National Aeronautics and Space Administration

Space Technology

Game Changing Development Highlights

March-April 2015

Nanotechnology Process Goes Big
Advancements in Thermal Protection Materials Change the Game for Orion
NASA 3D Prints First Full-Scale Copper Rocket Engine Part
Flight Laser Transceiver Climbs Ladder to TRL Goal

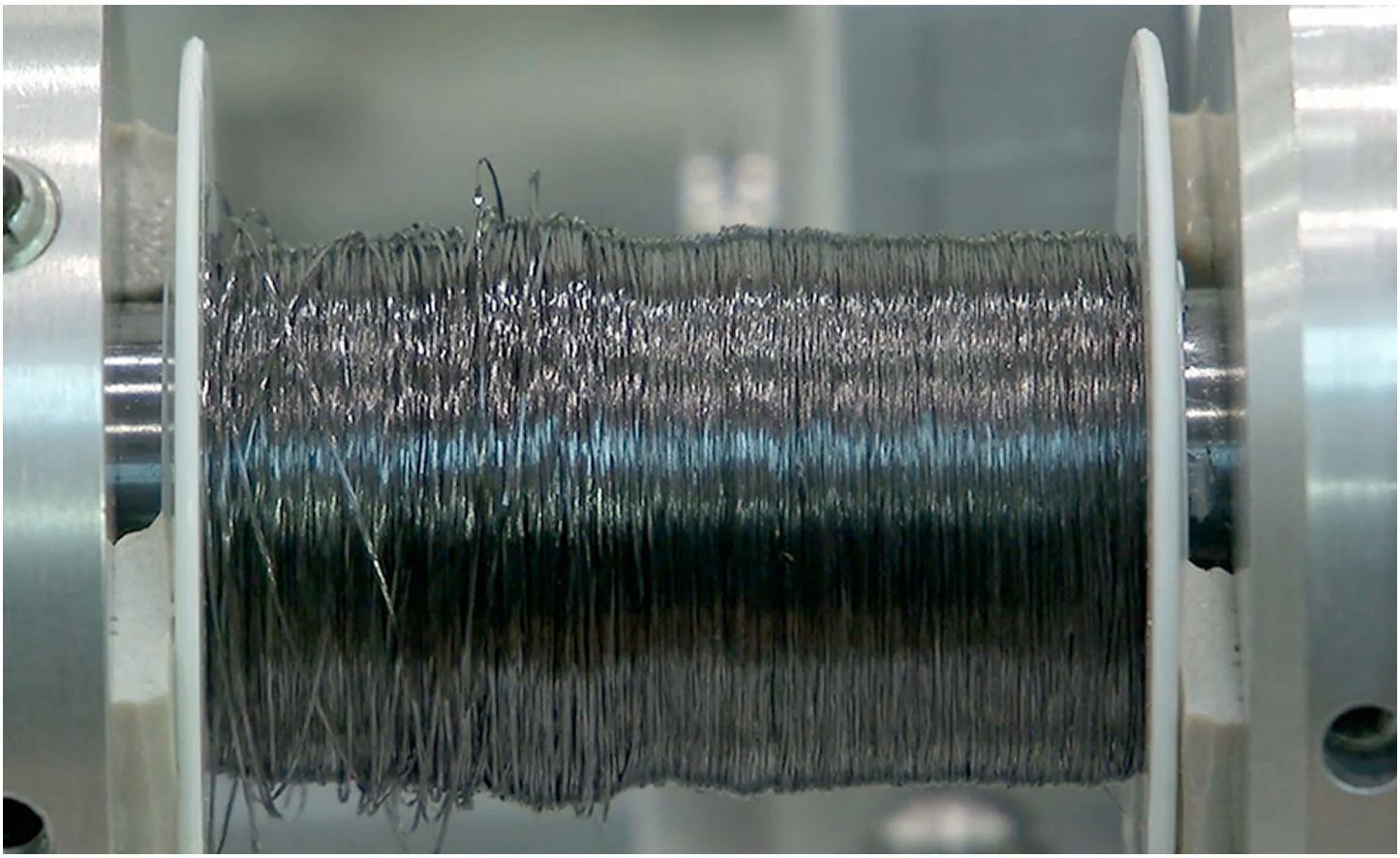


Image credit: NASA

Nanotechnology Process Goes Big

—Denise M. Stefula

Game Changing Development's Nanotechnology project is preparing to push the carbon nanotube (CNT) composite winding process to the next level by transitioning to larger scale testing. Nanoscale technologies deal with dimensions and tolerances of less than 100 nanometers—a nanometer is a billionth of a meter—and the project seeks to demonstrate scaling up the use of high-tensile strength CNT composites.

In the lab at NASA's Langley Research Center, Mia Siochi and a team of researchers from Langley and other Centers, industry, and academia have been performing CNT solution infiltration, and winding and variable temperature mechanical testing of CNT composite wound cylinders.

"This is a multidisciplinary effort across branches to engage skills in materials synthesis, characterization, processing, test method development, testing, structural design, and systems analysis," says Siochi. "We've received tremendous support from the Program Office for guiding programmatics and from the Procurement Office for Small Business Innovation Research support to obtain materials."

Siochi reports Langley testing has yielded consistent results and a streamlined, simple processing method, and in realizing those achievements, now is the time to move toward larger scale manufacturing of CNT composite wound pressure vessels. NASA's flight article manufacturing is performed at Marshall Space Flight Center and this emerging

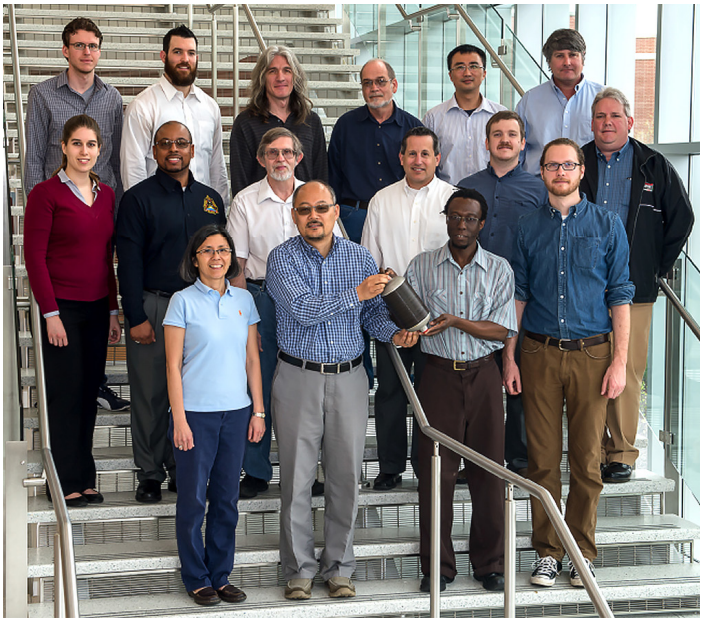


Image credit: NASA

Mia Siochi (first row, left) and a team of researchers from Langley and other Centers are looking beyond the current state-of-the-art lightweight material—carbon-fiber composites—to promising nanostructured materials, namely carbon nanotube composites.

high-strength material technology will be flight tested on a CNT composite overwrapped pressure vessel, so the team is challenged with carrying the process from a research scale to the next level: operating on a commercial scale.

The Nanotechnology team completed the wet winding process development and has transferred the process to Marshall Space Flight Center for adoption to a commercial winder, taking the project's technology readiness level from 3 to 4.

"Process transfer is the logical next step to also push the CNT manufacturing maturation level because it moves the technology development from the laboratory to infrastructure used to manufacture larger articles that are integrated into aerospace applications," says Siochi. "In the process, steps have been taken to work with the CNT manufacturer in order to supply the material in the format required for larger commercial winders and to meet the rigorous standards needed for flight testing a CNT composite wound pressure vessel."

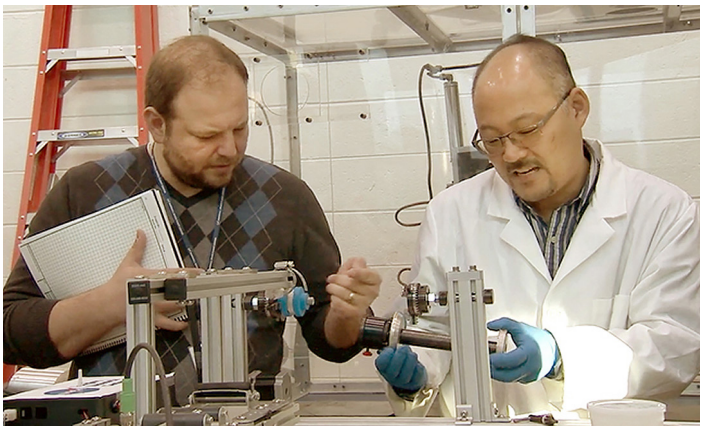


Image credit: NASA

Chad Hastings (left) from MSFC works with Jae-Woo Kim of the National Institute of Aerospace; Kim is part of the LaRC team.

Among the challenges in process scale-up is making modifications to existing commercial equipment so that it can handle carbon nanotube yarns. Siochi explains: "Marshall's capability is in the fabrication of carbon fiber composite. CNT yarns do not have the same characteristics as carbon fibers, so some of the components of the commercial machine have to be modified to accommodate the characteristics of CNT yarns."

Siochi says the broad impact for the field of nanotechnology is that this testing constitutes a first step toward demonstrating the attractive mechanical properties of CNTs.

"Despite the fact that CNT composites we are currently making and testing are far from optimum, these composites are displaying tensile properties comparable to conventional carbon fiber composites, suggesting that there's a lot of upside to this technology yet to be exploited. The better we understand how to use this material, the greater the potential for significant improvements in mechanical properties."

Mia Siochi is cotechnical lead and structural CNT task lead for Game Changing's Nanotechnology project, and a senior research materials engineer in the Advanced Materials and Processing Branch of Langley's Research Directorate.

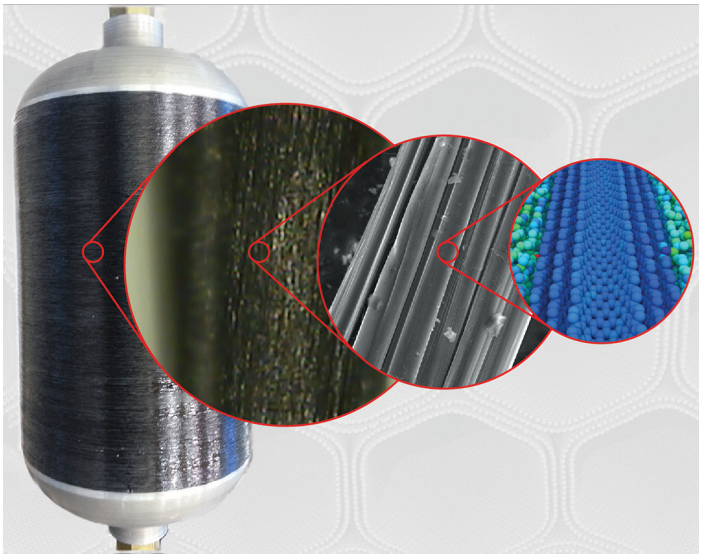


Image credit: NASA

Demonstration flight article wrapped with carbon nanotube composite. Zoom shows carbon nanotubes used and simulation developed to support process development.

Advancements in Thermal Protection Materials Change the Game for Orion

—Maria Alberty, Ames Research Center

Just as old clunky ink jet printers from the 1990s evolved into today's state-of-the-art 3-D printers, thermal protection materials used on NASA spacecraft are getting a facelift—a major three-dimensional one.

Engineers used the original material, called two-dimensional carbon phenolic, in the past on the space shuttle to protect it from the rocket flames during launch, on planetary exploration probes and on the 10-inch disc-shaped compression pads on NASA's Orion spacecraft, which flew in space on its first flight test in December 2014.

Orion (above), NASA's new exploration spacecraft, being prepared for its first flight test. The 10-inch holes on the bottom of the spacecraft designate placement of the compression pads.
Image credit: NASA

But for Orion's next flight and on the journey to Mars, engineers have developed a more efficient material to replace carbon phenolic called Three-Dimensional Multi-Functional Ablative Thermal Protection (3D-MAT). The material was developed by NASA's Ames Research Center in Moffett Field, California, in collaboration with Bally Ribbon Mills in Bally, Pennsylvania, and San Diego Composites in San Diego, California, for NASA's Space Technology Mission Directorate (STMD). STMD funded the incremental maturation of the novel technology from investigation of the basic concept through proof-of-concept performance testing in the severe thermal environment expected for Orion's future missions.

The pads are wedged between the crew module and the service module of Orion to support the extreme forces the

crew module experiences on launch and ascent into space. Each pad supports approximately 55,000 pounds. That's the equivalent of withstanding the force of 16 elephants jumping on Orion at the same time.

"Orion's second flight will have the spacecraft enter Earth's atmosphere at a much higher velocity than during its first flight, which means it will generate a lot more heat than pads made of carbon phenolic could withstand," said Jay Feldman, the technical lead for 3D-MAT, who works for ERC, Inc. at Ames.

Because carbon phenolic wasn't a solution for the second flight, engineers explored numerous other options including single-type or hybrid-type fibers, 2-D or 3-D techniques, weaving or layering and various gooey resins.

"3-D weaves offer superior strength to 2-D weaves," Feldman explained. "The combination of quartz fibers—not carbon—and 3-D weaving gives 3D-MAT the robustness it needs to perform structurally. It is less massive and survives extremely high heating, keeping the structure and contents underneath, like astronauts, cool."

The difference between a 2-D and 3-D object is that a 2-D one only has length and width. 3-D objects have height as well as length and width. Thus, materials are weaved with fibers not only length- and widthwise but also vertically (i.e., height) up and down through the length and width.

To make the material, 5,000 quartz fibers, each individually controlled, are woven together, making a 50-layer chunk

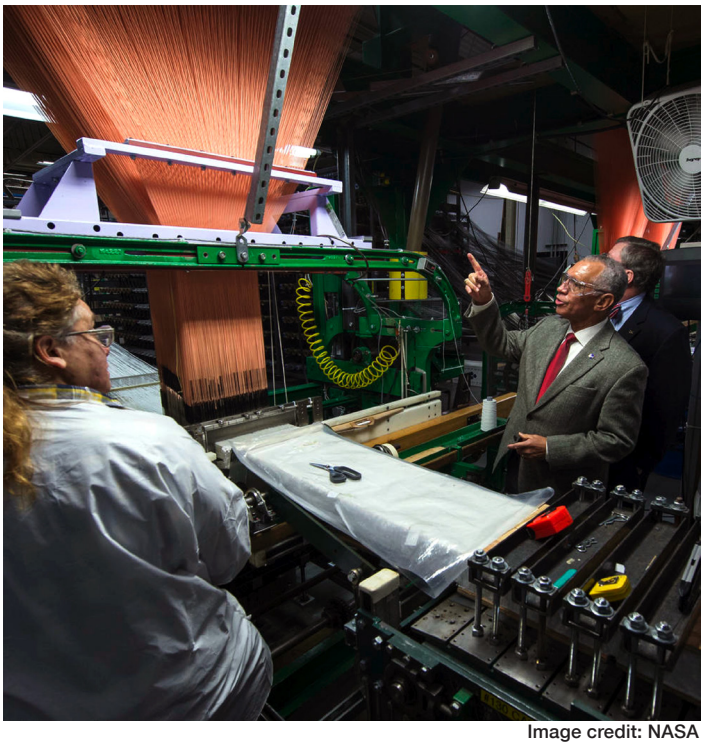


Image credit: NASA

NASA Administrator Charles Bolden inspects a weaving loom at Bally Ribbon Mills facility in Bally, Pennsylvania.

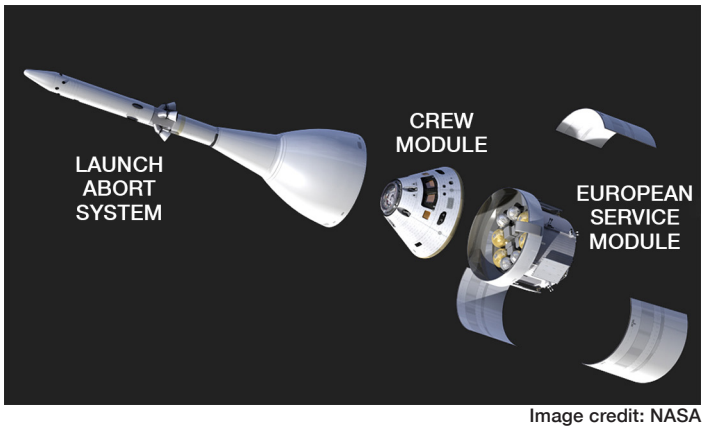


Image credit: NASA

Orion, NASA's new exploration spacecraft, will carry the crew to distant planetary bodies, provide emergency abort capability, sustain the crew during space travel, and provide safe reentry from deep space.

stretching 13 inches long by 12 inches wide by 3 inches thick. The piece is injected with special glue to fill tiny pores between the fibers and layers, curing the material into its final masterpiece.

When the first samples of the material were completed, it was time to turn up the heat, and test them in Ames' Arc Jet Facilities.

Arc jets simulate the extreme heat and pressure spacecraft experience when entering a planet's atmosphere at extreme speeds. The arc jets fire electricity at air particles so fast the particles turn into supersonic plasma. This gives engineers controlled test data on the ground before flight.

In arc jet tests of 3D-MAT, the material withstood impressively high heat fluctuations, temperatures and pressures—consistently better than carbon phenolic, which cracked under the same conditions.

After three years of STMD funding, the team is ready to hand over their research and development efforts to the Orion program for its next mission's development and flight hardware.

"When we first started woven thermal protection systems technology, we felt it had the potential to significantly impact future NASA missions by changing heat shield development from a challenge to overcome into a mission-enabling component," said Ames' Ethiraj Venkatapathy, chief technologist for the Entry Systems and Technologies Division. "In less than 36 months, we are celebrating this technological achievement and delivering a highly developed, multi-functional material with superior performance to meet Orion's needs as well as to address the critical needs of NASA's journey to Mars."

Originally published April 3, 2015.

NASA 3D Prints First Full-Scale Copper Rocket Engine Part

NASA engineers used 3-D printing to make the first full-scale copper engine part, a combustion chamber liner that operates at extreme temperatures and pressures. Structured light scanning, seen on the computer screen, helped verify that the part was built as it was designed.

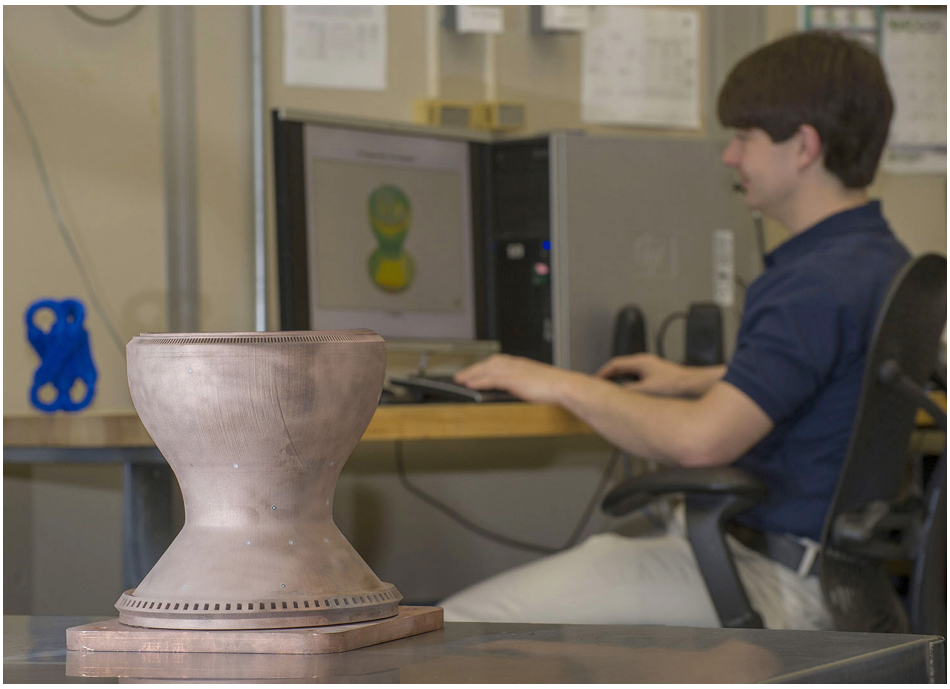


Image credit: NASA/MSFC/Emmett Given

"Building the first full-scale, copper rocket part with additive manufacturing is a milestone for aerospace 3-D printing," said Steve Jurczyk, associate administrator for the Space Technology Mission Directorate at NASA Headquarters in Washington. "Additive manufacturing is one of many technologies we are embracing to help us continue our journey to Mars and even sustain explorers living on the Red Planet."

Numerous complex parts made of many different materials are assembled to make engines that provide the thrust that powers rockets. Additive manufacturing has the potential to reduce the time and cost of making rocket parts like the copper liner found in rocket combustion chambers where super-cold propellants are mixed and heated to the extreme temperatures needed to send rockets to space.

"Copper is extremely good at conducting heat," explained Zach Jones, the materials engineer who led the manufacturing at Marshall Space Flight Center. "That's why copper is an ideal material for lining an engine combustion chamber and for other parts as well, but this property makes the additive manufacturing of copper challenging because the laser has difficulty continuously melting the copper powder."

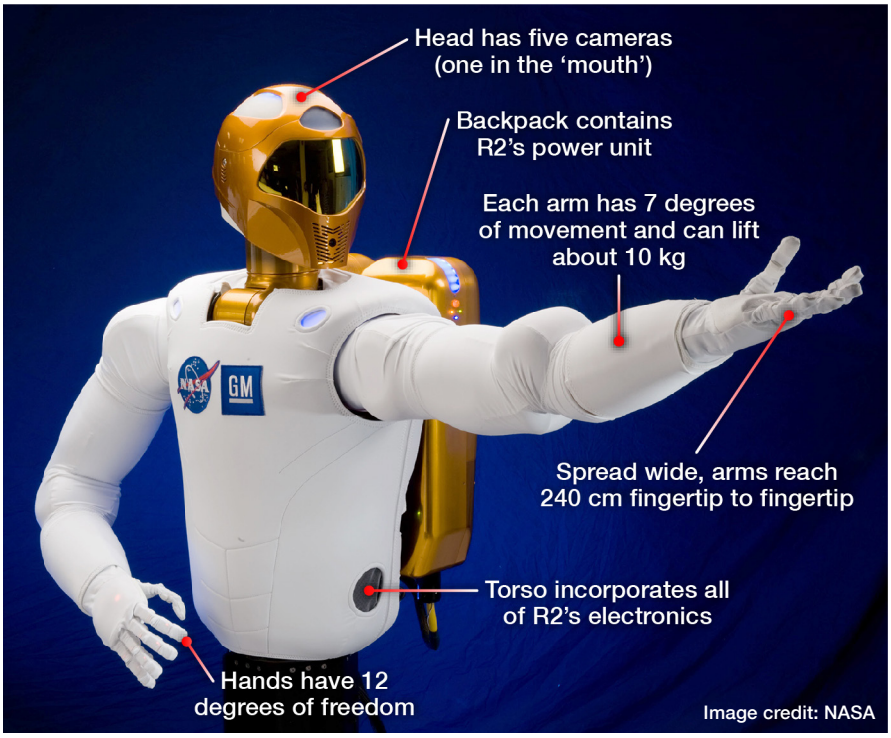
Only a handful of copper rocket parts have been made with additive manufacturing, so NASA is breaking new technological ground by 3-D printing a rocket component that must withstand both extreme hot and cold temperatures and has complex cooling channels built on the outside of an inner wall that is as thin as a pencil mark.

"Our goal is to build rocket engine parts up to 10 times faster and reduce cost by more than 50 percent," said Chris Protz, the Marshall propulsion engineer leading the project. "We are not trying to just make and test one part. We are developing a repeatable process that industry can adopt to manufacture engine parts with advanced designs. The ultimate goal is to make building rocket engines more affordable for everyone."

Manufacturing the copper liner is only the first step of the Low Cost Upper Stage-Class Propulsion Project funded by NASA's Game Changing Development Program in the Space Technology Mission Directorate.

Adapted from an MSFC article by Tracy McMahan, "NASA 3D Prints First Full-Scale Copper Rocket Engine Part." Read the full story here: http://www.nasa.gov/marshall/news/nasa-3-D-prints-first-full-scale-copper-rocket-engine-part.html

R2 Wins NASA Invention of the Year



The Government Invention of the Year (IOY) is "Robonaut 2" (R2), from Johnson Space Center. R2 has established itself as the first of its kind in numerous ways: the first humanoid in space; the first robot inside a manned space vehicle operating without a cage; the first robot to work with human-rated tools in space; the first robot to use American Sign Language in space; and the first robot to use standard ultrasound equipment to scan a medical mannequin. Its development is due to the efforts of many inventors, and several patents have issued that relate to R2.

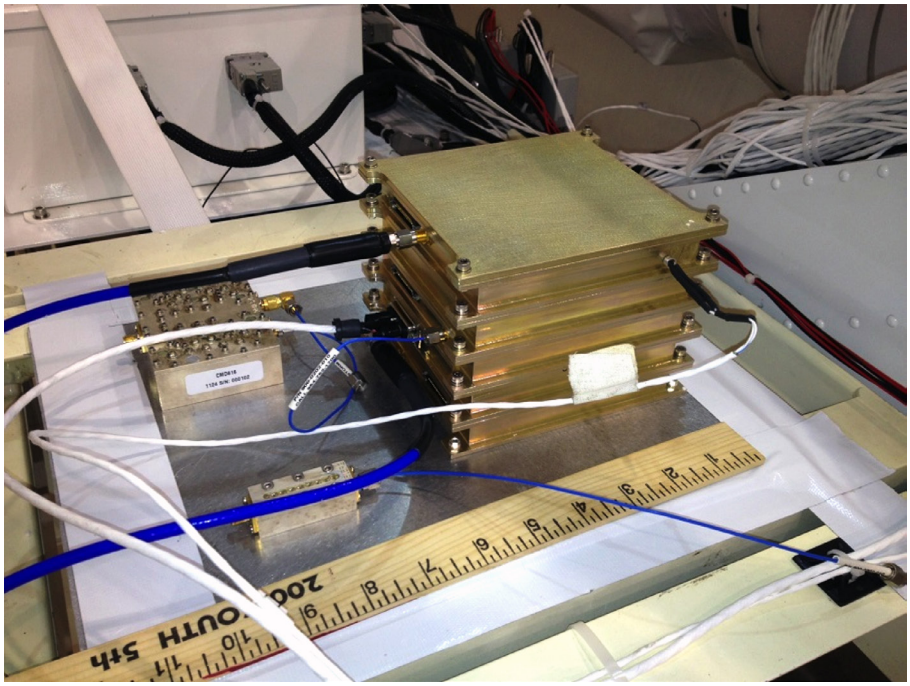
NASA develops and funds the development of many valuable innovations. The annual IOY program recognizes those inventions that have significantly contributed to NASA programs, or that exemplify NASA's mission to transfer cutting edge technology to U.S. industry.

Composites Materials and Manufacturing Technologies Meeting a Success

The Composites Materials and Manufacturing Technologies for Space Applications Technical Interchange Meeting was held in New Orleans, La., on May 6-7. The event drew more than 100 participants, including top experts in the fields of composites and representatives from industry, academia and government. The event included a review of the Game Changing composite tank project (and many other NASA composites efforts) along with activities, lessons learned and future technology discussions with top representatives from the U.S. composites community. The meeting was hosted by the National Center for Advanced Manufacturing and Louisiana State University.

Image credit: Amy McCluskey

PULSAR Recognized as a Top 100 Technology



—Denise M. Stefula

The Programmable Ultra Lightweight System Adaptable Radio (PULSAR), an Autonomous Systems technology under advancement with the Game Changing Development Program, was honored earlier this year by Tech Briefs as a Create the Future Design Contest 2014 Top 100 Entries for electronics submissions.

Nearly 900 entrants participated in the 2014 contest, 71 being in electronics. Submissions to this category are products that improve computing, communications, and other fields that rely on advances in electronic components, boards and systems.

Art Werkheiser, element lead for PULSAR, said, "The Small Satellite and Cube-sat market will benefit tremendously by getting this technology into the X-band downlink frequencies."

The PULSAR team is currently based out of NASA's Marshall Space Flight Center (MSFC) and includes PULSAR cocreators Eric Eberly, Dr. Herb Sims, and Kosta Varnavas, who entered the technology to the Tech Briefs contest with this description:

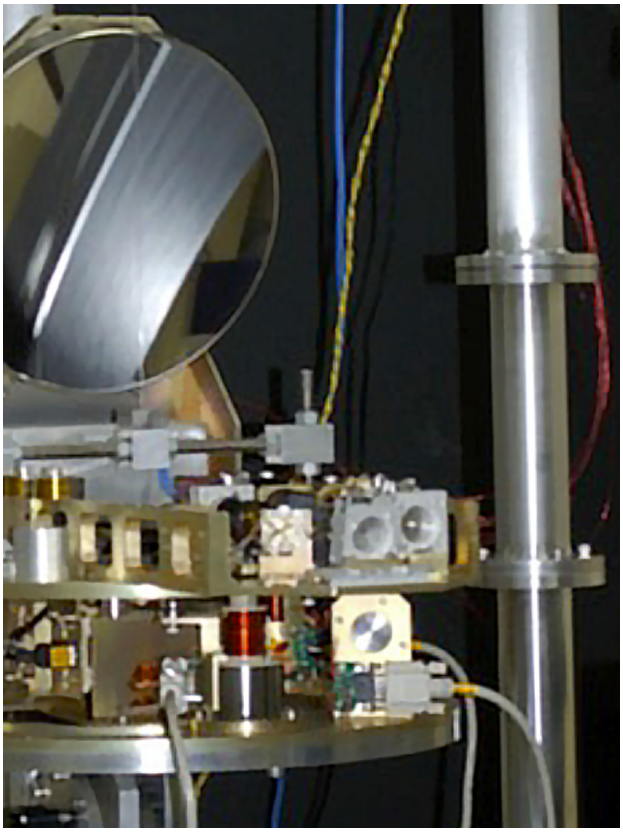
"Software Defined Radio (SDR) technology has been proven in the commercial sector since the early 1990s. Today's rapid advancement in mobile telephone reliability and power management capabilities exemplifies the effectiveness of the SDR technology for the modern communications market.

"PULSAR leverages existing MSFC SDR designs and commercial sector enhanced capabilities to provide a path to a radiation tolerant SDR transponder. These innovations (1) reduce the cost of NASA low-Earth orbit and deep space standard transponders, (2) decrease power requirements, and (3) commensurately reduce volume."

The Create the Future Design Contest was launched in 2002 by the publishers of NASA Tech Briefs magazine to help stimulate and reward engineering innovation. The annual event has attracted more than 10,000 product design ideas from engineers, entrepreneurs, and students worldwide. The submission categories are: aerospace and defense, automotive/transportation, consumer products, electronics, machinery/automation/robotics, medical products, and sustainable technologies.

While popular vote prizes are awarded, contest winners of grand or category prizes are selected based upon scores of an independent industry panel judging entries strictly on contest rules criteria. Winning entries are selected solely on the basis of three criteria: innovation, manufacturability, and marketability.

The PULSAR base design (above) has 5 selectable decks—power deck, processor deck, S-band receiver deck, and S- and X-band telemetry transmitter decks. Mission applications determine the final configuration. PULSAR operates electrically isolated from the satellite bus. Image credit: NASA



Flight Laser Transceiver Climbs Ladder to TRL Goal

—Denise M. Stefula

The Game Changing Development Program's Deep-Space Optical Communications project recently marked a major milestone advancing the technology readiness level (TRL) of its integrated Flight Laser Transceiver (FLT) to TRL 3. This achievement marks the halfway point in advancing to a TRL of 6, a prerequisite for transitioning into a flight Technology Demonstration Opportunity (TDO) with a future NASA Discovery or other mission potentially hosting the TDO.

The recent testing approach was a laboratory demonstration of laser beacon acquisition and tracking in the presence of injected vibrational disturbance. The power spectral density exceeded measured spectra from several representative NASA spacecraft, advancing the integrated FLT to TRL 3.

Project Manager Abi Biswas of Jet Propulsion Laboratory shared the testing details.

"For the TRL-3 demonstration, a 22-cm off-axis telescope with an optical design identical to a future flight implementation was utilized. The telescope was mounted on an active isolation pointing assembly. The integrated telescope and assembly, which comprise the FLT, were mounted on a motorized 2-axis platform. Activating the motors injected disturbance to the base of the FLT.

"With the aid of gravity off-load, the isolation pointing assembly was activated to provide isolation from high frequency disturbance while executing a step-stare scan in order to acquire a laser beacon on the charge coupled device (CCD) focal plane array. Following acquisition, closed loop control was implemented in order to maintain the laser spot on a prescribed location of the CCD camera. A radial 1-sigma, 2.9-μrad residual jitter was targeted and a 1.7-μrad measured.

"The completion of TRL 3 validates the FLT architecture and its ability to isolate and reject disturbances greater than what is expected on spacecraft."

Biswas also described a challenge observed during testing.

"The demonstration was limited by air currents and laboratory environmental noise, which will be addressed more carefully in future advancement to TRL 4 where a photon-counting camera and modulated beacon will replace the CCD and the continuous wave beacon."

Once TRL 6 is achieved, and a flight TDO is planned, successfully demonstrating the FLT from deep space is game changing because it will enhance downlink data rate from deep space by at least an order-of-magnitude while requiring comparable mass and power from the host spacecraft. Future human exploration and use of higher resolution instruments will both be enabled by these augmentations.

FLT integrated to 2-axis disturbance emulator (above).
Image credit: NASA

March and April 2015 GCD Employees of the Month: Kevin Kempton and Wade May

"Within our Game Changing team, members contribute to the STMD mission of 'building, flying, testing' in everything they do. Each month we are recognizing a GCD Employee of the Month, one who embodies the strong STMD 'can do' attitude." I am pleased to recognize Kevin Kempton for March 2015 Employee of the Month and Wade May for April 2015. Please join me in congratulating them; and thanks to you both, Kevin and Wade!

—Steve Gaddis, GCD program manager

Kevin and Wade became Game Changers in 2014 to fill opportunities in the newly defined Program Office structure for Project Element Managers. It was a busy year with many programmatic and portfolio changes, and both hit the ground running. As PEMs, Kevin and Wade act as a primary interface between projects and the Program Office. Having two PEMs allows for increased management responsiveness for project advocacy while also ensuring projects are executing to L1 expectations.

Last fall we had the opportunity to interview Kevin and Wade at length for the 2014 GCD Annual Magazine. Beginning on page 28, that article can be read by accessing the document from our *Game On!* website: https://sites-e.larc.nasa.gov/gcd/files/2015/01/Game_On_2014_AnnMag_141104.pdf

During those interviews, our PEMs shared some poignant information on what they hoped to bring to the team. We've selected two quotes that exemplify their philosophies.

Kevin: Leadership starts with trust. If the project personnel do not have confidence that the PEM is there to help then they will not provide honest assessments and it will be difficult to solve little issues before they become big issues. The best way to earn that trust is to go out of your way to do things that make it easier for people to do their jobs.

Wade: I like to define leadership as the ability to bring out the best in the people you are leading. And I believe we should lead by example. I'm hoping that my leadership philosophy helps facilitate the technology development work that is being accomplished by employees.

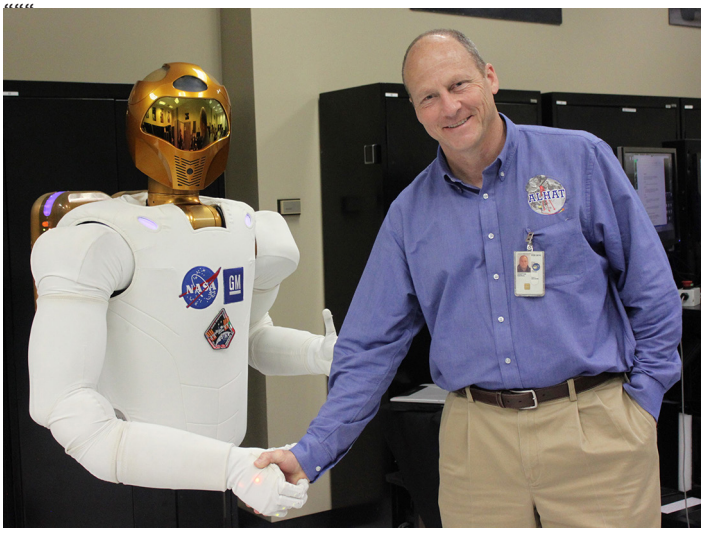


Image credit: Kevin Kempton

"Kevin Kempton is doing a fantastic job and always working long hours to ensure our success. Always a professional and a pleasure to work with, Kevin is a great asset to the team and we are fortunate to have him. We appreciate his commitment to the program and all of his hard work."—Steve Gaddis

Image credit: Wade May

"Wade is doing a wonderful job and always a pleasure to work with. We stole Wade away from SAGE-III here at LaRC. They were not very happy about this, but it has certainly been our gain. He is very committed and always a professional. We appreciate all of his hard work. "—Steve Gaddis

Education & Public Outreach

Congressional Staff Tour

At NASA Langley, The Game Changing Development Program Office supported a tour of around 50 congressional staffers representing congressmen from across the United States. Integration Manager Mary Beth Wusk and Communications Manager Amy McCluskey talked with staffers about the Program's diverse technology portfolio and featured work in Hypersonic Inflatable Aerodynamic Decelerator (HIAD), Human Robotics, Nanotechnology and Advanced Radiation Protection.

Image credits: NASA/George Homich

Prinicipal Investigator Neil Cheatwood gives an overview of the HIAD project to staffers.

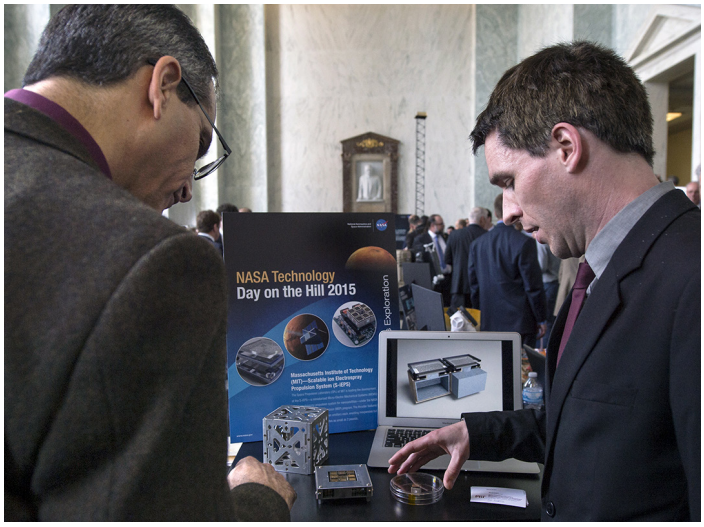
NASA Technology Day on Capitol Hill Showcases Critical Journey to Mars Tech

To demonstrate how technology drives exploration, NASA highlighted key space technologies at its annual Technology Day on the Hill event held April 29 in the Rayburn House Office Building Foyer in Washington.

NASA's Technology Day on the Hill showcased the latest transformational technologies from NASA and the aerospace industry. Many Game Changing technologies were on display including hardware from the Additive Manufacturing, Next Generation Life Support, and Entry Descent and Landing projects. GCD industry partners also exhibited to showcase the work they are doing in conjunction with NASA—those included: Creare, Busek, MIT and Bally Ribbon Mills.

NASA's Chief Technologist David Miller and Associate Administrator for Space Technology Steve Jurczyk provided media with a guided tour of the displays. NASA Administrator Charlie Bolden also toured the displays. NASA experts explained to the more than 300 congres-

NASA Administrator Charlie Bolden (third from left) takes a picture with NASA industry partner representatives from Bally Ribbon Mills and, at Bolden's right, Jay Feldman, of NASA Ames and the Woven TPS project. Bolden visited Bally Ribbon Mills earlier this year to get an up close look at the innovative work being done in support of the 3D MAT technology.

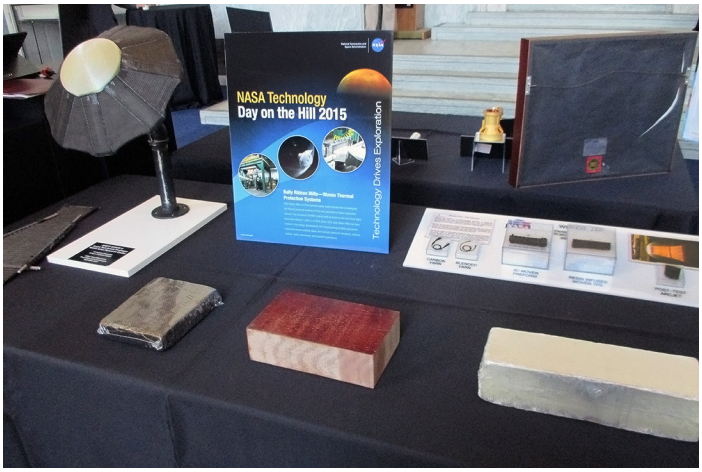


Industry representatives from MIT (left) and Busek (right) displayed the work they are doing for the Micro Electrospray Propulsion project under Game Changing.

sional staffers the various technologies and the roles those technologies play in the Agency's journey to Mars.

Technology is vital to reaching new heights, revealing the unknown and benefitting life on Earth, as well as sending American astronauts to new destinations including an asteroid and Mars. These technologies show how sustained investments made by NASA, industry and academia directly benefit our Nation's innovation economy, help America maintain its global leadership in space and enable NASA's current and future missions of exploration and discovery.

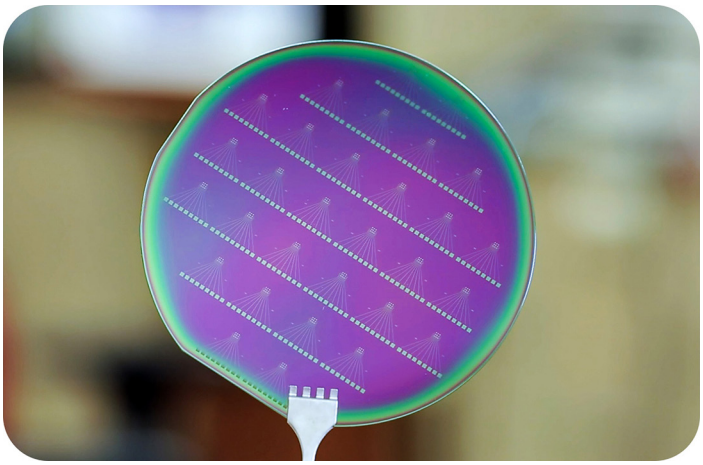
All image credits: Amy McCluskey and Steve Moon



NASA Edge

NASA Edge finished its filming for an upcoming episode on Game Changing's Nanotechnology project. NASA Edge hosts Chris Giersch and Blair Allen interviewed Jessica Koehne and Meyya Meyyapan about their work on nano sensors and how that work could also affect human lives on Earth.

Image credits: NASA Edge



University of Virginia's Ladies in the Lab Workshop: An Interactive Showcase of Women in STEM

Game Changing Development Program Office's Mary Beth Wusk supported the first ever University of Virginia's Ladies in the Lab: An Interactive Showcase of Women in STEM. This workshop was designed for middle and high school girls from the state of Virginia. More than 100 girls attended the event participating in 15 interactive exhibits run by more than 70 volunteers from several female UVA engineering groups. Game Changing Development Program personnel and astronaut/professor Kathy Thornton appeared as the guest speakers. The GCD displays included the EVA glove box and Makerbot 3-D printer.

Name of Challenge:

Flexible Sealing Device: A device to reversibly join and form an airtight seal between the edges of fabric material.

Posted when and where?

April 28, 2015

https://www.innocentive.com/ar/challenge/9933747

The challenge ends June 17, 2015. To compete for the $15,000 award, submit a written solution online.

Challenge details:

Help NASA design a lightweight flexible hatch seal device to use in future inflatable airlocks and surface habitation modules. This hatch could be used in space station airlocks, on the Orion spacecraft, and various exploration spacecraft habitation modules.

NASA is seeking new sealing method or device to reversibly join the edges of flexible fabric-like materials. The seal device will be integrated into an inflatable airlock, and utilized to facilitate extravehicular activity (EVA). This effort is part of a new concept of inflatable membrane-based space modules, which can be deployed when needed to provide expandable working and living space for astronauts.

The device should be easy to use, light and flexible for storage, yet robust and reliable. Astronauts should be able to open and close the seal device with one-gloved hand in a microgravity environment within a minute's time.

How is it game changing?

The development of a new flexible seal device will enhance the capabilities of future space missions by reducing mass and volume parameters.

What are the biggest challenges?

- Maintaining air-tightness while subjected to nominal pressure loads.
- The identification of hardware components, which enable easy open and close operations by an astronaut in a space suit.

Game On!

http://gameon.nasa.gov

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