National Aeronautics and
Space Administration

Space Technology Game On

Game Changing Development Program

2014

Team,

This marks another successful and exciting year. We had many changes including implementing the "light touch" initiative, transitioning to quarterly reviews, streamlining processes, and planning content to a more realistic budget mark.

Focusing on this year brings attention to the successful completion of many of our technologies that have been in development since early 2012, and in some cases longer.

For example, we completed HIAD and had a successful transition to a new Technology Demonstration Mission (TDM) named Terrestrial HIAD Orbital Reentry (THOR).

The Composite Cryotank and Technologies Demonstration (CCTD) project successfully completed testing and will go forward to support NASA's new Space Launch System with a new TDM named Composites for Exploration Upper Stage. Boeing will also take this technology forward to many of its customer applications.

We launched the first 3D printer into space and delivered Robonaut's legs to the International Space Station.

We completed the Advanced Radiation "all clear" space weather forecasting software and model, completed engine testing of the SWORDS engine prototype, and we had many technology firsts and made important deliveries to Agency missions.

Looking ahead, we are kicking off two Mars In-Situ Resource Utilization project activities, a compact fission surface power source called Kilopower, the next round of Mars Entry, Descent and Landing Instrumentation (MEDLI), and a new robotic vehicle. These are just a few of the exciting activities completed and new work that will be starting.

Additionally, we plan to kick off a Space Technology Academy initiative where students will work closely with technologists and principal investigators on exciting projects.

In this magazine, you will read about our technology accomplishments and student work.

We have several goals for the upcoming year. We will focus on working the STMD "pipeline"—both receiving and delivering technologies. We want to see how we can effectively implement more public-private partnerships, Space Act Agreements, and new technology reports for industry spin-offs. Finally, we want to strengthen communications with our projects, Center leads, and key stakeholders.

Again, thank you for all you do. You are the real heroes. Congratulations to you all.

Warmest regards,

Steve Gaddis

GameOn 2014

Space Technology Mission Directorate

Game Changing Development Program Office

gameon.nasa.gov

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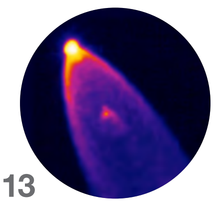
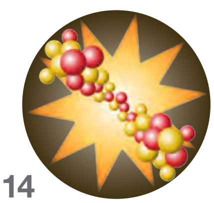




Dr. James R. Gaier and Deborah Waters work with Glenn's Environmental Effects and Coatings Branch.

Nanotechnology Project Reaches World Record in Conductivity

Nearly 300 years ago, Englishman Stephen Gray, whose early life trade was textile and yarn dyeing, introduced to the Royal Society of London for Improving Natural Knowledge the discovery of a new class of nonrigid electrics, including hair, silk, feathers, and even gilded ox guts. Gray was the first to perform systematic experiments in electrical conduction after observing what he called "virtue being communicated" from a statically charged glass tube through various attached materials: from the cork capping the tube through sticks of fir and other materials, including a length of thread.

Fast forward to the 21st century, and Space Technology Mission Directorate's nanotechnology research has realized a world record surpassing current capabilities in conductivity, and it, too, involves "a length of thread."

In this research effort, Game Changing Development Program's Nanotechnology project seeks to improve the electrical properties (conductivity, current capacity) of carbon nanotube yarns to enable their use as replacements for metallic conductors in power cables. Testing with carbon nanotube yarns revealed a significant reduction in the weight of data and power cables could be realized for future mission payload mass when using these much lighter weight materials.

"Replacement of copper wires and aluminum RF cladding with carbon nanotube yarns and sheets led to a 30- to

70-percent reduction in the weight of coaxial data cables," says Project Manager Mike Meador, Glenn Research Center. "If we were to get to the right conductivity level we would expect a similar weight reduction in power cables."

The reduction was realized when testing commercially available and experimental carbon nanotube wires and yarns that were chemically treated with halogens such as bromine or iodine. This creates charges on the carbon nanotube yarns that reduce their electrical resistivity, thereby increasing their ability to transport electrons.

"An increased ability to transport electrons enables the use of carbon nanotube wires in power distribution applications (wires, cables, harnesses) that could enable reductions in mass on the order of 30 percent," Meador specified. "In addition, use of these higher conductivity yarns in data cables could also lead to further reductions in data cable mass over what has previously been achieved with carbon nanotube cables."

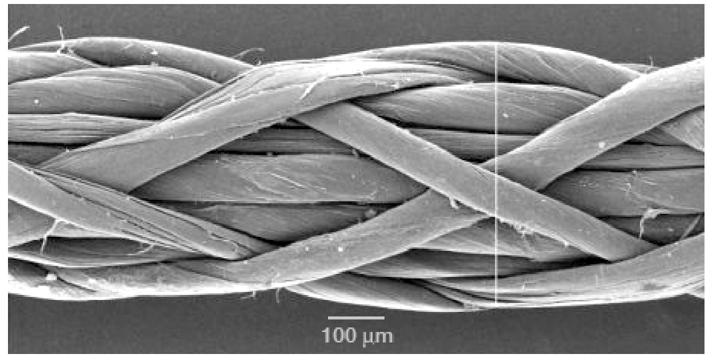
Mass reduction equates to mission cost reductions. According to NASA's Advanced Space Transportation Program fact sheet, *Paving the Highway to Space*, it costs $10,000 to put a pound of payload in Earth orbit.

"The space shuttles each had over 250 miles of data and power cables and a typical Boeing 777 has over 4,000 pounds of wiring," said Meador.

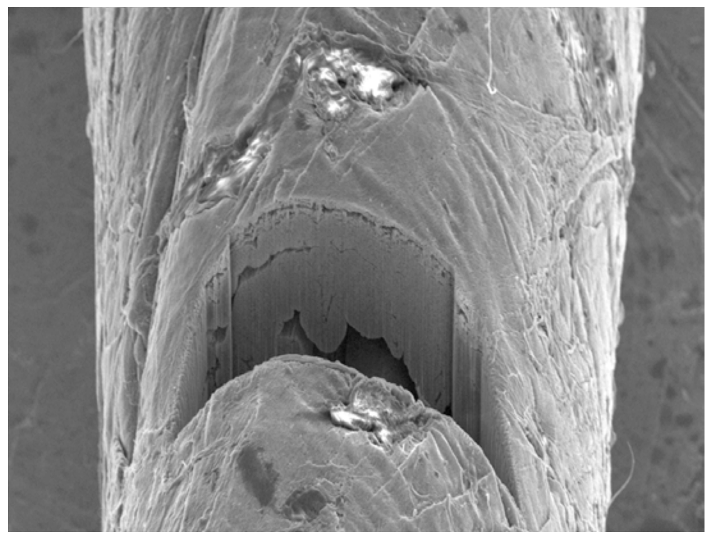
In addition to saving weight, carbon nanotube wires are more durable than copper wires and can be made much thinner. Meador believes the limits of how high we can go with electrical conductivity have not yet been reached, and the research continues under the leadership of Dr. James R. Gaier and support of Deborah Waters, who work with Glenn's Environmental Effects and Coatings Branch.

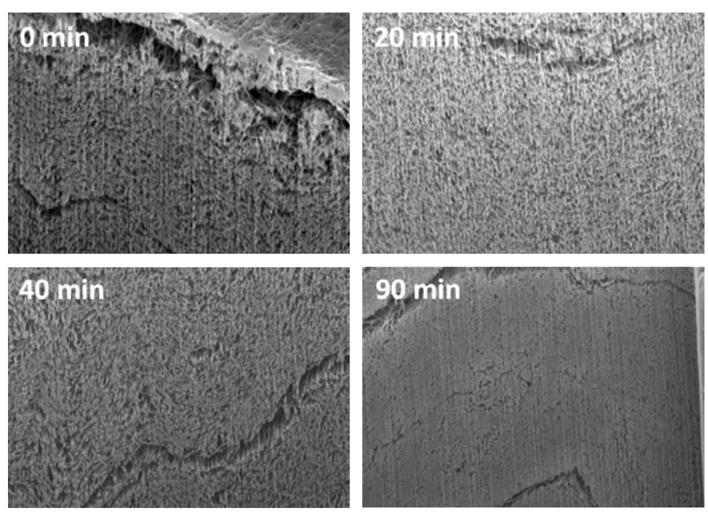
"Our industry/academia partners continue to improve the conductivity of the carbon nanotube fibers they provide to us, and we in turn continue to improve our chemical modification of the fibers. Together we have produced a fiber with conductivity-per-pound equal to that of copper, but with much better strength and fatigue resistance," said Gaier. "This is important as it is the strength and fatigue that limit how much copper you need in an aircraft or spacecraft wire, not the conductivity."

NASA's goal is to reduce the cost of getting to space to hundreds of dollars per pound within 25 years and tens of dollars per pound within 40 years.



Ultra-lightweight materials were identified as one of 16 top technologies by the National Research Council in its reviews of the Space Technology Roadmap.


In the lab, researchers machined a trough into CNT yarns to image cross-sections for observation of test results.



When assessing test results, the scanning electron microscope images showed that voids evident in unirradiated CNT yarns appear to collapse and CNTs coalesce with increasing irradiation time.

Made In Space CEO Aaron Kemmer looks at the Zero Gravity Printer in the Microgravity Science Glovebox. Image courtesy of NASA / Emmett Given.

Off-World Manufacturing is Here

MOUNTAIN VIEW, Calif., September 19, 2014 — On September 20 at 2:14 a.m., the first 3D printer intended for in-space use will depart aboard a rocket from Cape Canaveral, Fla., headed for the International Space Station (ISS).

This "machine shop for space" will mark the first time that a multi-purpose manufacturing device will be utilized off-world to create parts, tools and emergency solutions. Developed by Made In Space, Inc., under a contract with NASA Marshall Space Flight Center (MSFC), the 3D printer is part of a technology demonstration intended to show that on-site, on-demand manufacturing is a viable alternative to launching items from Earth.

"Everything that has ever been built for space has been built on the ground. Tremendous amounts of money and time have been spent to place even the simplest of items in space to aid exploration and development," said Aaron Kemmer, Chief Executive Officer of Made In Space. "This new capability will fundamentally change how the supply and development of space missions is looked at."

Following delivery to ISS, the 3D printer is scheduled to be installed in the Microgravity Science Glovebox (MSG) to conduct its series of prints. The printer will create a series of test coupons, parts, tools, use case examples and even STEM project designs by students as part of the 3D Printing in Zero-G Experiment. This experiment, intended to demonstrate additive manufacturing capabilities in space, was developed through a partnership between Made In Space and NASA MSFC. Made In Space is working with business partners to formulate additional use case examples to demonstrate printer capabilities.

Made In Space's additive manufacturing technology creates 3D objects layer by layer from filament through an extrusion method specifically adapted for the challenges of the space environment. In addition to designing and building the hardware, Made In Space will be operating the printer from a mission control ground station.

"There were dozens of specific problems we had to solve in constructing a 3D printer for the Space Station. From thermal process adjustments to rigorous safety requirements, the challenges our team had to overcome were numerous, and we're deeply proud to see the results of the work done by the Made In Space and NASA MSFC team now head out for a grand field test," said Kemmer.

This first printer will be using ABS plastic while the second generation unit, scheduled for delivery to ISS in 2015, will offer multiple material capacity and an increased build volume. The second Made In Space printer will be available for use by businesses, researchers and anyone who wants to create in-space hardware rapidly, affordably, and safely.

Zero Gravity Printer. Image courtesy of Made In Space, Inc.

"Placing additive manufacturing in space will lead to similar capabilities on every future space station, deep space exploration vehicle, and space colony," said Kemmer. Rapid construction of important materials is a critical need if humans are going to establish a greater footprint in our universe."

Made In Space developed the zero-gravity printer through NASA's Small Business Innovation Research (SBIR) program. The prototype unit was tested on Zero-G Corporation's modified Boeing 727 parabolic airplane, made possible by NASA's Flight Opportunities Program. The flight unit passed NASA's extensive safety and operational standards on the way to being deemed flight ready.

Kemmer said, "This is more than a 3D printer. It's more than a machine shop in space. It's a landmark for humanity. For the first time in the history of our species, we will be manufacturing tools and hardware away from the Earth. Now that we've made this breakthrough, the sky is no longer the limit for additive manufacturing—the era of off-world manufacturing has begun."

Article courtesy of Made In Space, Inc.

About Made In Space

Founded in 2010 with the goal of enabling humanity's future in space, Made In Space, Inc. has developed additive manufacturing technology for use in zero-gravity. By constructing hardware that can build what is needed in space, as opposed to launching it from Earth, the company plans to accelerate and broaden space development while also providing unprecedented access for people on Earth to use in-space manufacturing capabilities.

Made In Space's team consists of successful entrepreneurs, experienced space experts and key 3D printing developers. With over 30,000+ hours of 3D printing technology testing, and 400+ parabolas of microgravity test flights, Made In Space's experience and expertise has led to the first 3D printers designed for use on the International Space Station.

For more information about Made In Space, visit: www.madeinspace.us

Partnerships Bring Life to STMD Mission Successes

During a panel discussion September 18 at Kennedy Space Center, scientists and researchers previewed various technologies flying as payload and being delivered to the International Space Station on the Space-X CRS-4, which launched September 21 from Cape Canaveral Air Force Base. The panelists covered the utilization of ISS for research and development for their technologies and talked about the partnerships that led them to launch.

Among the panelists whose technologies launched in the Dragon capsule was Niki Werkheiser, project manager for 3D Printing in Zero G. Niki brought along and discussed examples of the printer and several of its products. She also talked about the project's partnering successes with Made In Space, Inc., who manufactured the 3D printer.

"We worked very closely, NASA and Made In Space, throughout the design process to ensure that when we went through the flight certification operations and the

Space Technology Mission Directorate's Chief Technologist Jeff Sheehy discusses the Made In Space partnership during a NASA TV panel discussion.

Niki Werkheiser, project manager for 3D Printing in Zero G, explains the printer and examples of its products.

safety process that the design did pass," said Niki. "And through the very first run of safety and flight cert it passed successfully, which for a brand new technology and brand new hardware is challenging, so we're very proud of that."

See the full panel discussion, including Q&A with attendees, here: http://www.youtube.com/watch?v=4x_yvE_M11w

During a separate segment of NASA TV panel discussions, Space Technology Mission Directorate's Chief Technologist Jeff Sheehy talked about the partnership with Made In Space.

"The themes that you will hear over and over again are partnerships and using the ISS as a demonstration platform and so this is a partnership between NASA and a company called Made In Space. Within NASA it's a partnership between the Space Technology Mission Directorate and Human Exploration Operations Mission Directorate…so we're proud to be a part of that partnership.

"This printer is really an American success story if you think about it in terms of it was a proposal to the Small Business Innovative Research fund. It got maybe $100,000 as a start off to explore the concept—does the concept really hang together—to rethink printing things in space, printing tools in space, would it work. Then after that success, it looked like the concept was sound…then to Phase II SBIR award to try out an initial implementation of the concept. We were able to, in Space Technology, to use our Flight Opportunities Program, which pairs promising technologies with vendors who offer suborbital flights to put the printer in a space environment for very short durations—thirty seconds at a time—let them tweak it and test it and determine what parameters they'd have to change to make it work well in the space environment. And now we've got it to the point where we've delivered it to the Dragon capsule and we're going to take it up to the space station, have it installed there and do a full demonstration of its capability to actually operate successfully in the microgravity environment of space.

"From initial concept to demonstration, it's partnerships like this that help carry technologies across what some people call the "valley of death" that sometimes stands between a promising technology and its infusion into missions, like we want to do at NASA, or its transfer to the marketplace. So it's partnering like this within NASA and with companies external to NASA that really helps carry technologies along."

Quoted materials transcribed from NASA TV news coverage held at Kennedy Space Flight Center in Florida.

Composite Materials Continue Advancing in Technology Readiness Level Testing

One of the largest composite cryotanks ever built recently completed a battery of tests at NASA's Marshall Space Flight Center in Huntsville, Alabama. The tank was lowered into a structural test stand where it was tested with cryogenic hydrogen and structural loads were applied to simulate stresses the tank would experience during launch.

With thanks due in large part to the Game Changing Development Program's Composite Cryotank Technologies and Demonstration (CCTD) project, a new effort is commencing in the Technology Demonstrations Missions (TDM) Program: the Composites for Exploration Upper Stage (CEUS) project. CEUS will evaluate the benefits from composite structures for launch vehicles, building on the great successes CCTD realized in materials, design, manufacturing and testing.

"Game Changing's CCTD project paved the way for the TDM project," said John Vickers, project manager for CCTD. "CCTD advanced the composites technology and gave NASA a big boost in confidence for using composites."

While CCTD and CEUS have many similarities in critical technology areas, the CCTD project's focus was to mature the technology readiness of composite cryogenic propellant tanks; CEUS will demonstrate technology for composite dry structures.

"Composites are the materials of the future," said John. "Missions to Mars require lightweight structures, and composites offer the greatest promise for lightweight space structures."

As the CCTD project announced in August its completion of an elaborate series of tests on the largest manufactured composite cryogenic fuel tank, Space Technology's Associate Administrator Michael Gazarik said the results were "one of NASA's major technology accomplishments for 2014."

"This is the culmination of a 3-year effort to design and build a large high-performance tank with new materials and new processes, and to test under extreme conditions," said John. "The goals for the CCTD project were very aggressive and the project's ability to accomplish many firsts, such as testing the largest ever out-of-autoclave tank, was remarkable."

At the beginning of the project, it was unknown if the tank would resist permeation and contain the hydrogen, but testing confirmed this capability. Consistently throughout rigorous testing, analytical predictions matched the experimental results.

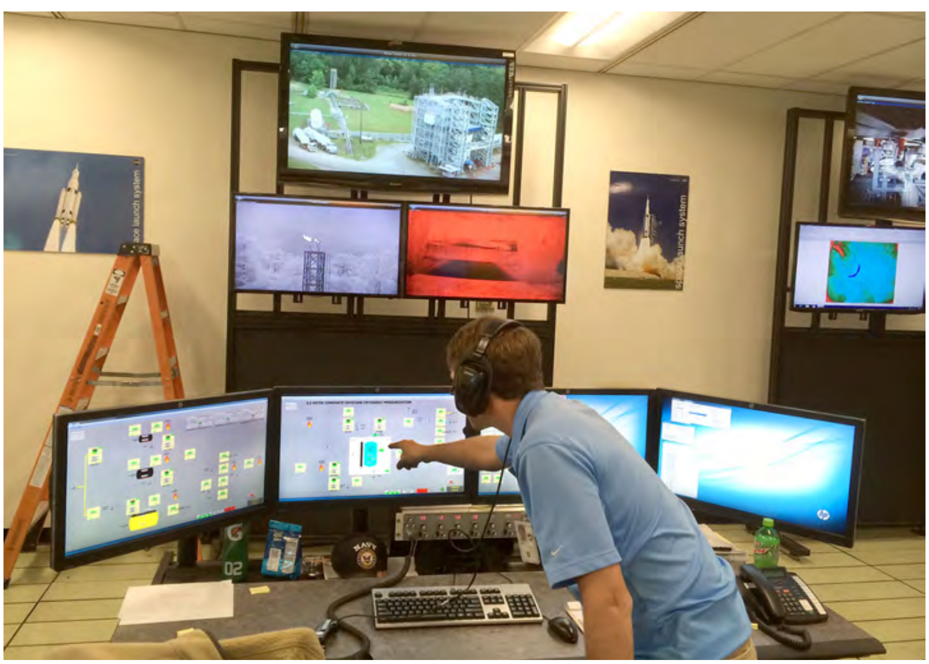
"Never before has a composite tank of this size been successful in sustaining the loads and environment of liquid hydrogen," said John. "This gives us confidence that we have good capability to predict performance."

CCTD's 5.5-m tank design is applicable to existing heavy lift launch vehicles capable of payloads into low-Earth orbit. The objective for CEUS is to design, build and test composite structures at the 8.4-m scale applicable to the super-heavy lift class of launch vehicles specific to NASA's Space Launch System (SLS). Key performance objectives include lightweight, thermal efficiency, reduced cost, and demonstrated confidence.

"The goal for CEUS is to advance technologies for large composite structures for the SLS exploration upper stages plus provide SLS extensibility for other structures, to develop and demonstrate critical composites technologies with a focus on full-scale," said John. "Challenges for the team will exist in materials, design, manufacturing and testing using NASA in-house capabilities."

The CEUS team is ready for those challenges, though. "The team is very excited about and has great hopes for the technology," said John. "We have been interested in the benefits from composites for launch vehicles for a long time, but the realization of that goal has not yet happened."

Industry and academic partners are yet to be determined; however, several NASA Centers are participating in CEUS. Marshall will lead project management, design; manufacturing and testing; Glenn is the lead for materials; and Langley is lead for analysis and joints development.



An engineer reviews test data in the control room during testing of the 5.5-meter tank.

John Vickers shows off the Combined Strength Award.

NASA-Boeing Team Wins Big at CAMX Conference

NASA and Boeing received the Combined Strength Award category in Awards for Composites Excellence (ACE) on Tuesday, Oct. 14, during the Composites and Advanced Materials Expo (CAMX) in Orlando, Fla. CAMX is the largest composites industry trade show and conference held in North America.

The award was given to the Composite Cryogenic Technology Demonstration (CCTD) project. The project, funded by NASA's Space Technology Mission Directorate's Game Changing Development Program, utilized innovative manufacturing and design techniques to build the largest composite liquid hydrogen fuel tank built out-of-autoclave. Efforts from this project have led to a 30-percent weight savings and a 25-percent cost savings, allowing insertion of higher mass payloads to low-Earth orbit and beyond.

According to CAMX, this new award recognizes "the cutting-edge innovations and innovators that are shaping the future of composites and advanced materials in the marketplace." The entries were judged on the following: concept and design, value, impact, production, and delivery collaboration.

The collaborative effort between NASA and Boeing on this project was particularly highlighted.

"Receiving an award from the largest audience focused on composites and advanced materials gives us great pride," said Dan Rivera, Boeing program manager for CCTD. "I'd like to congratulate our strong NASA and Boeing team."

"We are honored to receive this distinguished award," added John Vickers, NASA's CCTD project manager. "Our government and industry team has been very resilient to overcome adversity to be successful and bring new life to the composite tank technology."

Vickers and Rivera accepted the award together.

New Commercial Rocket Descent Data May Help NASA with Future Mars Landings

NASA successfully captured thermal images of a SpaceX Falcon 9 rocket on its descent after it launched in September from Cape Canaveral Air Force Station in Florida. The data from these thermal images may provide critical engineering information for future missions to the surface of Mars.

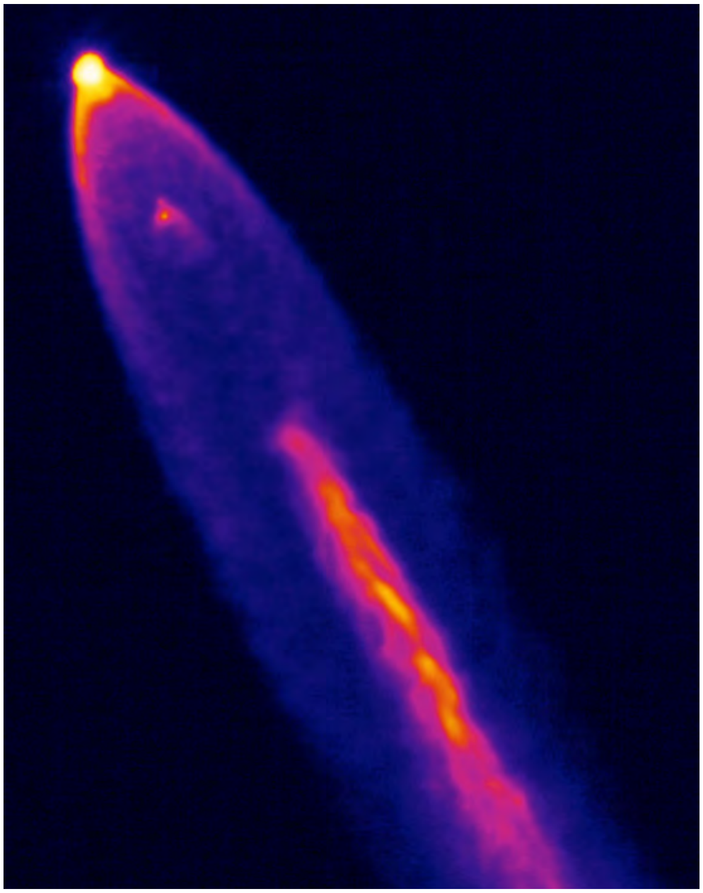
"Because the technologies required to land large payloads on Mars are significantly different than those used here on Earth, investment in these technologies is critical," said Robert Braun, principal investigator for NASA's Propulsive Descent Technologies (PDT) project and professor at the Georgia Institute of Technology in Atlanta. "This is the first high-fidelity data set of a rocket system firing into its direction of travel while traveling at supersonic speeds in Mars-relevant conditions. Analysis of this unique data set will enable system engineers to extract important lessons for the application and infusion of supersonic retropropulsion into future NASA missions."

NASA equipped two aircraft with advanced instrumentation to document reentry of the rocket's first stage. The first stage is the part of the rocket that is ignited at launch and burns through the rocket's ascent until it runs out of propellant, at which point it is discarded from the second stage and returns to Earth. During its return, or descent, NASA captured quality infrared and high definition images and monitored changes in the smoke plume as the engines were turned on and off.

"NASA's interest in building our Mars entry, descent and landing capability and SpaceX's interest and experimental operation of a reusable space transportation system enabled acquisition of these data at low cost, without standing up a dedicated flight project of its own," said Charles Campbell, PDT project manager at NASA's Johnson Space Center in Houston.

"Through our partnership with SpaceX we're gaining access to real-world test data about advanced rocket stage design and retropropulsion," said Michael Gazarik, NASA's associate administrator for Space Technology at NASA Headquarters in Washington. "Through this partnership we're saving the taxpayer millions of dollars we'd otherwise have to spend to develop and test rockets and flights in-house. This is another great example of American companies partnering with NASA to enable our future exploration goals."

This research and technology effort is funded by the Game Changing Development Program in NASA's Space Technology Mission Directorate.



Thermal imagery of the Space X Falcon 9 first stage performing propulsive descent Sept. 21. Supersonic retropropulsion data obtained from this flight test is being analyzed by NASA to design future Mars landing systems.
Image Credit: NASA

System Technology Nears Milestone Testing

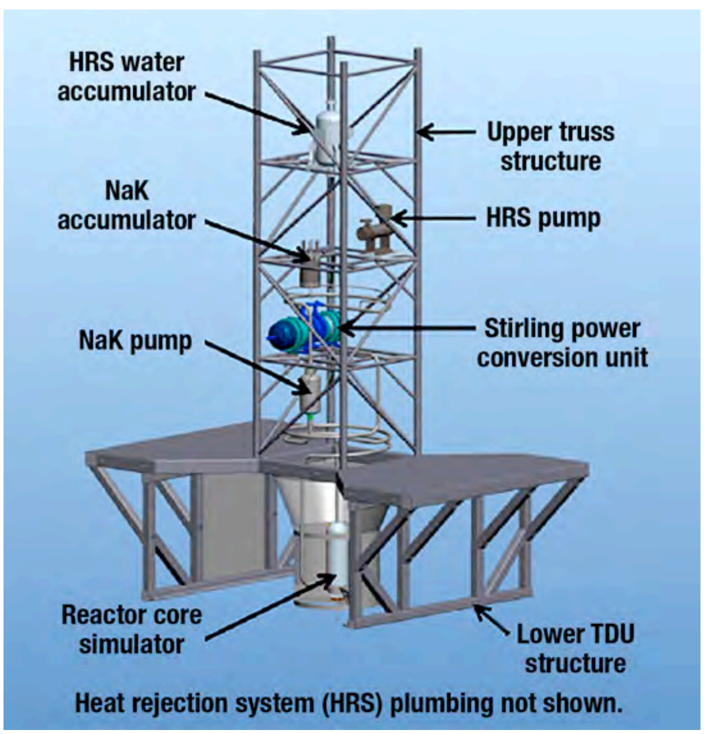
TDU in the GRC Vacuum Facility 6.

In FY15, the Nuclear Systems project, part of NASA Space Technology's Game Changing Development Program, will test laboratory hardware that functions like a fission space power system. Fission power systems offer plentiful energy that can be used anywhere humans or our robotic probes may go, regardless of availability of sunlight.

In this non-nuclear demonstration, the Nuclear Systems project seeks to test the subsystem level readiness of fission power for space exploration applications now that the Technology Demonstration Unit (TDU) has been developed and is nearing completion.

The TDU is the integrated combination of an electrically-heated reactor simulator, a power conversion unit, and a facility cooling system. It will undergo testing in Glenn Research Center's Vacuum Facility 6, a 25- by 60-ft cylindrical chamber offering a high quality, space-like vacuum equivalent to that found on the moon and well below surface pressure found on Mars.

"Subsystem-level testing of a simulated fission reactor heat source with power conversion at kilowatt-class electrical power levels in a relevant environment is a technology first," says Don Palac, project manager for Nuclear Systems.



TDU concept layout.

Solar arrays and radioisotope thermoelectric generators (RTGs) have performed well for decades of space missions, but there are limits in their usefulness for some future science and exploration missions. To generate the power necessary for deep space missions, solar arrays that collect and convert the Sun's energy into electricity would have to be so large that they would be too massive to launch. RTGs, which convert heat from radioactive decay of plutonium-238 into electricity, transform only around 8 percent of the heat energy released to electricity.

Building on prior work by a joint NASA and Department of Energy team, Don and his team want to reveal that fission power technology is a viable option to enable missions needing abundant power where sunlight is in short supply.

"Future power system needs may vary by power level and performance requirements, but this TDU test will demonstrate that there are no system-level technology barriers to kilowatt-class fission power systems for use in space science and exploration," said Don.

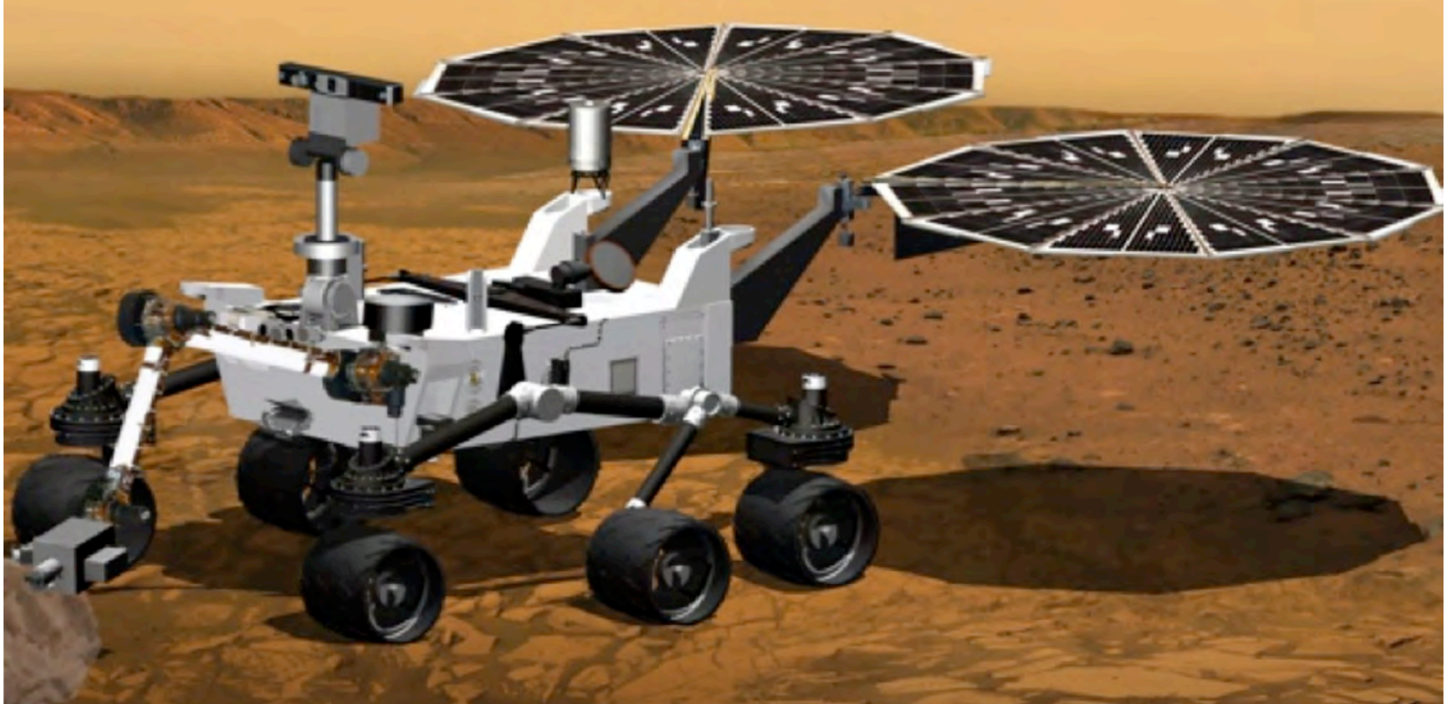
Originally planned for testing in 2014, funding cuts in FY14 impacted fabrication and assembly of the TDU power conversion unit (PCU) and, combined with unexpected difficulties in PCU final assembly, have delayed PCU delivery into FY15.

Despite this delay, the Nuclear Systems team otherwise continues preparing for testing. The reactor simulator has been operated in vacuum to demonstrate its readiness to provide hot NaK working fluid to the power conversion unit. The facility cooling system has also been independently operated in thermal vacuum to demonstrate its readiness to remove waste heat from the power conversion unit. The PCU's Stirling engine pair has been operated at full power at Sunpower, Inc., converting heat from electrical heaters into electricity.

"The completion of the PCU is in the last steps prior to delivery," said Don. "Once delivered, the PCU will be integrated into the TDU, test readiness will be reviewed, and testing will commence."

Partnering on fission power systems development with NASA Centers Glenn and Marshall are the Department of Energy, Sunpower, Inc., and Material Innovations, Inc.

Mars 2020 Payload to Include Science from Across NASA Mission Directorates



In July 2014, NASA announced seven carefully-selected instruments to conduct unprecedented science and exploration technology for the Mars Exploration Program's investigations of the Red Planet. Two of the seven instruments include technologies being developed and advanced within multiple NASA mission directorates: Space Technology, Science, and Human Exploration and Operations.

These instruments are the Mars Environmental Dynamics Analyzer (MEDA) and the Mars Oxygen ISRU Experiment (MOXIE).

- MEDA is a set of sensors that will provide measurements of temperature, wind speed and direction, pressure, relative humidity and dust size and shape. The principal investigator is Jose Rodriguez-Manfredi, Centro de Astrobiologia, Instituto Nacional de Tecnica Aeroespacial, Spain.
- MOXIE is an exploration technology investigation that will produce oxygen from Martian atmospheric carbon dioxide. The principal investigator is Michael Hecht, Massachusetts Institute of Technology, Cambridge, Massachusetts.

"We are extremely excited about the opportunity to partner with HEOMD and SMD," said Ryan Stephan, program executive for STMD's Game Changing Development Program Office. "The in situ production of oxygen for use as a propellant and for life support is an enabling capability for future exploration missions. There have been numerous system-level trade studies quantifying the tremendous benefits of this technology. The demonstration of the proposed ISRU technology will mitigate the risks, and address the concerns, associated with baselining this enabling capability on future missions to Mars."

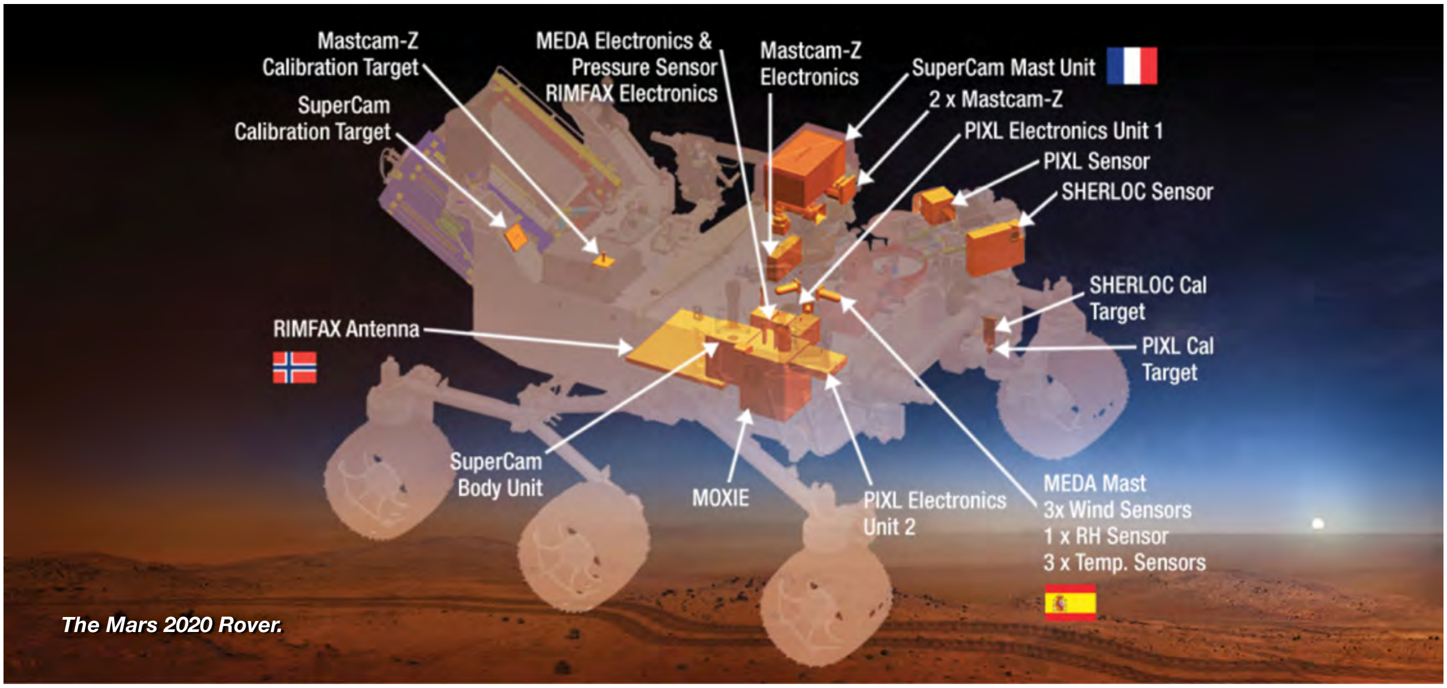
"Learning to use indigenous materials for human habitation and transportation for the first time on Mars, or any other planet for that matter, is incredible and revolutionary. Doing the "incredible" is what Game Changing is all about. We are excited to be partnering with SMD and HEOMD/AES on these innovative technologies." —Steve Gaddis

One year before NASA announced the selected instruments, the Mars 2020 Science Definition Team (SDT) published its report laying out the scientific objectives of the Mars 2020 mission. The SDT defined its concept, in part, as seeking to incorporate new in situ scientific instrumentation in order to explore for signs of past life, select and store samples in a returnable cache, and demonstrate technologies for future robotic and human exploration of Mars.

Fifty-eight proposals were received for review in January 2014 from scientists, researchers and engineers worldwide, twice as many as have been submitted for other recent instrument competitions. The new instruments will be incorporated onto a new rover similar to Curiosity, which began exploring and returning science from Mars in 2012.

"The Mars 2020 rover, with these new advanced scientific instruments, including those from our international partners, holds the promise to unlock more mysteries of Mars' past as revealed in the geological record," said John Grunsfeld, associate administrator of NASA's Science Mission Directorate in Washington.

NASA's Mars Exploration Program seeks to characterize and understand Mars as a dynamic system, including its present and past environments, climate cycles, geology, and biological potential. In parallel, NASA is developing the human spaceflight capabilities needed for future round-trip missions to Mars.



The Mars 2020 Rover.

MEDA Overview Presented at Annual Lunar and Planetary Science Conference

A suite of sensors sets out to probe and provide characteristics of Mars planetary near-surface conditions.

Poster sessions at the Lunar Planetary Science Conference (LPSC) are inherently great opportunities to share knowledge and showcase advancing technologies or hardware, such as that found in the MEDA instrument. The five-day annual conference brings together nearly 2000 international specialists in petrology, geochemistry, geophysics, geology, and astronomy to present the latest results of research in planetary science. According to the LPSC website, this is the premiere conference for planetary scientists, and has been a significant focal point for planetary science research since its beginning in 1970, when it was known as the Apollo 11 Lunar Science Conference.

The 45th Lunar and Planetary Science Conference was held in Woodlands, Texas, in March 2014, during which the Mars Environmental Dynamics Analyzer (MEDA) suite of sensors was presented in the poster session on "Instruments and Payload Concepts."

MEDA is a Rover Environmental Monitoring Station (REMS) follow-on set of sensors designed to address the Mars 2020 investigation goals of characterizing dust size and morphology along with numerous other environmental factors while maximizing heritage technologies.

MEDA is characterized as lightweight and requires low power resources to operate. It offers autonomous operations functionality and it provides a cost savings to the mission having started from an internationally recurrent design.

In this excerpt from the poster session's abstract, MEDA Principal Investigator Rodriguez-Manfredi reports:

MEDA's design makes it more than a dust characterization and MET station package, as it offers synergies with the goals of other Announcement Opportunity investigations, Mars Program objectives, and with Mars Strategic Knowledge Gap investigations.

MEDA will monitor dust properties and in situ near-surface pressure, relative humidity, the air and surface thermal environment, wind, and the solar radiation cycle autonomously on Mars around the clock.

The solar radiation sensors will track direct and diffuse radiation in a geometry that characterizes the prevailing en-

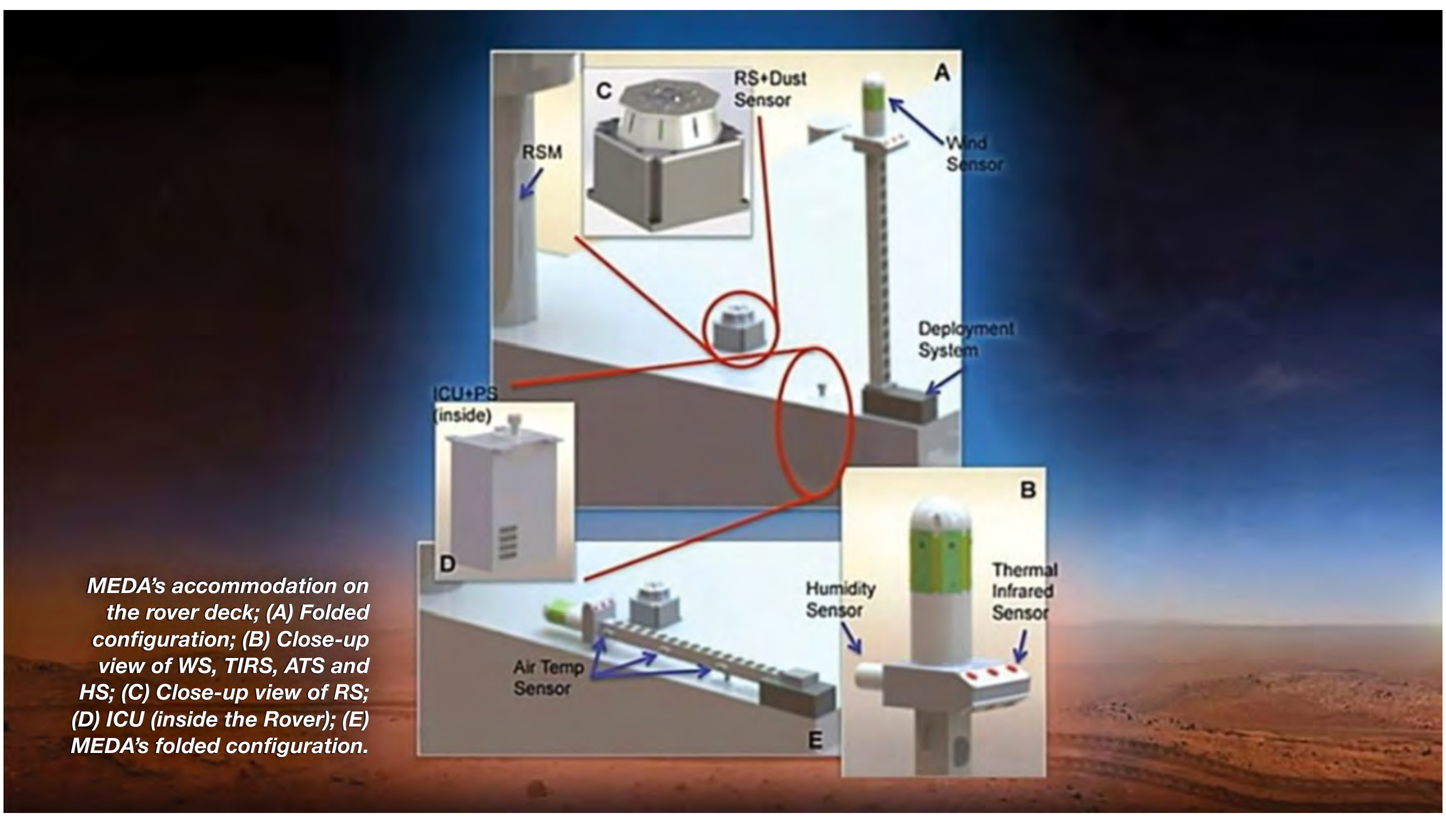
vironmental dust properties, the behavior of solar radiation on subdiurnal time scales, and the impact of solar radiation on local photochemistry, thus supporting assessments of the preservation potential for organics on a cache sample.

Resolving dust and environmental variables over many time scales is required to (a) understand the predictive capabilities of models of the near surface environment on Mars, and (b) assess how the environment affects operational and rover engineering cycles. Therefore, MEDA's operation concept is to work autonomously and continuously with a programmable continued temporal coverage and a variable sampling rate, including during rover sleep periods.

The suite of sensors chosen will enable comparisons to the environments measured at other surface locations previously explored on Mars, with the Mars Science Laboratory REMS heritage enabling very robust comparisons to the meteorological station currently operating in Gale Crater.

To understand the different Mars surface scenarios, which requires sampling the planet's near-surface environment at geographically diverse locations, Rodriguez-Mandfredi et al. say MEDA addresses the following investigations:

a. The physical and optical characteristics of the local atmospheric dust. Its particle abundance, size distribution, nonsphericity, and how these optical properties relate to the meteorological cycles (diurnal, seasonal, interannual).
b. The conditions leading to dust lifting and how the aerosol diurnal (daytime and night time) cycle responds to the atmospheric wind regimes.
c. How do the current environmental pressure, temperature, relative humidity, solar radiation, net infrared radiation, and winds at the landing site differ from those at the Viking, Phoenix, MPF, and Curiosity locations?
d. The relationship between the surface environment and the large-scale dynamics observed from orbiting instruments.
e. What are the energy and water fluxes between the surface and the lower atmosphere of Mars near the rover?
f. What are the annual cycles of the solar UV, visible and NIR radiation on the surface of Mars?
g. The environmental context for weathering and preservation potential of a possible cache sample.
h. How do pressure, humidity, temperature and winds influence the ISRU engineering efficiency?
i. How do the MEDA observations agree with models extrapolations to the Martian surface?



MEDA's accommodation on the rover deck; (A) Folded configuration; (B) Close-up view of WS, TIRS, ATS and HS; (C) Close-up view of RS; (D) ICU (inside the Rover); (E) MEDA's folded configuration.

Michael Hecht of MIT's Haystack Observatory will lead development of the MOXIE instrument that will fly on the Mars 2020 mission. Image credit: Jose-Luis Olivares/MIT

Going to the Red Planet

An MIT oxygen-creating instrument has been selected to fly on the upcoming Mars 2020 mission.

—by Maia Weinstock

July 31, 2014 — Whenever the first NASA astronauts arrive on Mars, they will likely have MIT to thank for the oxygen they breathe—and for the oxygen needed to burn rocket fuel that will launch them back home to Earth.

On Thursday, NASA announced the seven instruments that will accompany Mars 2020, a planned $1.9 billion roving laboratory similar to the Mars Curiosity rover currently cruising the Red Planet. Key among these instruments is an MIT-led payload known as MOXIE, which will play a leading role in paving the way for human exploration of our ruddy planetary neighbor.

MOXIE—short for Mars OXygen In situ resource utilization Experiment—was selected from 58 instrument proposals submitted by research teams around the world. The experiment, currently scheduled to launch in the summer of 2020, is a specialized reverse fuel cell whose primary function is to consume electricity in order to produce oxygen on Mars, where the atmosphere is 96 percent carbon dioxide. If proven to work on the Mars 2020 mission, a MOXIE-like system could later be used to produce oxygen on a larger scale, both for life-sustaining activities for human travelers and to provide liquid oxygen needed to burn the rocket fuel for a return trip to Earth.

"Human exploration of Mars will be a seminal event for the next generation, the same way the moon landing mission was for my generation," says Michael Hecht, principal investigator of the MOXIE instrument and assistant director for research management at the MIT Haystack Observatory. "I welcome this opportunity to move us closer to that vision."

An oxygen factory on Mars

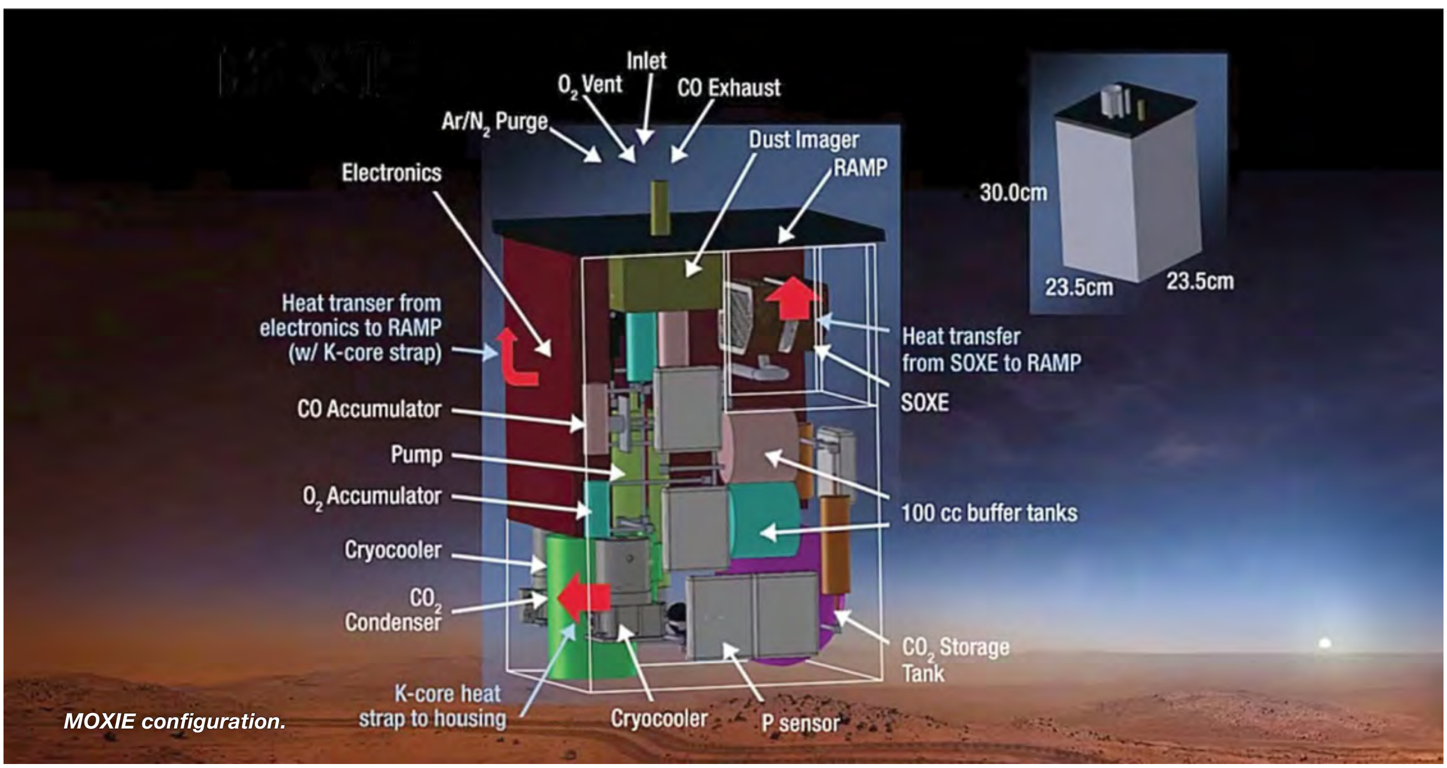
One of the main goals of the Mars 2020 mission will be to determine the potential habitability of the planet for human visitors. To that end, the MOXIE instrument will attempt to make oxygen out of native resources in order to demonstrate that it could be done on a larger scale for future missions.

To do this, MOXIE will be designed and built as what Hecht calls a "fuel cell run in reverse." In a normal fuel cell, fuel is heated together with an oxidizer—often oxygen—producing electricity. In this case, however, electricity produced by a separate machine would be combined with carbon dioxide from the Martian air to produce oxygen and carbon monoxide in a process called solid oxide electrolysis.

"It's a pretty exotic way to run a fuel cell on Earth," Hecht says, "but on Mars if you want to run an engine, you don't have oxygen. Over 75 percent of what you would have to carry to run an engine on Mars would be oxygen."

Of course, setting up a system to create oxygen that human explorers could breathe would be extremely helpful for a mission of any duration. But there's an equally important reason to be able to produce oxygen onsite, Hecht says: "When we send humans to Mars, we will want them to return safely, and to do that they need a rocket to lift off the planet. That's one of the largest pieces of the mass budget that we would need to send astronauts there and back. So if we can eliminate that piece by making the oxygen on Mars, we're way ahead of the game."

According to Hecht, a long-term plan for getting humans to Mars—and back—would look something like this: First, a small nuclear reactor would be sent to the Red Planet along with a scaled-up version of the MOXIE instrument. Over a couple of years, its oxygen tank would fill up in preparation for human visitors. Once the crew arrives, "they have their power source, they have their fuel, and the infrastructure for the mission is already in place," Hecht says. "That's the piece we're after."



MOXIE configuration.

Hecht adds that producing oxygen on the Martian surface is likely the simplest solution for a number of reasons. It would, for example, eliminate the difficulty and expense of sending liquid oxygen stores to Mars.

To be sure, MOXIE won't be the only instrument aboard the Mars 2020 mission. It will occupy valuable space on a rover that will also conduct other important scientific experiments — such as searching the Martian soil for signs of life. So why do scientists and engineers need to demonstrate that they can produce oxygen on the surface, when they're confident they can make that reaction happen on Earth?

"If you were one of those astronauts depending on an oxygen tank for your ride home, I think you'd like to see it tested on Mars before you go," Hecht explains. "We want to invest in a simple prototype before we are convinced. We've never run a factory on Mars. But this is what we're doing; we're running a prototype factory to see what problems we might come up against."

MIT connection

To develop MOXIE, MIT will partner with NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Calif. JPL will lead design and development of the payload, while MIT will establish the mission architecture, oversee the development, and plan operations on the surface of Mars.

At MIT, MOXIE's home will be the Haystack Observatory, an interdisciplinary research center in Westford, Mass., that specializes in radio science related to astronomy, atmospheric science, and applied measurement of the Earth known as geodesy. Hecht admits that developing and building the MOXIE instrument will be something of a departure from Haystack's typical projects, but he and his colleagues are excited to take on the challenge.

"Haystack has been involved in the space program since its inception, even before it was officially Haystack Observatory," Hecht says. "We really pride ourselves on our ability to pioneer new, ultraprecise scientific instrumentation and get it out into the field. We're kind of a bridge between an engineering production shop and a fundamental science shop, so this plays to our strength in every way but the fact that there's no radio science [on Mars 2020]."

Of course, Hecht and his Haystack colleagues won't be working on MOXIE in a vacuum. The instrument will also benefit from the expertise of Jeff Hoffman, a former astronaut and professor of the practice in MIT's Department of Aeronautics and Astronautics. Associate Professor of Nuclear Science and Engineering Bilge Yildiz, who has unique experience with the technology that will fly on the MOXIE experiment, will also play an important role.

"It's a collaboration I never expected, between nuclear engineering, AeroAstro, and Haystack Observatory," Hecht says. "But in the end, our leadership team ended up with a very competitive product."

Humans key to future Mars exploration

If all goes according to plan, the Mars 2020 mission, with MOXIE in tow, will launch in July 2020. Assuming a safe landing and deployment, Hecht hopes the MOXIE instrument will transform the future of Martian exploration by demonstrating that humans can live directly off the land, with as few resources as possible shipped in from Earth.

When will humans actually get to Mars? An independent mission known as Mars One aims to send humans on a one-way trip to the Red Planet in 2024—but critically, the explorers who have signed up for that mission know they won't be returning. Sending humans on a government-funded return trip will take much more effort, both in terms of science and technology and political will.

"It's not a science and engineering question, it's a political and programmatic question," argues Hecht, who believes it's not unreasonable to think NASA could launch humans on a return trip to Mars in 20 years. "What that will take is, I'd say, a political bipartisan commitment, a sustained investment, and the best and brightest minds of the generation, just as Apollo did," Hecht says. "It's a really challenging project, just as Apollo was. It's doable, it won't break the bank in the United States, and we can afford it, but it's a large commitment.

"I was thinking about [President John F.] Kennedy's speech," Hecht adds, "when he talked about going to the moon not because it's easy, but because it's hard. And I was really struck by what came after that quote, the part that nobody remembers. He said, 'Because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win.' That just said it. We will get to Mars in 20 years when we are willing to embrace that challenge."

Courtesy of MIT News Office
http://newsoffice.mit.edu/2014/going-red-planet

The MRV: Next-Gen Automobile?

—written by Justin Ridley, adapted by Denise M. Stefula

Seated in vehicle, left to right: Bill Bluethmann (project lead), Lucien Junkin (chief engineer)
First row, left to right: Josh Figured, Justin Ridley, Mason Markee, Kelly Mann, Raymond Guo (GM), Andy Dawson (Oceaneering)
Back row, left to right: Keith Chambles, Tom Waligora (Oceaneering), Jonathan Lutz, Jim Rogers (Jacobs), Ross Pettinger (Jacobs), Anthony Lapp (Oceaneering), Logan Farrell, Ed Herrera, Nathan Fraser-Chanpong, Ivan Spain (Jacobs), Pedro Curiel.

The Modular Robotic Vehicle, or MRV, was developed at NASA's Johnson Space Center in order to advance technologies that have applications for future vehicles both in space and on Earth. With seating for two people, MRV is a fully electric vehicle well-suited for busy urban environments.

The MRV steering wheel appears relatively conventional but has a design that makes it "feel" as though the driver is having a standard mechanical driving experience.

Anthony Lapp rides shotgun during a demonstration of the MRV operating under remote control.

Close-up of the "e-corner."

One of NASA's key purposes for the project was to have access to a technology development platform.

"This work allowed us to develop some technologies we felt were needed for our future rovers," said Justin Ridley, Johnson Space Flight Center. "These include redundant by-wire systems, liquid cooling, motor technology, advanced vehicle control algorithms. We were able to learn a lot about these and other technologies by building this vehicle."

Just as NASA helped pioneer fly-by-wire technology in aircraft in the 1970s, MRV is an attempt to bring that technology to the ground in modern automobiles. With no mechanical linkages to the propulsion, steering, or brake actuators, the driver of an MRV relies completely on control inputs being converted to electrical signals and then transmitted by wires to the vehicle's motors. A turn of the steering wheel, for instance, is recorded by sensors and sent to computers at the rear of the vehicle. These computers interpret that signal and instruct motors at one or all four of the wheels to move at the appropriate rate, causing the vehicle to turn as commanded. Due to a force feedback system in the steering wheel, the driver feels the same resistance and sensations as a typical automobile.

Not having a mechanical linkage between the driver and the steering wheel introduces new risks not seen on conventional automobiles. A failed computer, or cut wire, could cause a loss of steering and the driver to lose control. Because of this, a fully redundant, fail-operational architecture was developed for the MRV. Should the steering motor fail, the computer system responds immediately by sending signals to a second, redundant motor. Should that computer fail, a second computer is ready to take over vehicle control. This redundancy is paramount to safe operations of a by-wire system.

MRV's redundant drive-by-wire architecture allows for advanced safety and dynamic control schemes. These can be implemented with a driver operating either within the vehicle or by remote interface. In the future this system can be expanded to allow for autonomous driving.

MRV is driven by four independent wheel modules called e-corners. Each e-corner consists of a redundant steering actuator, a passive trailing arm suspension, an in-wheel propulsion motor, and a motor-driven friction braking system.

Each e-corner can be controlled independently and rotated ±180 degrees about its axis. This allows for a suite of driving modes allowing MRV to maneuver unlike any traditional vehicle on the road. In addition to conventional front two wheel steering, the back wheels can also articulate allowing for turning radiuses as tight as zero. The driving mode can be switched so that all four wheels point and move in the same direction achieving an omni-directional, crab-like motion. This makes a maneuver such as parallel parking as easy as driving next to an available spot, stopping, and then operating sideways to slip directly in between two cars.

"This two-seater vehicle was designed to meet the growing challenges and demands of urban transportation," said Mason Markee, also with Johnson. "The MRV would be ideal for daily transportation in an urban environment with a designed top speed of 70 km/hr and range of 100 km of city driving on a single charge of the battery. The size and maneuverability of MRV gives it an advantage in navigating and parking in tight quarters."

The driver controls MRV with a conventional looking steering wheel and accelerator/brake pedal assembly. Both of these interfaces were specially designed to mimic the feel of the mechanical/hydraulic systems that people are used to feeling when driving their own cars. Each device includes its own redundancy to protect for electrical failures within the systems. A multi-axis joystick is available to allow additional control in some of the more advanced drive modes. A configurable display allows for changing of drive modes and gives the user critical vehicle information and health and status indicators.

Each propulsion motor is located inside the wheel and capable of producing 190 ft-lbs of torque. An active thermal control loop maintains temperatures of these high powered motors. A separate thermal loop cools the avionics, including custom lithium-ion battery packs.

"While the vehicle as a whole is designed around operating in an urban environment, the core technologies are advancements used in many of our robotic systems and rovers," explained Mason. "Actuators, motor controllers, sensors, batteries, BMS, component cooling, sealing, and software are all examples of technologies that are being developed and tested in MRV that will be used in next generation rover systems."

The technologies developed in MRV have direct application in future manned vehicles undertaking missions on the surface of Earth's moon, on Mars, or even an asteroid. Additionally, MRV provides a platform to learn lessons that could drive the next generation of automobiles.

Andy Dawson takes the MRV for a test drive.

Andy Dawson demonstrates a parking maneuver.

With a designed top speed of around 70 km/hr, test driving proved to be a bit of fun. Justin Ridley describes the experience: "It's like driving on ice but having complete control. It's a blast to ride in and even more fun to drive. We've talked about it being like an amusement park ride. The "fun" of driving was not something we tried to design for, just something that came out of the design. Once we got it running many of us commented that we had no idea it was going to be able to do the things it does."

The "Gould" Standard

Dana Gould, deputy program manager for Game Changing Development since the GCD Program Office commenced, transitioned in August 2014 to the aero side of NASA's research efforts and is now serving as deputy director for Langley's Aeronautics Research Directorate. Dana served as a program element manager with the Exploration Technology Development Program just prior to joining the GCD team.

To consider that "game changing development" is an apt moniker for the GCD Program Office, the thought is truly underscored by Dana's tenure with GCD, along with the continued work its team members are doing and will do.

"Dana is a consummate professional and a passionate technologist in his own right. He helped establish a 'game changing' office that dared to push the boundaries and challenge the status quo," says Program Manager Steve Gaddis. "He was my right hand and an advocate for the technologies. Dana's help in leading the program was invaluable and our success will always have his fingerprint on it."

Dana's duties evolved quite a bit over time as the organization stood up. "In the early days we had only five folks and we all just pitched in wherever help was needed," he says.

As the organization matured, the team reached out and partnered with industry, spending a considerable amount of time developing initial solicitations/NRAs, evaluating proposals, making selections/awards and, of course, inaugurating associated processes. As the program office roles and responsibilities became more established, Dana developed the contract vehicles, or task plans, to get the support in place to meet these requirements.

"As we became established, my activities really fell into three areas," Dana says smiling. "Keep the org running, put out the fires, and the ever-present other-duties-as-assigned."

Dana, Bob Hodson and Chuck Brooks.

A dynamic energy grew as the team spread itself out, making the effort to visit each Center with the GCD message, to tell the NASA community what the program was about, and to learn about the space technology capabilities at those Centers.

Dana feels one of the most important things he learned working within this dynamic environment was that the people who really pushed themselves, those not afraid to take risks, often saw some of the greatest and most interesting results. They challenged the norm, were sometimes on the edge, and not afraid to fail.

"Technologists at each Center showed us some of the great work they were doing, and this was incredibly exciting. There is so much great technology work going on across the Agency—and by passionate developers," Dana says. "These visits were very inspiring and also satisfying in that I am confident we have the ability within the Agency to meet the challenges of our exploration missions."

Advancing technologies to program or mission readiness means putting them through a process referred to as "rapid technology infusion." The GCD team ensured each technology proposal had a solid infusion story.

"It was one of the criteria of the evaluation process," says Dana.

Rapid technology infusion takes a proposed technology from its existing readiness level of laboratory demonstration, TRL 3, and advances it through validation and verification—a step that is often very costly and can therefore be a barrier—to getting that promising research, science and hardware to a prototype-level demonstration, TRL 6, and eventually implemented into relevant missions or industry environments. Proposed technologies are evaluated on many things, very importantly, if those technologies can demonstrate capabilities that will fit with and advance specific mission needs or goals.

"Documented plans like memorandums of understanding were the gold standard," Dana explains. "As the program became more established, we began investing in more joint efforts with sister mission directorates SMD and HEOMD where these technologies will be infused into NASA missions."

An example Dana believes best illustrates infusion as it works through the GCD Program is the woven thermal protection system technology.

"I've always considered the woven TPS technology a poster child for our program," he says. "A PI at ARC gets Center Innovation Funds to develop an idea of combining modern textile technology with ARC's TPS technology for a new class of materials. The work looks promising and they are able to win an award from a Broad Agency Announcement. The work attracts the attention of both HEOMD and SMD, and with those infusion targets in mind GCD steps in to cover the "valley of death"—getting the technology to the point of mission infusion."

Part of GCD's mission is to develop technologies that produce dramatic impacts for NASA's Space Exploration and Science Missions. Dana sees many within the program's areas of research—nanotechnology, miniaturizing and automating sensors, computation, and 3D printing—that could well change the way we live, sooner rather than later.

But his first thought as to the most beneficial results of a program like GCD goes to the "big" things, like big cryogenic propellant tanks, big solar arrays.

"They clearly are very important," he says, "for the new capabilities they mature for the Agency as well as our industry partners. These successes also build confidence with our stakeholders as well as our NASA-industry team. Being able to tackle big challenges quickly with relatively modest cost demonstrates that we are able to push the boundaries, as a high-tech agency should."

Game Changing Welcomes New Program Element Managers

The GCD Program Office defined in 2014 the need to incorporate an additional efficiency in its management structure, the program element manager (PEM). The PEM is one who manages a portfolio of multiple and diverse technology activities, a simple description belying work that is hardly an effortless undertaking for Game Changing staffers, so two new team members were brought on board in August to fulfill this challenging need. Welcome aboard, Wade May and Kevin Kempton.

The PEM serves as primary interface with the projects and as focal point with the program office for project data calls and information, acting as a singular conduit for project information needed for upward and external communications. Operational efficiency in knowledge and information management is enhanced by the addition of the PEMs, enabling project success and compliance with NASA policy and standards.

"Prior to having PEMs, the projects dealt with many interfaces and touch points," said Program Manager Steve Gaddis. "During execution, the PEM benefits his project areas and the program office with a streamlined approach, a 'lighter' touch."

Steve describes Wade and Kevin as go-getters who are detail-oriented, competent engineers and technologists that quickly jumped right in to their responsibilities.

"Kevin and Wade are hardworking and responsive," Steve said. "Already I appreciate their diligence, level-headedness, anticipatory and proactive natures. They are welcome additions to the team."

Both PEMs previously worked with LaRC's Engineering Directorate, playing key roles during their tenures with many projects. To highlight just a few: Wade wore many hats on the SAGE III project, including integration and

Wade May lives in York County with his wife Tracy, their son Russell, and the family's four-pound Yorkie-poo, Gemma. He enjoys reading, playing video games with Russell, and is very active at Northside Christian Church. Whenever possible, Wade and his family like to trek off for visits with extended family, but admits his favorite vacation spot is Disney World.

Kevin Kempton lives in Yorktown with his wife Paula and their three sons. Ben is in college and Liam and Harrison are both in high school. Kevin's is a busy family, engaging in camping, hiking, soccer, woodworking and sailing; but he still manages time to be a scout leader, and for over 12 years now. When it's "me time," Kevin is likely off somewhere fossil collecting, R/C flying, or maybe settled in at home whittling away at one of his many wood carving projects.

test lead, payload manager, and lead systems engineer; he also served as chief engineer on the STORRM project. Kevin was project manager for ALHAT Sensors and Reconfigurable Scalable Computing projects, served as lead systems engineer on both CLARREO and Ares I-X, and was software manager for GIFTS.

Game Changing's numerous projects fall within several thematic categories. Both Wade and Kevin will work with projects under Affordable Destination Systems and Scientific Instruments; Wade heads up Advanced Entry Descent and Landing, and Future Propulsion and Energy Systems projects; and Kevin oversees Lightweight Materials and Advanced Manufacturing, and Revolutionary Robotics and Autonomous Systems projects.

When discussing methods to solve the technology development challenges specific to their assigned domain areas, it becomes clear the PEMs are here to take charge in making sure plans are executable within given resources and schedule, and that progress can be tracked to an appropriate degree. Also evident is that inherent duality successful leadership exhibits when spearheading such large-scale efforts: you collaborate and pilot in such a way that allows your talented people to steer their ships, to discover, innovate and achieve results.

"Technology challenges are primarily left with the project and element leads," Kevin said, "On some projects, PEMs can provide recommendations based upon their experiences and insights into what the stakeholders are looking for."

Wade said he would "rely heavily on the principal investigators, the GCD chief engineer, and subject matter experts for helping to solve technical challenges," particularly those that fall outside his own realm of experiences.

Because leadership and collaboration are key capabilities in managing such a broad portfolio of technology research and potential products—across multiple governmental organizations, industry and academia, and NASA Centers—we decided to put the conversation on the table. Despite their busy schedules, Wade and Kevin took time to share their leadership styles and what excites them about working with the Game Changing Development Program.

GCD Q: *What is your leadership/management philosophy?*

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. This means a lot of extra work but it shows you are a team member and not just a manager. It is also important in being effective that the PEMs meet the project teams face-to-face and understand what they are doing technically.

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 used to work with the Boy Scouts and we taught the patrol leaders that a good leader shows his patrol how to get to the chow hall and then makes sure they all get through the chow line before getting in line himself.

GCD Q: *How will your philosophy benefit GCD's endeavors to pioneer technologies in achieving previously unattainable capabilities and characteristics?*

Kevin: Like most people who work at NASA, I believe the job is important and interesting. I believe this comes through to the people I work with whether on the projects or in the program office. I believe most overwhelming problems can be deconstructed into smaller problems that can be managed one at a time.

Wade: Through efforts to bring out the best in people, and supporting project execution, I hope to facilitate the technology development work that is being accomplished by Center employees.

GCD Q: *How will it enable project team members in the successful execution of their assigned projects?*

Kevin: I will do my best to shield the projects from excessive status reporting and distractions so they can focus on the critical work of advancing the key technologies NASA needs. Also, NASA has great systems engineering and project management tools in the 7123 and 7120 procedures. Many lower level TRL projects do not take advantage of these tools as well as they should.

Wade: I see our program office as a potential tool to help identify and get rid of barriers to technology development so that the project teams can be successful. It takes a village to raise a child and an Agency to develop a technology. I see myself as part of the program office team that collaborates together to help our project managers to be successful.

GCD Q: *What excites you most about working with GCD?*

Kevin: Clearly the wide variety of interesting projects and people. I wish I had time to work on them all. Also, I really believe I have the experience and skills to help projects succeed.

Wade: The range of technologies that are being matured and the network of people that are working on the projects.

GCD Q: *What do you think is going to be your most interesting challenge?*

Kevin: The most interesting challenge may be the need to transform the GCD culture itself so that it becomes more efficient in managing the information we need to do our jobs.

Wade: The biggest challenge is the breadth of technologies and being able to speak intelligibly with the projects about their technologies. For the first year, a big challenge will be traveling to all the Centers to visit the GCD projects to meet the teams face to face.

GCD Q: *What is the overarching achievement you hope to realize for GCD, NASA, and partners?*

Kevin: Increasing systems engineering rigor and improving information management.

Wade: Facilitating development of transformative technologies for space exploration.

CCTD Project Coordinator Lynn Machamer (pictured above), STMD Principal Investigator LaNetra Tate and Communications Manager Amy McCluskey helped staff the Advanced Manufacturing Technologies booth at the Composites and Advanced Materials Expo (CAMX) in Orlando, Fla., in October. The booth featured a 3D printer, CCTD samples, and various models and videos. The CCTD and Boeing team received the CAMX Combined Strength Award during the conference.

Want to learn more about Game Changing?

Web: gameon.nasa.gov
NASA Technology
NASA_Technology
NASA Game Changing Development

EPO

In 2014, the Game Changing Development (GCD) Program Office and its projects supported more than two dozen outreach events across the United States including congressional visits, media days, college talks, large-scale conferences and Agency supported events like the U.S. Science and Engineering Conferences.

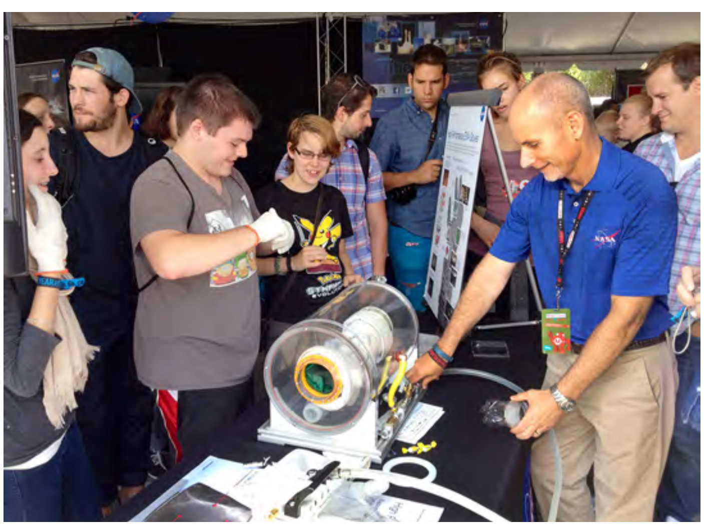
The program office and projects reached tens of thousands of people ranging from students, staffers, teachers and the general public to innovators, industry representatives, potential customers and stakeholders.

Among a few technologies that caught the interest of the media were a 3D printer, a large cryotank, sloshing liquid and a pair of legs.

Whose legs? Robonaut's of course. And as expected, the Composite Cryotank Technologies and Demonstration project received a lot of coverage, gracing several materials magazines and winning awards. The SLOSH project shined on social media, with a picture of the experiment onboard the ISS becoming the first Space Technology Mission Directorate project to make the official NASA Instagram account.

The launch of the first 3D printer into space made the cover of Tech Briefs and was picked up by nearly every media outlet that hosts a website.

In addition to all that good press, the Space Technology Mission Directorate also successfully completed its first communications campaign, "Technology Drives Exploration," which resulted in successful Technology Day events at NASA Centers, beefed up social media postings about space technology and afforded a heightened presence at colleges and universities.



More than 85,000 people attended the World Maker Faire New York 2014 held in September. GCD Program Office staffers Bob Hodson (far left) and Amy McCluskey (above right) staffed the new EVA Glovebox exhibit, which was a big draw during the two-day event. Even NASA Chief Technologist David Miller (pictured with McCluskey) came by.

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