National Aeronautics and
Space Administration

Space Technology

Game Changing Development Highlights

2016 Space Tech Academy

April-June 2016

PUFFER field testing at Rainbow Basin
Astrobee's prototype makes 'Big Splash'
DSOC delivers laser transmitter assembly
SEXTANT off to Kennedy, readying for 2017 flight

Top row left to right: Scott Conklin, Sam Wywrot, Austin Fuller, Benjamin Libben, Joseph Williams, Marquis Burgess, Austin Scott.
Bottom row left to right: Sashank Gummella, Steven Kosvick, Monty Noblezada, Maggie Story, Tim Burks.
Not pictured: Maria Hovanessian, Nathan Roscoe, Lin Li.

GCD Welcomes Summer 2016 Space Tech Academy Students

—Scott Conklin

On June 6, 2016, Game Changing Development (GCD) welcomed 15 interns to the program office as a part of its second annual Space Tech Academy. This year's students come from eight different states and range in education level from college sophomores to graduate students. Interns will work mainly on two different projects through the summer.

Six students make up the Rocket and Payload Integration Development group, or Team RaPID, and will be working on a sounding rocket payload for Orbital ATK titled LEO-II. LEO-II's primary objective is to characterize the flight properties of carbon nanotube composite structures and additive manufacturing to better understand how they can best be used for space applications. To prepare for work on LEO-II, Team RaPID will travel to Wallops Flight Facility to participate in the annual RockOn Camp, during which student teams build small payloads and launch them on a sounding rocket, all in the span of one week.

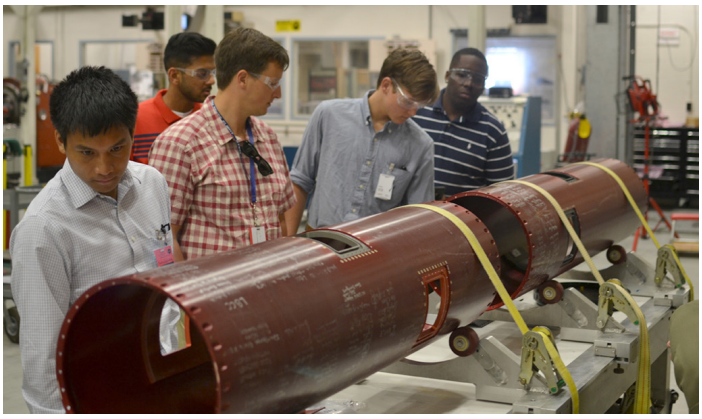
RaPID Team member Austin Fuller, a rising sophomore at Virginia Tech, says, "Working in aerospace research and development is one of my main goals and having the opportunity to work for NASA, the pinnacle of space technology, is a dream come true. RaPID was my first choice, and I am excited for this team, as it incorporates mechanical and electronic systems integration."

Teams HIPER and RAIDER, or Hypersonic Inflatable Prototyping for Entry Research and Radially Adjustable Inflatable Decelerator for Entry Refinement, consist of eight students who were finalists in the GCD's 2016 Breakthrough, Innovative, and Game-changing (BIG) Idea Challenge, which tasked students at universities from around the country to come up with engineering solutions for GCD's Hypersonic Inflatable Aerodynamic Decelerator (HIAD) project. More specifically, the challenge instructed participants to figure out how to control HIAD's inflatable aeroshell technology through the Mars atmosphere.

Having pitched the winning designs, teams HIPER and RAIDER will attempt to build small-scale prototype HIADs that incorporate their steerable concepts. Team RAIDER member Nathan Roscoe from the University of Maine says, "It was really exciting learning that we would be building our own small-scale HIADs and contributing our ideas to the development of entry, descent and landing technology. What GCD is offering us is not only an opportunity to learn, but also an opportunity to use our own ideas and concepts to enhance the technology that currently exists."

One other intern, Scott Conklin, is working with GCD's Education and Public Outreach (EPO) Manager Amy McCluskey to create outreach and communications materials for the Space Tech Academy teams and other GCD projects. The EPO intern also supported the GCD Industry Day in Washington, D.C., during which industry representatives enjoyed presentations by GCD project managers on the latest GCD projects. Industry Day was implemented to synergize industry partnerships and collaboration. Along with the presentations, there were exhibits including prototypes and models, and break-out sessions to discuss technologies directly with project managers.

"I'm very excited to be returning to GCD this summer to expand upon all of the skills and experiences I had last summer," Conklin says. "I look forward to getting some experience in event planning, while also learning more about public affairs and strategic communication."



From left: Monty Noblezada, Jack Verrier, Karan Bansal, Austin Fuller and Marquis Burgess examine a sounding rocket tube that flew to space as a part of the Wallops "RockOn" Camp carrying a payload from last summer's GCD interns.

GCD Big Idea Challenge winners Austin Scott, Steven Kosvick, Nathan Roscoe and Sashank Gummela assemble a one-meter HIAD with Communications intern Scott Conklin.

Although GCD interns gain a lot of experience throughout the summer, they are an integral part of the GCD program office. Acting GCD Program Manager Mary Beth Wusk says, "Students bring unique perspectives, new tools and creative ideas to resolving technical challenges that we are working in GCD. We establish a learning environment by giving the students work that is directly related to the efforts being worked in our portfolio. The students are briefed on the relevance of their work to NASA's mission, provided high-level design requirements and given the basic training needed to work in the labs."

Although this may seem like a tall order, students have historically enjoyed the challenges and freedoms the GCD Internship Program provides, allowing them to take control and excel at their tasks. Wusk says, "Each year, the students impress me more and more with their eagerness to be part of NASA's mission, their ability to deliver under compressed schedules and the quality of the products they are generating. We are growing NASA's next generation of engineers." With passionate students in NASA's pipeline and dedicated employees helping students realize their goals, GCD inspires not by talking about the great things NASA has done in the past but by having interns become active participants in NASA's future.

Front cover: Interns Tim Burks, Austin Fuller, Jack Verrier, Monty Noblezada, Karan Bansal, Marquis Burgess, Patricia Jackson, Maggie Story and Scott Conklin stand in front of a sounding rocket at Wallops Flight Facility's rocket integration building.

Back cover: Interns Austin Fuller, Patricia Jackson, Marquis Burgess, Maggie Story and Tim Burks look at a high power water jet cutter that helps cut steel components for sounding rockets.

PUFFER Prepares for Field Testing

—Denise M. Stefula

The PUFFER team hiking to Rainbow Basin to identify areas for field testing. Examples include overhung rocks (top inset), incline with prototype (middle), and a large region for general mobility testing (bottom).

The Pop-Up Flat Folding Explorer Robots technology, or PUFFER, is readying a prototype for field testing in Southern California's Mojave Desert through this summer and into the fall.

PUFFER is a low-cost pop-up rover that folds compactly—near the size of a smartphone—into a parent spacecraft and can then unfold when needed for exploring and gathering science from the extreme terrains of other planets, like Mars, or those here on Earth, such as on the polar ice sheets. As part of Space Technology's Game Changing Development Program, PUFFER has completed its field test plan, prepared a technical report on component-level testing of cold-tolerant batteries and brushless motors, and conducted a peer review, all important milestones for the project.

"The PUFFER team is off to an excellent start developing and testing designs for the robot's subsystems and in defining how these will come together in our next prototype," says Jaakko Karras, PUFFER project manager at NASA's Jet Propulsion Laboratory (JPL). "PUFFER's compact origami-inspired design requires that every component integrate very closely with the rest of the system. Our initial work is important for ensuring that everything comes together to provide the greatest new science and exploration capabilities possible."

In April, the PUFFER team made a preliminary visit to the Rainbow Basin field test site in the Mojave Desert to identify specific terrain features for testing, including four inclines of varying slope featuring sedimentary rock structure, two natural overhangs, and a large level region for general mobility testing. Observing the PUFFER prototype's capabilities as it navigates the natural terrain features will provide important data supplementing lab testing already underway.

"Our current testing is evaluating PUFFER's mobility in a lab setting at JPL, testing the platform's mobility on steep inclines and beneath confined overhangs. These early tests are excellent for initial prototyping of things like PUFFER's wheels and actuators, and for getting a sense of how energy efficient these types of maneuvers are," says Karras. "These findings will be compared against field test data to determine how our performance changes in 'real-world' conditions, which will allow us to better tune our designs for the natural terrain."

While testing in Rainbow Basin, the team hopes to see PUFFER use its small size and unique mobility architecture to drive up steep sedimentary rock slopes as well as beneath eroded rock overhangs, places that often present challenges for larger spacecraft. "These types of terrains are of high interest to Mars scientists, and we hope to one day use teams of PUFFERs to provide access into unexplored areas," says Karras.

The PUFFER team is currently finalizing with industry partner Pioneer Circuits, Inc., its latest production run of rigid yet flexible printed circuit board (PCB) structures, from which prototypes are being constructed for use as the field test articles. These circuit boards are unique in that they incorporate new materials, such as woven textiles, that can fold into the PUFFER robot's body.

"These new materials did present some early challenges because nobody had produced PCBs quite like this before, and we had to work with Pioneer Circuits to figure out how to get them manufactured. In the end, though, the process that we've come up with is perfect for these types of origami-inspired robots," says Karras.

Component-level testing reported on in May revealed very promising results, showing that both the batteries and actuators can survive the full –135 to 30 ˚C Martian thermal cycle. In order to maximize the science return PUFFER is capable of, Karras wants to see as much of the power budget as possible dedicated to driving and instruments. A good way to do this, he explains, is to operate PUFFERs without any onboard heating because heaters consume large amounts of power.

"By showing that our key components, such as the batteries and motors, can operate in cold environments without heating, we've taken an important first step toward our envisioned heaterless robot," Karras says.

Also in May, a peer review was conducted including 11 reviewers at JPL outside the core PUFFER team. Current progress toward the next generation of instrumented prototypes, as well as work being done to identify future mission opportunities, was presented. These reviews are an exciting

PUFFER FACTS

- Folds flat and stacks as a compact secondary payload
- Pops up without assistance from parent
- Sprawls to fit in confined spaces or position instruments
- Integrates electronics and sensors with structure
- Explores previously inaccessible terrain
- Images steep slope stratigraphy with ground-facing microscope
- Adjusts shape to fit under rock outcrops and measure microenvironments
- Survives falls from cliffs with compliant structure and ability to operate inverted

time for projects because it brings together elements from many different disciplines, spanning both engineering and science.

“Getting together with experts from these disciplines, like we did at our peer review, is an important way to get feedback to ensure that we bring all the different elements together effectively.” says Karras. “Our team received a number of good inputs regarding wheel design for mobility in the types of rough terrains that we are targeting. We are incorporating these inputs into the design and iteration of our wheels as we prepare for field testing on the natural rock features at Rainbow Basin.”

“Many of our reviewers have extensive experience from designing, testing, and operating past and present Mars rovers,” Karras continues. “They pointed us to good resources on topics such as operating electronics in the Mars environment and qualifying future designs for flight. Our reviewers also provided good inputs on formulating PUFFER mission scenarios to identify new mission infusion opportunities.”

Many of the most scientifically intriguing destinations in our solar system, such as caves and lava tubes on Mars or the “chaos terrains” on Europa, will require maneuvering over challenging extreme terrains. This makes extreme terrain mobility a high priority for NASA and its missions, particularly those with science objectives requiring craft to travel highly rugged, adverse surroundings. The PUFFER technology will provide future NASA missions with a low payload cost mission enhancement to explore these types of environments.

The PUFFER test article development yielded some major results.
Top two insets: it uses a novel textile-enhanced rigid-flex printed circuit board technology.
Bottom insets and main image: it is the first self-folding/unfolding actuation mechanism prototype.

"Astrobee's P4 really was the ultimate practice test.... We are now able to 'fly' the robot in our lab...."

—Chris Provencher, Astrobee project manager.

Astrobee P4 Achieves Big Splash—One Step at a Time

—Denise M. Stefula

The Human Exploration Telerobotics 2 project has reached another milestone in its numerous overlapping tests of four free flying robot prototypes for the Astrobee technology. In this "iterative" method, one test's results inform requirements and design for the next version. The importance of having these incremental prototype milestones is to develop a technology in the most efficient manner possible while accepting the proper amount of risk for that stage of development.

"Our ultimate goal is to be on track to deliver certified units ready to meet the technical needs of a project," says Mary Beth Wusk, acting program manager for Space Technology's Game Changing Development Program. "This approach, called iterative design, is used in many projects, not just Astrobee, because it provides a path to integrate the subsystems that are being developed concurrently and ensure the integrated system is progressing as planned."

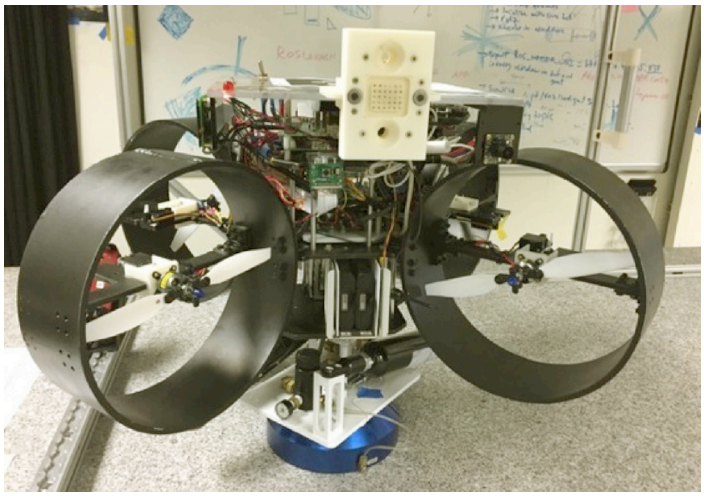
Future human space missions in Earth orbit, to the Moon, and to distant destinations offer many new opportunities for exploration. However, astronaut time will always be in short supply, consumables (e.g., oxygen) will always be limited, and some work will not be feasible, or productive, for astronauts to do manually. Robots such as Astrobee can complement astronauts by performing this work under remote supervision by humans from a space station, spacecraft, habitat, or even from Earth.

“One goal is to reduce the workload on astronauts using these highly functioning, remotely controlled robots capable of performing routine housekeeping and in-flight maintenance jobs so the astronauts can focus on the more important science missions at hand,” says Wusk. “The Game Changing Development Program is well on its way to deliver these Astrobee units to the International Space Station in order to improve the way humans live and work in space.”

Astrobee is an assistive, free flying robot being developed for use on the International Space Station to help save crew time and serve as a research platform. In space, every moment counts and alleviating crew members of conducting tasks robots can easily do frees up valuable time for engaging directly in research activities rather than setting up and tearing down equipment to do so.

“The most recent set of tests took place with Astrobee Prototype 4 (P4),” says Chris Provencher, project manager for the Astrobee technology at NASA’s Ames Research Center. “This prototype is the first to attempt a flight-like hardware design; the previous prototypes were ‘open-structure subsystem test platforms.’ P4 is the first to truly integrate all of the subsystems and the first that will really tell us if the robot can do what we expect it to. It’s also the last prototype before we build the certification unit.”

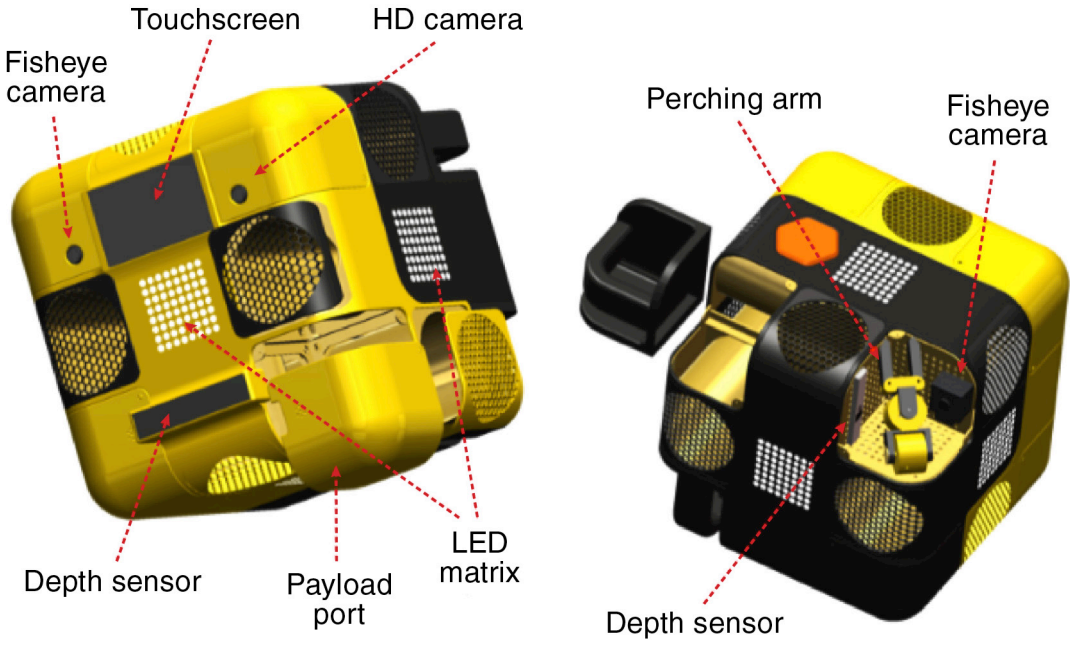
The primary purpose for P4 is a risk reduction activity on various features/components wherein the team is ensuring the hardware design will meet requirements, a critical milestone for this prototype, which reflects a flight-like hardware design. All bench testing, but with a big impact.



Open-structure subsystem platform design as seen in Astrobee P3.

P4 was put through the same tests the team would run on the certification unit. The milestone testing included checking that processors can read data correctly from navigation sensors, command the nozzles which in turn need to produce sufficiently for propulsion, and confirm the motors don’t overheat. Also tested were network connectivity and ensuring the free flyer can receive power from and communicate through the dock.

“The testing was very successful in that we demonstrated that the hardware design works. But, we also identified areas of the design that require modifications, and that’s what we needed to find out now rather than later. This gives us time to make corrections to the design before it’s too late,” explains Provencher. “One example of an area that requires



Astrobee P4’s functional features and those that will collect and feed operational data to ultimately assist astronauts in performing routine tasks.

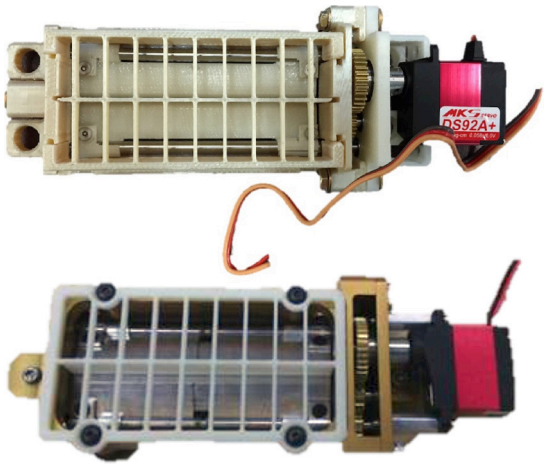
design modifications is in the thermal management system. Astrobee's biggest heat source is the processors. We are using smartphone quality processors, and our analysis indicated that they would provide enough heat that we had to do something about it."

The tests revealed a few flaws in the thermal management system design that need to be addressed, such as rerouting cables so that they don't impede air flow, installing mechanical louvers to direct the air over the processors, and improving the contact between the processors and their heat sink.

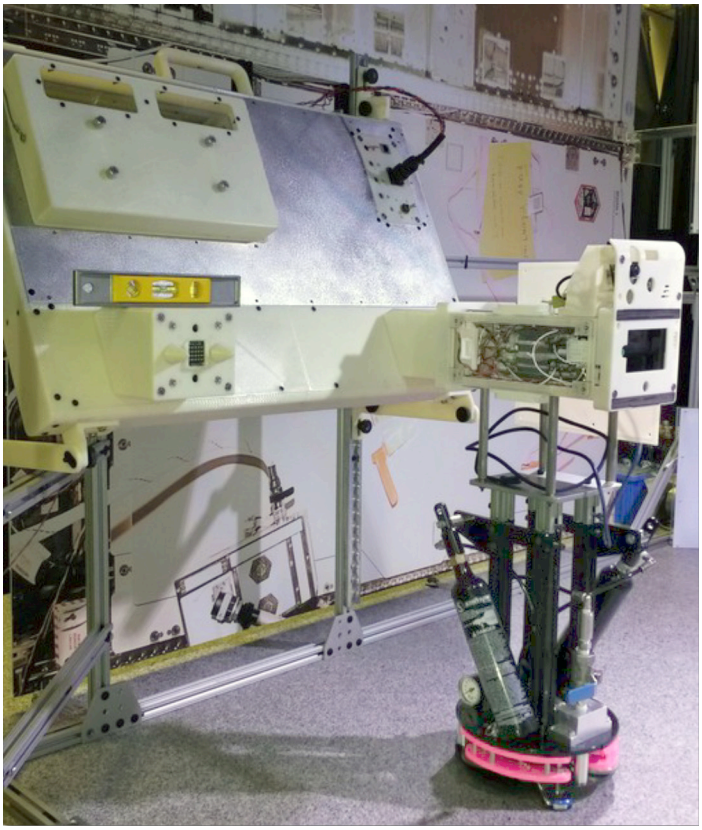
"Developing iterative prototypes has been a very effective development approach for us over the past 1.5+ years," says Provencher. "It allows us to address and reduce risks in a prioritized manner, we can focus on a subset of the robot subsystems instead of everything at once, we can make incremental changes to the design, and it reveals integration issues sooner rather than later."

Provencher likens the approach to that of a college student preparing throughout an academic year for that big exam. Smaller tests through the year gauge progress and help students and instructors identify which areas need more attention—"better to see what you've done wrong on the practice test than getting it wrong on the big exam," he says.

What makes Astrobee's milestone a big splash? P4 had a secondary purpose; it allowed the team to practice how to do the integration, assembly and testing of the certification unit. This was important because the central core module presented a real integration challenge. "We're trying to fit a lot of avionics components into a small volume. The order in which you assemble things makes a big difference," says Provencher. "We experimented with a few different sequences, then documented the way that worked best. Those draft procedures now set us up for successful assembly and testing with the certification unit. Astrobee's Prototype 4 really was the ultimate practice test."



Comparison of nozzle redesign, materials and manufacturing updates through iterative prototyping efforts. During prototyping efforts a lot of 3D printed parts were used, as shown on the top nozzle. However, the nozzles have small moving parts, and the parts kept jamming. The 3D printing didn't have sufficient manufacturing tolerances, so the team had to refabricate the nozzles using machined aluminum (bottom nozzle).



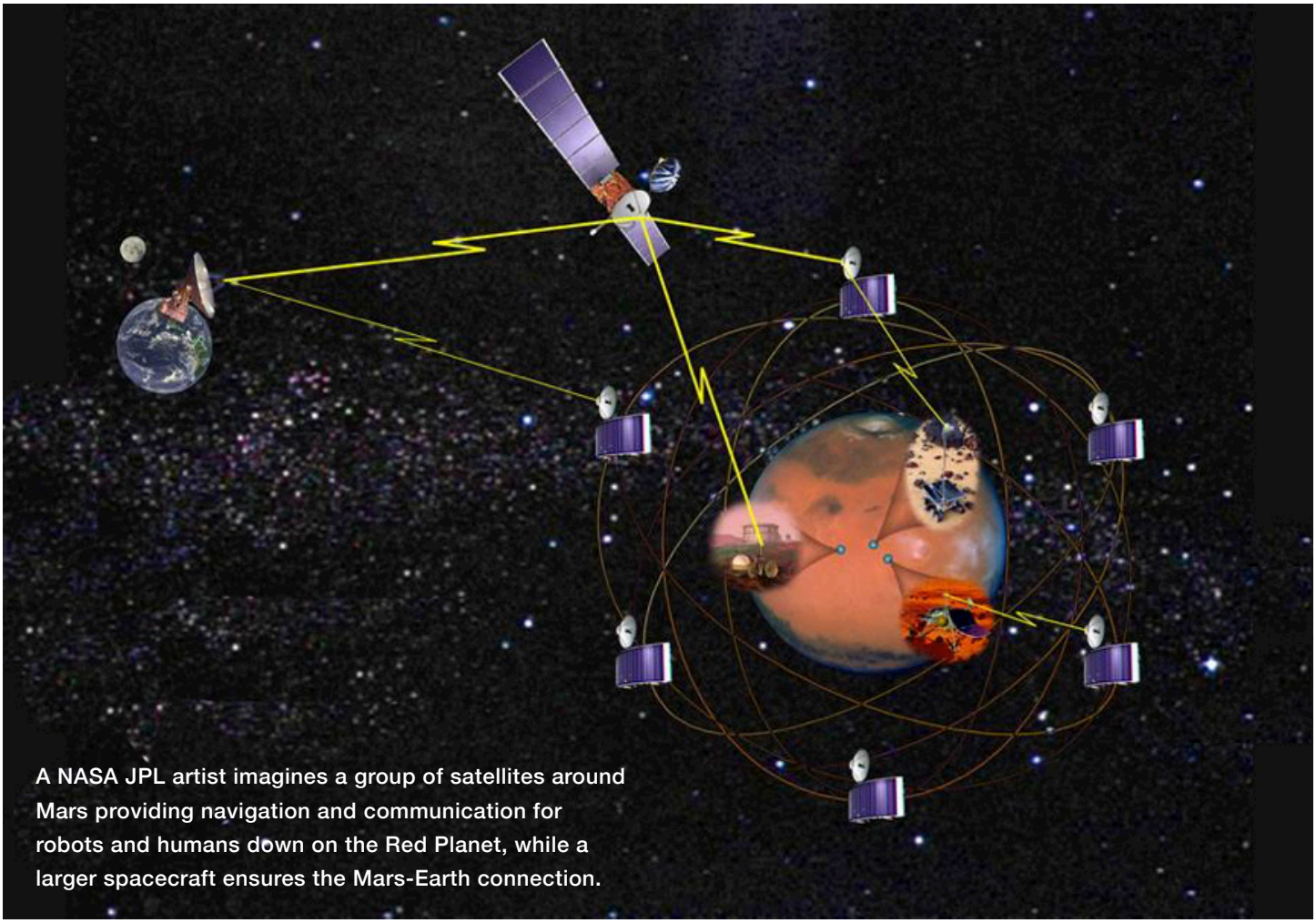
Testing dock showing free flyer interface.

Once the hardware testing was complete, the team began testing software and control of the free flyer. All of the simulator work paid off, and the software testing looks promising so far.

"We are now able to 'fly' the robot in our lab on a testing table that is similar to a giant air-hockey table. This table allows the robot to translate in two axes and rotate about one axis. So far we've successfully commanded the robot to move about the table in a very controlled manner. Next we will test the accuracy of our navigation by having the robot perform an automated docking," Provencher recounts.

Completing this testing milestone was a tremendous accomplishment for the team. Earlier prototypes were impressive, but they only tested subsets of the system, and they looked nothing like the final robot will.

"This prototype is a great technical achievement because it shows that the hardware design works, and that brings a huge sense of relief to the team. I'm really impressed with our project team. They've accomplished so much in the past year and a half," says Provencher. "And now we have something that we can point to and say, that's it…that's what Astrobee looks like."



A NASA JPL artist imagines a group of satellites around Mars providing navigation and communication for robots and humans down on the Red Planet, while a larger spacecraft ensures the Mars-Earth connection.

DSOC Delivers Key Project Milestone

—Denise M. Stefula

In May 2016, the Game Changing Development Program's Deep Space Optical Communications (DSOC) project completed TRL 6 milestone testing on its key deliverable, an integrated deep-space flight laser transmitter assembly. Proposed on several Discovery missions, the technology undergoes a transition review in June and is expected to advance to NASA's Technology Demonstration Missions (TDM) program.

"The technical achievement of this team has caught the eye of several Discovery mission proposers and we look forward to a successful transition to the TDM program and ultimately an infusion to a Discovery mission," says Mary Beth Wusk, Game Changing's program manager [acting].

DSOC seeks to increase by at least 10 times data return volumes from deep-space missions to enable larger science returns. Current optical communications for the lunar range will not perform sufficiently to communicate with spacecraft, particularly high resolution science data via downlink.

Completion of this milestone involved performing comprehensive testing at NASA's Jet Propulsion Laboratory after taking delivery of the laser from Fibertek, Inc., last fall. In addition to independent verification of laser characteristics, test patterns delivered over representative flight-like interfaces were successfully demonstrated for a number of operating points.

"Deep space communications requires high efficiency to achieve high data-rate returns from destinations like Mars," explains Abi Biswas, DSOC project manager. "High efficiency communications requires lasers that can transmit narrow pulses with 100's of watts peak power even though they utilize only 10's of watts of electrical power. The Fibertek-developed laser transmitter can transmit peak powers approaching a kilowatt while utilizing approximately 50 W of electrical power."

Testing at JPL revealed that the laser meets all design requirements. These include specifications on power, pulse-width and spectral characteristics, and passing initial environmental requirements such as thermal vacuum, vibration and radiation.

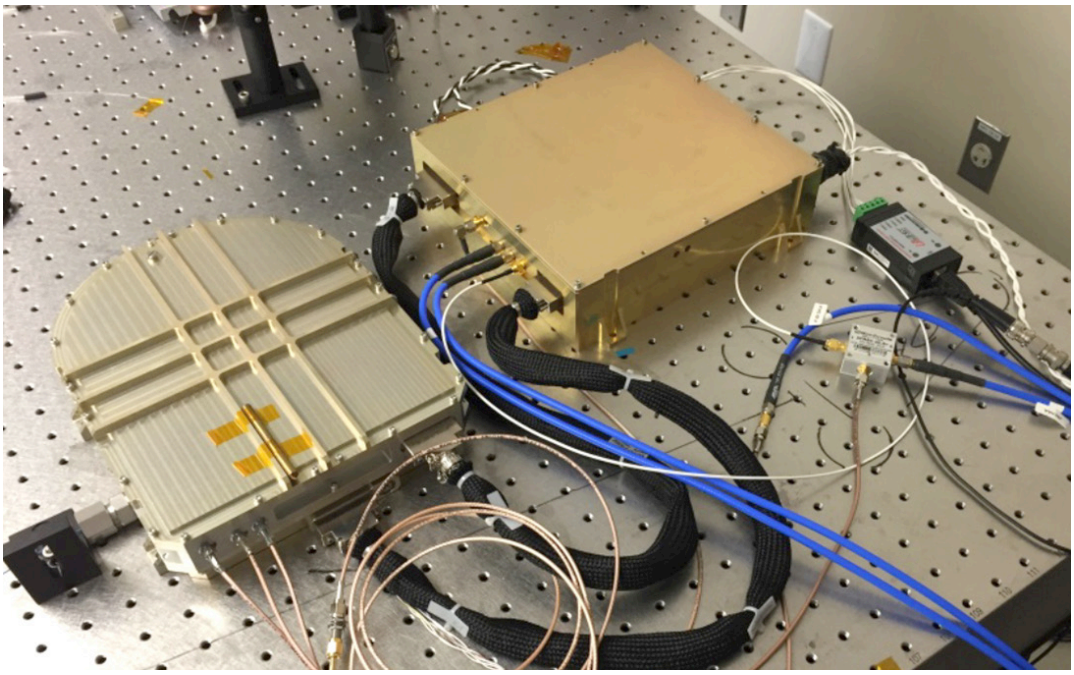
"The success in meeting performance specifications and passing initial environmental tests verifies that the deep-space optical communication signaling architecture can be practically implemented for an initial risk-retiring technology demonstration followed by operational mission implementation," says Biswas. "The development will also spur more detailed reliability and redundancy studies for the proven architecture."

After transitioning to TDM, Biswas says the team will start preparing for a preliminary design review of the DSOC flight lasers that will build on lessons learned, replacing non–flight electronics, and flight packaging of the flight module.

Along with Discovery missions, other potential uses for the technology are an optical communications terminal on a future Mars telecommunication orbiter, with the Asteroid Retrieval Mission, and maintaining communications with the Europa Clipper during cruise prior to arriving at Jupiter.

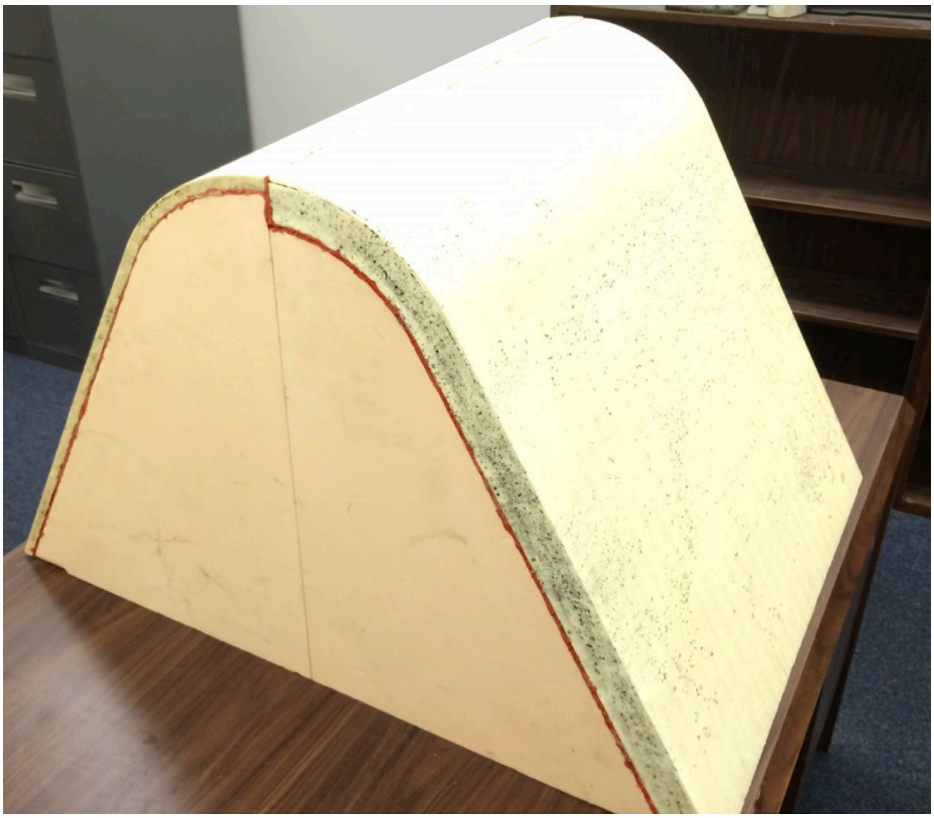
"GCD's goal is to develop disruptive technology through a technology readiness level (TRL) of 6 and then transition the technology to a flight demonstration mission to achieve the final advancements needed prior to mission infusion. DSOC is a poster child for how the technology pipeline is supposed to work. DSOC joined the GCD portfolio late in 2012 with a TRL of 2. The project has done an excellent job developing the subsystems to a TRL of 6 over the past few years and has now demonstrated the integration of a flight laser transmitter assembly with the completion of this milestone. The complete integrated system is on schedule to complete in October as it transitions to its new home in the Technology Demonstration Missions program."

—Mary Beth Wusk, GCD program manager



Laser transmitter assembly with module on the left in the laser optical module; the laser electrical module is shown on the right.

Missions such as Venus probes and landers, Saturn and Uranus probes, or any high-speed sample return mission, due to their extreme entry environments, require TPS solutions offering increased protection against the damages incurred from increased velocities. The goal of Advanced Entry, Descent and Landing thematic projects is to provide alternate TPS solutions for these missions.



TPS-M Molded Panels Bonded to PDU

—Denise M. Stefula

The Pathfinder Development Unit (PDU) was completed on May 13, 2016, a controlled milestone for the Conformal Ablative Thermal Protection Systems project element, a technology being advanced under the Thermal Protection Systems – Materials (TPS-M) project in Space Technology's Game Changing Development Program. Hitting this milestone means the project completed the conformal ablative material scale-up activities and successfully demonstrated manufacturing and handling of large scale conformal ablative parts.

Above: Completed PDU with bonded panels.

The demonstration unit allows researchers to walk through the challenges it takes to get from what starts out as a piece of felt and then—after resin infusion, molding and shaping—finishes as a heat shield. During the process, lessons are learned and the team develops solutions along the way.

"Conformal TPS starts with an off-the-shelf carbonized rayon felt," says Project Manager Raj Venkatapathy. "The felt is then resin infused inside a mold and cured. The molded and shaped panels are machined so it can be bonded on to the structure. Developing and demonstrating end-to-end processing at larger than lab scale is the goal of the PDU."

Fit check of curved conformal ablative TPS panels (machined to 0.5” and 1.5” thicknesses) on PDU.

This was a substantial design effort within the project. Given the coupled nature of the TPS with the structure it is attached to, design activities included developing a flight relevent carrier structure, a necessity for demonstrating an integrated heat-shield system can be built that will meet the demanding requirements of atmospheric entry. Results from the design effort provide critical data used to determine stress and strain requirements for the seam, which will be part of structural testing soon to follow.

Part of the molding development work was to identify industry partners to perform the molding operations and get that support in place for fabrication of the demonstration unit. In order to demonstrate scaled up processing, Applied Research Associates, Inc., was selected to implement the resin infusion and machining of the large scale panels (approximately 1 m by 0.5 m) at two different thicknesses.

“ARA was able to demonstrate resin infusion after a number of attempts; but to do so had to modify their equipment with our help. Due to the thickness (0.5 and 1.5 in.), concerns regarding handling during shipping and also bonding operations could only be addressed through a PDU,” Venkatapathy explains. “The molded panels were not as fragile as we thought at the scale we dealt with. In order to avoid damage, larger scale most likely will require additional handling tools.”

Until the PDU, all of the team’s efforts have been focused at lab scale, or less than 10 inches. Having panels at the approximate 1-m scale addresses and demonstrates bonding at a larger scale, one of many steps required for mission infusion.

Bonding of curved panels to PDU substrate.

R5 Deliveries Complete to Robotics Challenge University Awardees

The Space Robotics Challenge (SRC) team, part of the Game Changing Development Program's Human Robotics Systems project, delivered R5 humanoid robots to two selected universities in April. Selections were made through a competitive review based on results of the DARPA Robotics Challenge and a written proposal. The hosted robots will be used to validate SRC tasks, benefitting both the robotics community at large and providing direct access to university students and faculty.

"The robots in university labs will be used for multiple reasons," says Project Manager Bill Bluethmann. "First, they will investigate possible tasks applicable to setting up infrastructure on the Martian surface. Through that, autonomy research from top university laboratories will be folded back into NASA robotics labs. Lastly, these robots in university labs provide great hands-on learning opportunities for graduate students."

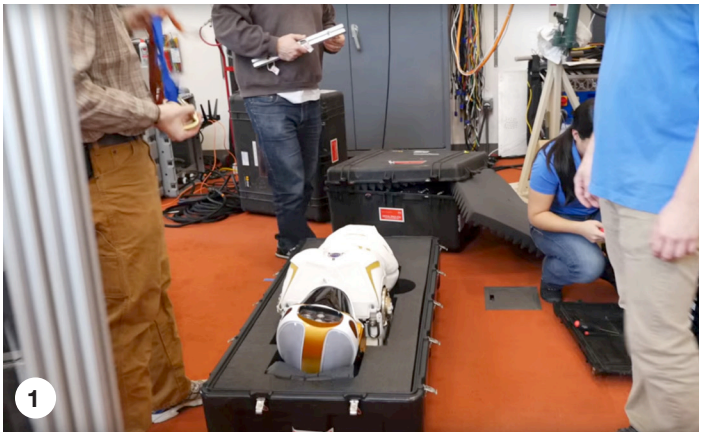
The SRC team delivered the first R5 and set up networking and support equipment at the New England Robotics Validation and Experimentation (NERVE) Center at the University of Massachusetts-Lowell on April 6. The NERVE Center is a dedicated research, testing, and training facility for improving the development of robotic systems by both academic researchers and corporations by facilitating evaluation throughout the design cycle.

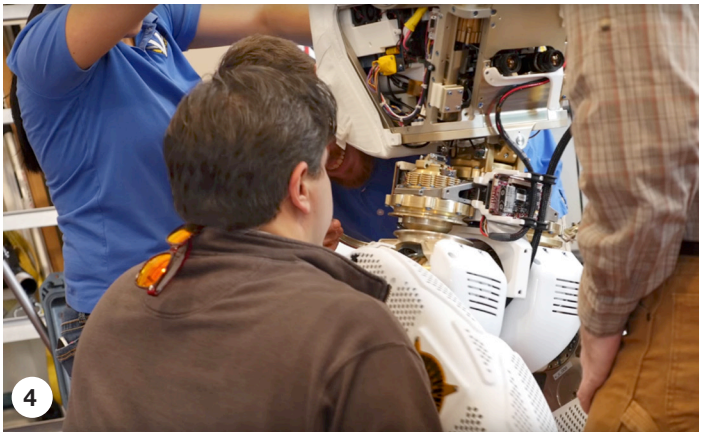
SRC team members were able to get the University of Massachusetts-Lowell and Northeastern University personnel (this awardee is a team from both institutions) up and running quickly. Researchers at the NERVE Center will be developing a set of tasks and test methods, in addition to the extreme environments already created, for R5 to experience in anticipation of the 2017 Space Robotics Challenge.

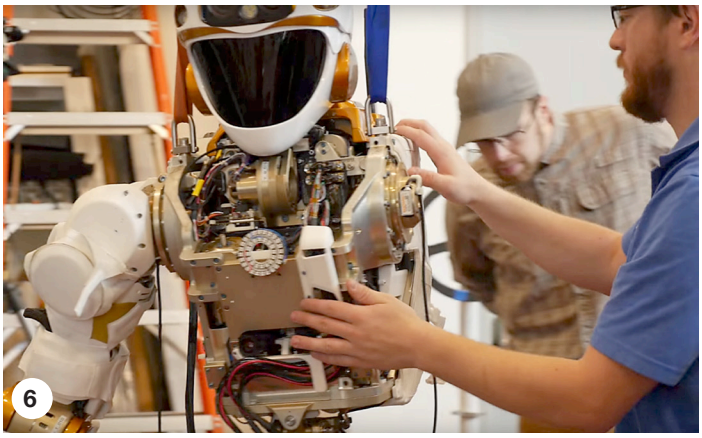
On April 25, the SRC team delivered the second awarded R5 to Massachusetts Institute of Technology's (MIT) Computer Science and Artificial Intelligence Laboratory (CSAIL). CSAIL offers collaborative opportunities for research that pushes the boundaries in MIT's largest lab with expertise across the spectrum of computer science and artificial intelligence.

Researchers at CSAIL will program R5 to autonomously perform tasks to help or even precede astronauts on future space missions. The team's work will focus on developing robust perception, planning and control algorithms.

R5 breaks down into five submodules for shipping; after each delivery it was unpacked, quickly reassembled, put through its paces, and functioned as expected. The image gallery captures that activity.







1. Unpacking the R5 Torso Unit at MIT. The robot comes apart in five subassemblies that pack into three cases.

2. Unpacking the R5 arms.

3. Frank Mathis and Vienny Nguyen attach a leg to the torso.

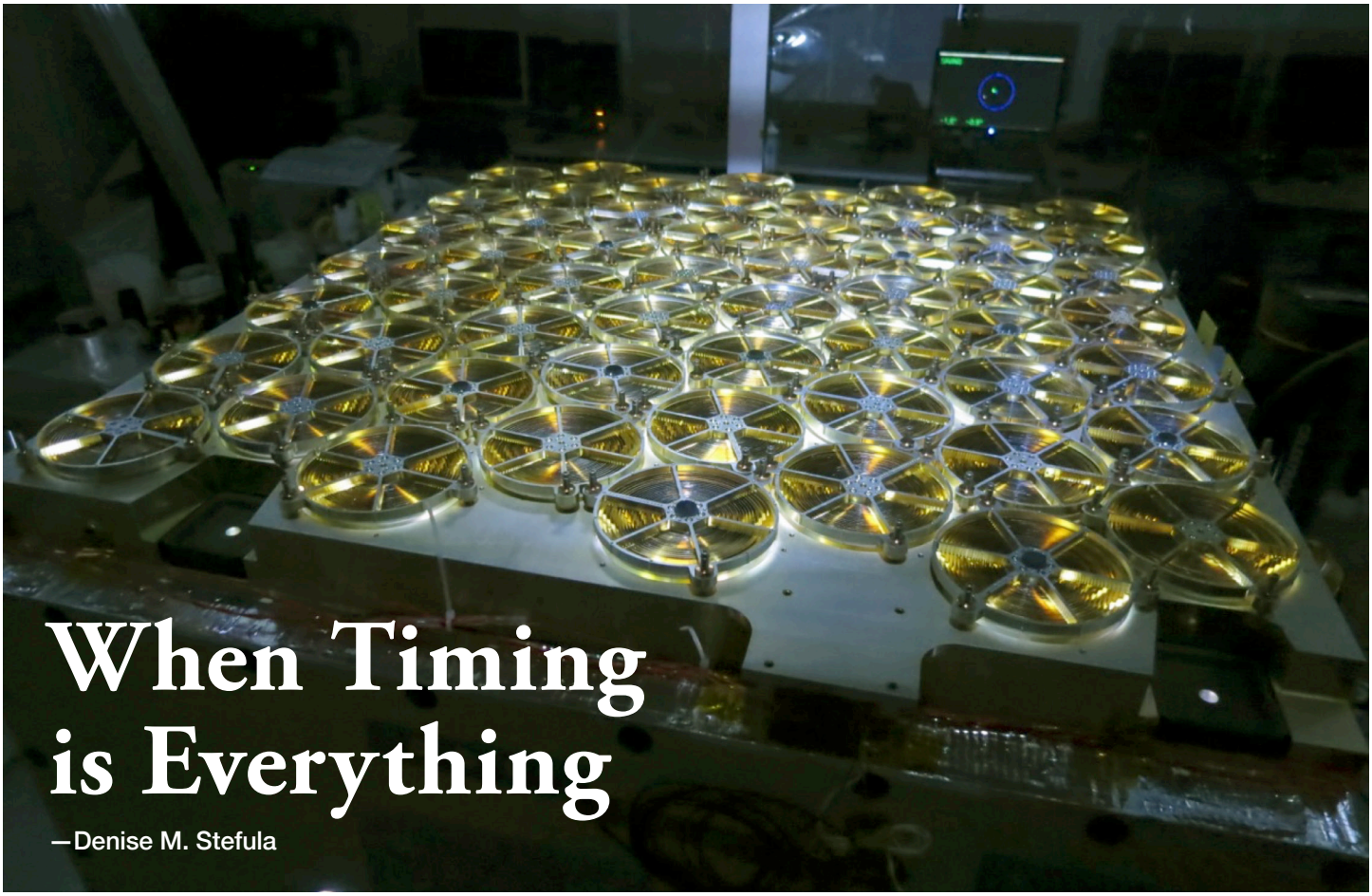
4. After shipping, R5 assembly team members have the robot back together and checked out in approximately two hours.

5. Vienny Nguyen and James Holley of the assembly team apply finishing touches to lower body assembly.

6. The arms and legs use Marman clamps for quick, rigid assembly.

7. The fully assembled R5 robot.

Opposite page: Systems checkout at MIT's CSAIL: all systems go.



When Timing is Everything

—Denise M. Stefula

The Game Changing Development Program's SEXTANT project for the NICER Mission met a key milestone on June 8, 2016. The project delivered its hardware and software package to NASA's Kennedy Space Center to prepare for a 2017 flight to explore timing of pulses from neutron stars.

During the flight, SEXTANT will perform a demonstration to advance a technology using a particular class of neutron stars, called pulsars, to enable autonomous navigation through our solar system and beyond.

"Navigation by the stars—at once inspirational and utilitarian, ancient and futuristic—will once again serve to broaden the horizons of humankind," says SEXTANT Project Manager Jason Mitchell of NASA's Goddard Space Flight Center.

SEXTANT stands for Station Explorer for X-ray Timing and Navigation Technology. The project is providing NICER with an instrument flight software package to enable a real-time, on-orbit demonstration of an autonomous navigation capability using measurements that time powerful beams of pulsated light emitted from neutron stars.

NICER, or the Neutron star Interior Composition ExploreR, seeks to answer questions about compact celestial bodies by investigating the characteristics of neutron stars. With NICER's X-ray timing instrument (XTI) as an attached payload aboard the International Space Station (ISS), SEXTANT plans to demonstrate the use of millisecond X-ray pulsars (MSPs) to provide a GPS-like, autonomous navigation capability in space, which will be a technology first.

"GPS was clearly a revolutionary technology," says Mitchell. "Likewise, SEXTANT will enable GPS-like capability available throughout the solar system, into the Kuiper belt, and even beyond. From a historical perspective, the ability for a spacecraft to autonomously maintain position knowledge may transform space exploration in the same way that John Harrison's H4 marine chronometer transformed exploration by sea from a dangerous and deadly activity to a safer and profitable enterprise."

From the ISS platform, the NICER XTI will be used to detect and very accurately time-tag X-ray photons received from neutron stars, including MSPs. MSP pulses have highly stable timing characteristics that rival atomic clocks in timekeeping accuracy and stability over long periods of time. This stability allows for the development of highly accurate timing models that can be used for referencing location.

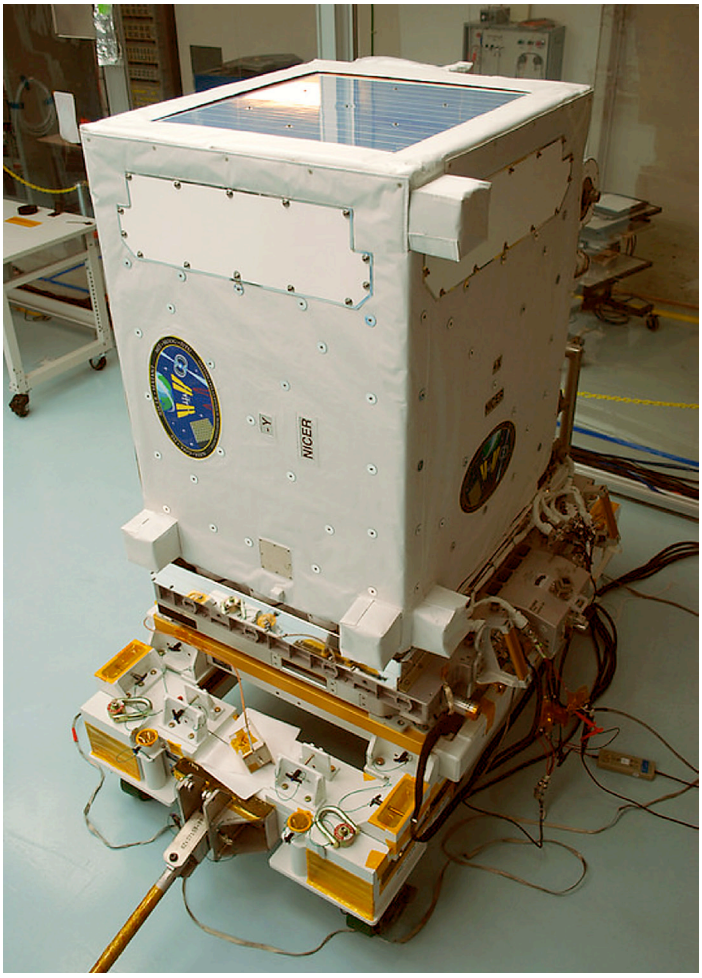
Above: Gold foils of NICER's 56 X-ray concentrators illuminated during alignment testing.

NICER Principal Technologist Keith Gendreau, also with Goddard, brings us up to date: “This calendar year, the NICER payload completed its environmental test campaign and post-environmental comprehensive performance test. Most recently, NICER successfully passed the pre-ship review and was approved for shipment to Kennedy. NICER was delivered to Kennedy in the early morning of June 8. Since arriving at Kennedy, NICER was unboxed, successfully completed its arrival checkout, and has started payload rack checkout unit testing, which verifies the payload interfaces to the ISS.”

Scheduled for flight in February 2017, the SEXTANT technology demonstration will perform two trials: the first using timing models developed from ground-based radio observations, and the second will develop pulsar timing models using only NICER XTI observations.

NICER being removed from truck at Kennedy.

NICER shipping container being removed at Kennedy.



NICER at Kennedy undergoing International Space Station interface testing.

“Initially, as a new observatory, NICER will not have enough historical data to construct the timing models SEXTANT needs to predict the pulsar pulse arrival times,” explains Gendreau. “To address this, SEXTANT will use raw timing data collected from terrestrial radio telescopes to develop these timing models. Combined with data obtained during NICER’s commissioning phase, this bootstrap will permit SEXTANT to function early in the mission. Once NICER reaches several hundred kiloseconds of observation time on the desired targets, SEXTANT timing models can be constructed directly from NICER data. Hence, two separate tests.”

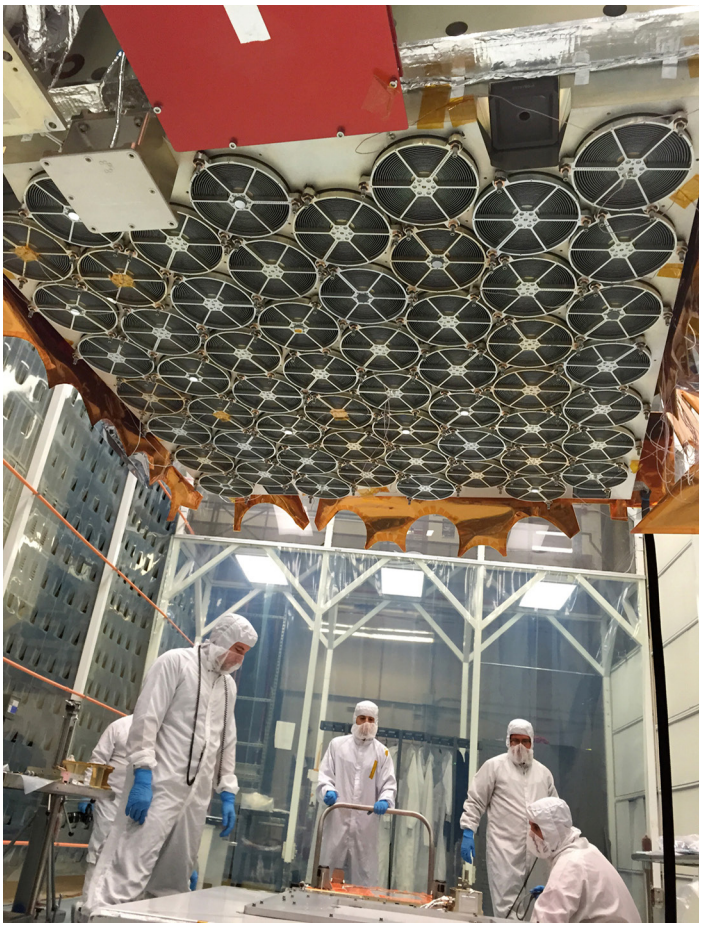
The NICER XTI data collection gathers the arrival times of individual X-ray photons emitted by observed pulsars.

“The absolute time of arrival is accurate to better than 100 nanoseconds (one standard deviation) with respect to Coordinated Universal Time, or UTC. Most of the millisecond pulsars have very low count rates, meaning that a single X-ray photon arrives every few seconds, but with very precise regularity,” says Gendreau. “While NICER telemeters this data to the ground for additional processing, SEXTANT uses this data onboard and in real-time to maintain the position knowledge of the payload on ISS.”

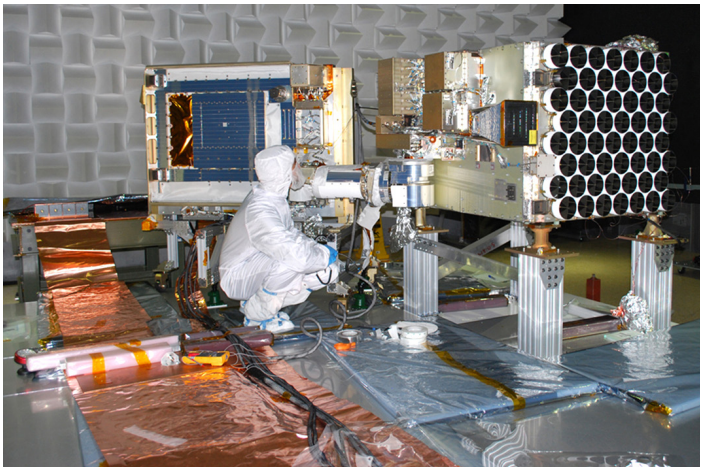
Having GPS available with NICER, Mitchell and Gendreau will be able to assess performance real-time in the NICER telemetry stream. Mitchell says that because all of the raw photon events will be telemetered to the ground, that data also will be used to 1) tune the ground test bed to match on-orbit performance; 2) evaluate navigation performance with realistic spacecraft local oscillator models; and 3) evaluate the performance of modified or new photon processing algorithms.

The complete technology demonstration will move the X-ray navigation, or XNAV, concept and algorithms to TRL 7, meaning it comes up a step from being a representation model to the system prototype being demonstrated in a space environment, and thus one step closer to being the highest TRL of 9, or flight proven.

"There are a number of obvious infusion paths for XNAV technology," says Mitchell. "First, as called out in the U.S. Space Policy, is in support of human exploration. Initially, XNAV could be used as a navigation 'hot backup' to support cislunar [the space between Earth and the moon] navigation during both planned and unplanned communication outages as we practice for crewed deep space missions. In the future, as we continue to improve the detector technology and processing algorithms, characterize the effects of the space environment, and learn more about the operational aspects of a complete system, XNAV will enable human missions to near-Earth objects, Mars, and beyond. Second is the infusion to science missions. This will enable established science in new and deeper places in the solar system, or allow for new measurements to be made."



NICER being lifted during integration.



NICER in electromagnetic interference/compatibility testing.

NICER undergoing a stowing test at Goddard.

With the rapid development of new launch vehicles and plans to colonize Mars and explore farther into the solar system and beyond, now is the time to demonstrate the methods that will lead humankind into deep space. The ISS is ready to support demonstrations of the required game changing technologies needed for this next big step. The SEXTANT team has developed the technologies and tested them on the ground—now is the time to test them in space.

Education & Public Outreach

Technology Day on the Hill

A number of Game Changing projects supported the 2016 Technology Day on the Hill, an annual event organized by STMD and OLIA that offers congressmen and staffers the opportunity to get an up-close look at real NASA technology projects. In addition to GCD industry partner Busek, the following projects showcased hardware at the event: Next Generation Life Support, Advanced Manufacturing Technologies, PUFFER, HIAD2, Nuclear Thermal Propulsion and CHIEFS.

Members of the PUFFER team pose with NASA Administrator Charles Bolden.

Nuclear Thermal Propulsion Project Manager Mike Houts discusses his project with Bolden.

CHIEFS Project Manager Josh Fody shakes hands with Congresswoman Barbara Comstock.

GCD Holds Its First Industry Day

More than 100 people attended the first Game Changing Development Industry Day held June 29-30 at the Lockheed Martin Global Vision Center in Arlington, Va. The event was available through Livestream and garnered 4,500 views online.

"Our goals were to let industry know what GCD is about and to give them insight into certain technologies to see if there is the potential for infusion paths or partnerships," said Mary Beth Wusk, GCD acting program manager.

Attendees ran the gamut, ranging from Lockheed Martin and Boeing representatives to smaller businesses, such as Mindseeker, an IT consulting firm.

On the first day, project managers from the following areas gave 15-minute presentations on their specific technologies: Dan Barta, Next Generation Life Support; Bill Bluethmann, Human Robotic Systems; Azlin Biaggi, Nanotechnology; Josh Fody, CHIEFS; Neil Cheatwood, HIAD2; Scott Roberts, Bulk Metallic Glass; Charles Bacon, Satellite Servicing; Jim Cockrell, Affordable Vehicle Avionics; Allan Villorin, IDEAS; John Fikes, Advanced Manufacturing Technologies; and Wes Tayon with Near Net Shape.

In addition to the presentations, there was an exhibit area with hardware from each presenter, and generous breaks throughout the day allowed for ample networking time.

Industry representatives could sign up for one-on-one meetings with program management on the second day. All 12 slots were filled by midday.

"The event was a success," said Wusk. "I believe we met our goal, hands down. Industry has a much better understanding of what we are all about, and it's about making the connections."

The presentations are posted here:
http://www.nasa.gov/directorates/spacetech/home/game-changing-development-industry-day.html
The recorded presentations can be viewed here:
http://livestream.com/viewnow/GameChanging

Ladies in the Lab

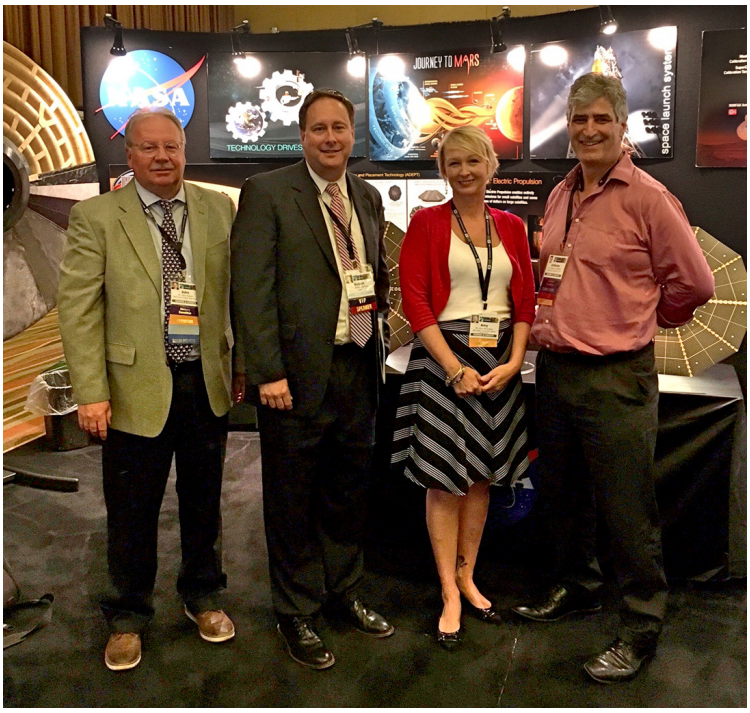
For the second year, Acting GCD Program Manager Mary Beth Wusk supported the Ladies in the Lab event at the University of Virginia. Wusk's daughter Grace is a co-lead of the event, which aims to combine girl power and STEM education. Wusk, along with the help of UVA student and current GCD intern Maggie Story, led the girls in a series of group hands-on activities related to aerospace work.

UVA student and GCD intern Maggie Story (foreground) and Mary Beth Wusk (background) work with middle-school-age girls on STEM activities related to NASA and aerospace.

NASA Langley's Carrie Rhoades also assists at the Ladies in the Lab event.

National Space and Missile Materials Symposium

GCD projects were also on display at the 2016 National Space and Missile Materials Symposium in Colorado. NASA Associate Administrator Robert Lightfoot gave a plenary discussion at the conference and then visited the booth, which highlighted HIAD2, Affordable Vehicle Avionics, MEDLI2, ADEPT and CHIEFS. NASA's Space Launch System, Orion, Curiosity and the Asteroid Redirect Mission were also highlighted.



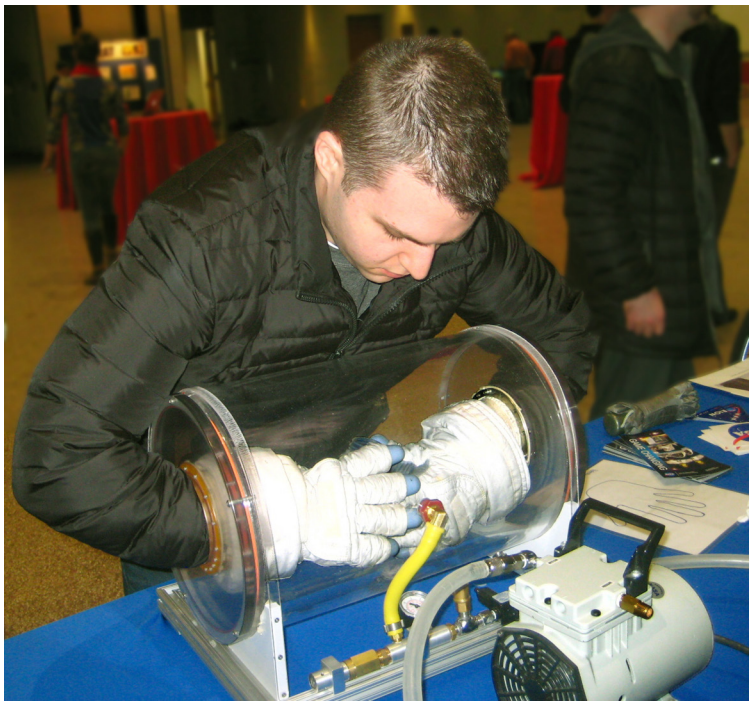
Principal Technologist John Vickers, NASA Associate Administrator Robert Lightfoot, GCD Communications Manager Amy McCluskey and GCD Chief Engineer Anthony Calomino at NSMMS.

U.S. Science and Engineering Festival

During the U.S. Science and Engineering Festival in Washington, D.C., GCD staffers Brandon Guethe (pictured) and Joey Patterson educated thousands of students and families about NASA's plans for rovers on Mars and about how NASA is improving glove designs for astronauts.

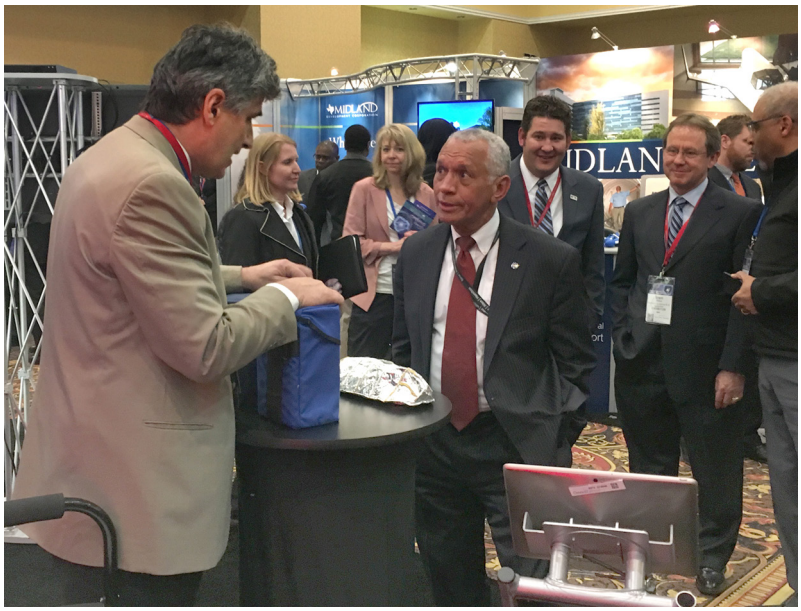
TEDxNavesink

GCD Exhibit Tech Brandon Guethe also supported the TEDxNavesink event in New Jersey earlier this year. In this image, a Maker Gallery participant interacts with the EVA Glovebox exhibit. The Glovebox offers users the simulated experience of working in space.

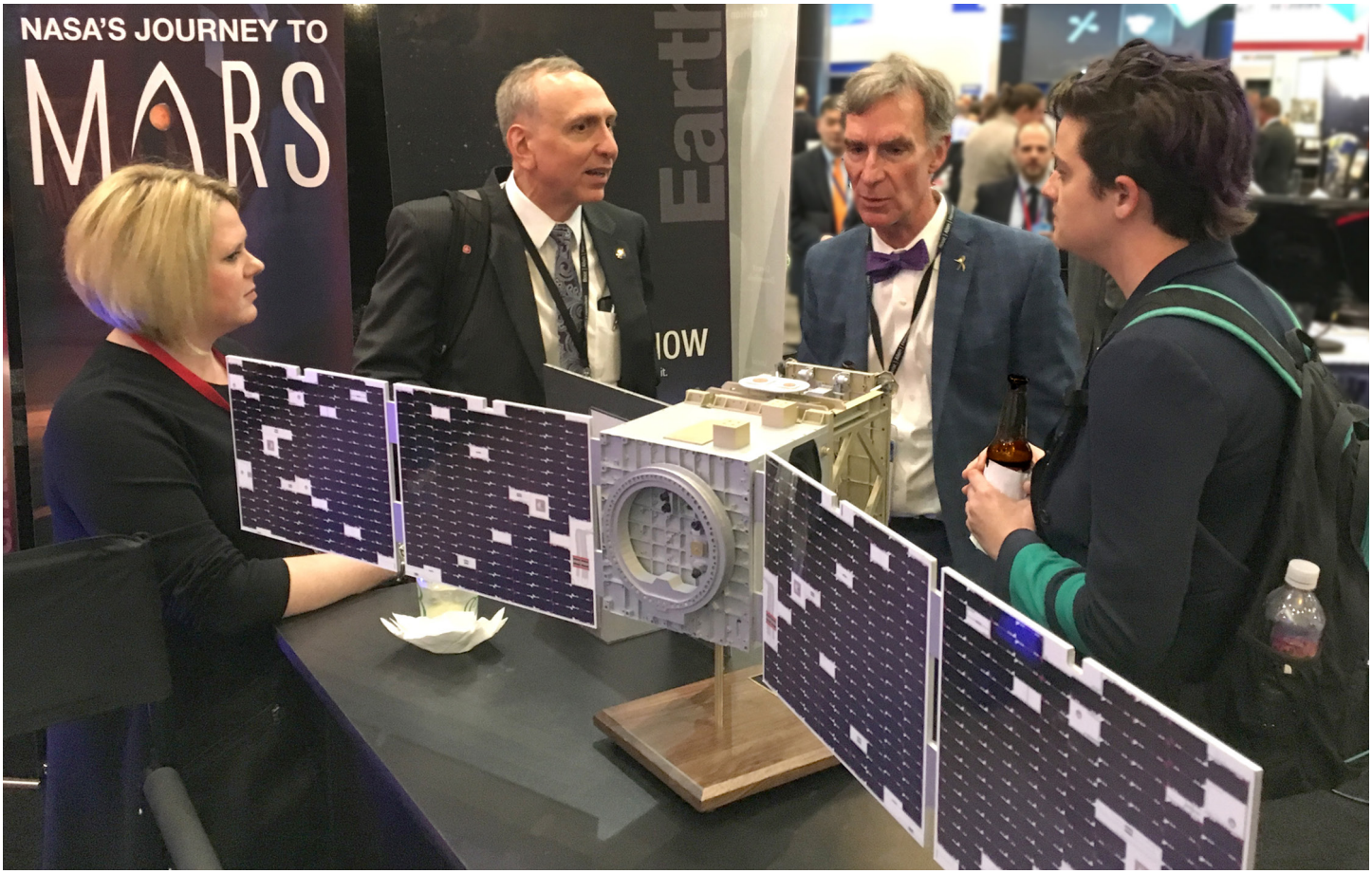


32nd Space Symposium

NASA Administrator Charles Bolden, STMD Associate Administrator Steve Jurzyck, and Bill Nye the Science Guy were just a few of the people who stopped by the NASA booth at the 32nd Space Symposium in Colorado. GCD Chief Engineer Anthony Calomino and GCD Communications Manager Amy McCluskey staffed the GCD exhibit which featured HIAD2 and CHIEFS. Staffers from MSFC talked about America's next new rocket system, SLS, and technology projects Green Propellant Infusion Mission and Deep Space Atomic Clock were also featured.



Chief Engineer Anthony Calomino discusses the CHIEFS project with NASA Administrator Charles Bolden.



Bill Nye the Science Guy (second from right) talks with STMD Associate Administrator Steve Jurzyck.

Game On!

http://gameon.nasa.gov

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