space Shop.

EDSN and PhoneSat engineers printed whole series of prototyped assemblies. They printed individual boards and integrated them into an existing aluminum CubeSat frame and fit-checked sheet metal parts by laser cutting acrylic. Each set of prototypes would have cost thousands had they gone outside the Center; as it is, the final machined parts were perfected with cheap in-house prototypes.

To Code S, SpaceShop represents an invaluable opportunity to improve hardware to be flown on the Space Station. For example, the fruit fly project has used the Shop to laser-cut acrylic and thin stainless steel meshes for their habitat. They recently printed the whole assembly of their prototype in the newest configuration on a 3D printer in one shot.
This allowed researchers to physically demonstrate their project. The Rodent Research Project has prototyped several components of their habitat and their operational support hardware as well to reduce design time and support important reviews.

Ideally, Mazhari says, everyone (even non-technical people) would have SpaceShop training so they can develop an appreciation of how rapid prototyping and the facility's other capabilities can support their work. He notes that while Codes R, S, and T have been using the Shop extensively, he would love to explore how Codes A and P – and the mission support organizations, for that matter – could benefit from using SpaceShop.

Mazhari emphasizes that while several NASA Centers have SpaceShop-like facilities, Ames is unique in offering the entire Center full access to the Shop's capabilities. Ames has a highly creative workforce, he says, and he wants SpaceShop to help Ames' innovators turn ideas into reality. ■

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TechEdSat 4 Validates Fast Prototyping with Successful Deployment from ISS

When the Nanorack on ISS ejected the TechEdSat (TES) 4 payload into space on the morning of March 3, an Ames team led by Marcus Murbach and Ali Guarneros-Luna held its breath, waiting to see if this latest product of a nanosat assembly line would work. Technical glitches with the Nanorack kept the little satellite locked up on the ISS for a year, and its builders fretted that its untended battery had died. But the battery worked like new, and TES 4 became only the second government cubesat currently in orbit and the first satellite ever to communicate with the ground via e-mail. And even as it recharged its battery through solar power, it successfully deployed an Exo-Brake, a de-orbit system consisting of a tension-based, semi-stiff parachute that is deployed from an aft cavity of the satellite to dramatically increase drag.

TechEdSat Flight Model.

Iterative Approach. One of the things that makes TES 4 special is the well-structured, iterative approach that created it. The Ames Chief Technologist (CCT) at the time, John Hines, funded the first TechEdSat in 2012 to test whether a cubesat can be jettisoned from the International Space Station (ISS). Among other things, the experience allowed the team to master the ISS safety process. Subsequent iterations tested different technologies in a "triad" approach: first in high-altitude balloons, then suborbital flights, then orbital flights. TES 2 featured the first validation test of iridium short burst data modem in orbit; it exceeded expectations by getting twice the predicted amount of data in a 24-hour test. TES 3 was the first 3-U nanosat jettisoned from ISS, and conducted the first test of exo-brake. TES 5 will fly a new x-band telemetry system (ISM-band), and test drag modulation on the exo-brake in late 2015.

Between TES launches, the team works on the Soarex program. The Soarex 8 suborbital mission will conduct the first full-scale exobrake, a flight test of the ISM band transmitter, and the first tests of a novel space camera and wireless sensor technology. Following TES tradition, if

Some members of the TES team: Perikles Papadopoulos, Marcus Murbach, Emil Joh Chavera, Jon Benson, Mike Scales, Adam Reuter, Jose Mojica, Anthony Wiedrick, Romalyn Mirador, Nick Hopkins, Jose Ramil Seneris, Steven Navas

TechEdSat after launch from ISS.

successful, these elements would graduate to a flight mission in the form of TES 6. Every time we fly, says Murbach, we validate or demonstrate something new, building on success.

Leanness. Another special aspect of TES is its leanness. It relies on inexpensive, off-the-shelf components assembled by a team of students led by just two civil servants, Murbach and Guerneros-Luna. The students hail from San Jose State and the University of Idaho. They volunteered their services in return for, Guarneros-Luna says, “practical experience that they can apply in real life, something they can’t learn in the classroom.” Murbach emphasizes that the TES project exposes students to a “skunkworks-style approach that has taught them rapid technology development.” Both express immense pride in their student team, and also highly praise the university advisers: San Jose State’s Dr. Perikles Papadopoulos, and David Atkinson of the University of Idaho.

Flexibility. Flexibility has been a hallmark of the TES team from its inception. For example, the Safety Team in JSC implemented a 3rd switch to inhibit the TES 1 cubesat from turning on. Despite the fact that the cubesat was 90% fabricated, the TechEdSat team rose to the challenge, developed a solution—the Auxiliary Lateral Inhibit (ALI) Switch – and implement the design within a week. The ALI Switch has now become part of the standard requirements for Cubesats that are going to be jettisoned from ISS.

Similarly, TES 4 seized an unexpected NanoRack opening created when another payload could not meet the integration date. The team assembled and delivered the cubesat in all of 6 weeks.

Implications for NASA. TES will contribute to NASA capabilities in a number of ways. For example, it will dramatically improve command and control over nanosatellites at a very low cost. Its ability to communicate in short packets already validates the small-sample via smart-phone communication model. If successful, TES 5 will add “deluge data”: short bursts with very high data rates every time the spacecraft goes over a ground station – and the ground station is your smart-phone. TES has also demonstrated the possibility of independent small sample return capability from the ISS, on-demand, using the exo-brake. TES also pioneered the use of the JEM Small Satellite Orbital Deployer (J-SSOD) on ISS for satellite deployment.

TES technologies might eventually be used in a Mars nanosatellite mission. The approach would enable access to areas on Mars (e.g.,mid-latitude gullies) that would be too high-risk for larger, more expensive missions. These future iterations would feature a next-generation entry vehicle that combines the capabilities of the TES-type exo-brake with the ability to withstand high heating.

Funding. Funding for TES came from a variety of sources. In addition to seed money from the CCT, the Center awarded Center Innovation Fund support for exo-brake development. NASA Engineering and Safety Center (NESC), Code R, and Space Technology Mission Directorate’s (STMD) entry analysis task also provided funding.

But in the final analysis, the TES program was made possible by a dedicated team fueled by pizza, Coke, and the joy of building satellites. ■

This story is dedicated to Ames senior engineer and TES mentor, Bob Ricks of Ames

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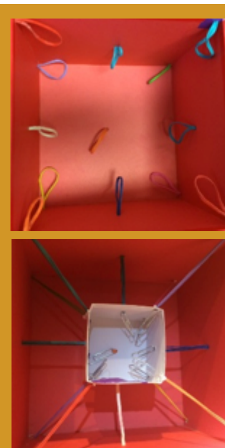
The Egg Drop Challenge: The Importance of Prototyping II

Innovation is relatively easy if it involves only ink drawings on napkins. The trick is to go from scrawl of basic principles - Technical Readiness Level (TRL) 1 - to an actual system that has been thoroughly demonstrated and tested in an operational environment - TRL 9. Our adjoining story on the SpaceShop demonstrates how novel technologies can make prototyping relatively quick, inexpensive, and easy.

Inventor Paulina Plater, a third grader at the International School of the Peninsula in Palo Alto, attempts to create a successful egg drop challenge entry.

But we offer you a real example of the dangers of failing to prototype and test: the Egg Drop Challenge.

Emerging innovator and technologist, Miss Paulina Plater, a third grader at the International School of the Peninsula in Palo Alto, approached her NASA mom in the Office of the Center Chief Technologist (OCCT) for support with implementing her concept for a impact system that would enable a highly sensitive payload (i.e., egg) to survive impact with high velocity (i.e., from the school roof top). With a wealth of resources available to her–state-of-the-art materials (straws, cotton, balloons, rubber bands, boxes, etc.), and access to the Center Chief Technologist–Miss Plater designed and developed her concept: an impact attenuation system involving a sophisticated multi-point payload suspension system (i.e., rubber bands), sub-system level redundancy (i.e., two boxes), and two failure mode systems (i.e., cotton and balloons).

Project requirements (e.g., no parachutes, packing material or helium allowed) were reviewed, and the preliminary analysis, definition and design phases of her project met cost and schedule. However, schedule slip during development (due to homework procrastination) meant that the engineering unit, testing, and the Flight Readiness Review (FRR) were canceled. Against the advice of the Ames Center Chief Technologist (CCT), only a flight unit was developed, and no system testing was performed. How could such a sophisticated, well-thought out system fail? While an actual photo of the end of mission (EOM) is not available, it would have looked a bit like this:

In the customer's report to the CCT, Miss. Plater wrote, ". . .(we) made a bad design because the egg broke on the very first time they dropped it because we didn't test it at all!!!!!!!!!!!!!!!!!!!!!!!! And I am very, very mad." Lesson learned: Prototype and Test! ■

AMES UPCOMING EVENTS AND OPPORTUNITIES

- **2016 Science Innovation Fund (SIF) proposals due June 26.** *Questions regarding the 2016 SIF should be directed to Dr. Jacob Cohen.*
- **2016 Center Innovation Fund (CIF) proposals due July 31.** *Questions regarding the 2016 CIF should be directed to Dr. Jill Bauman.*
- **Small Business Technology Transfer (STTR) and Small Business Innovation Research (SBIR) potential subtopics due June 22.** *Questions regarding STTR and SBIR subtopic submission should be directed to Dr. Rich Pisarski.*