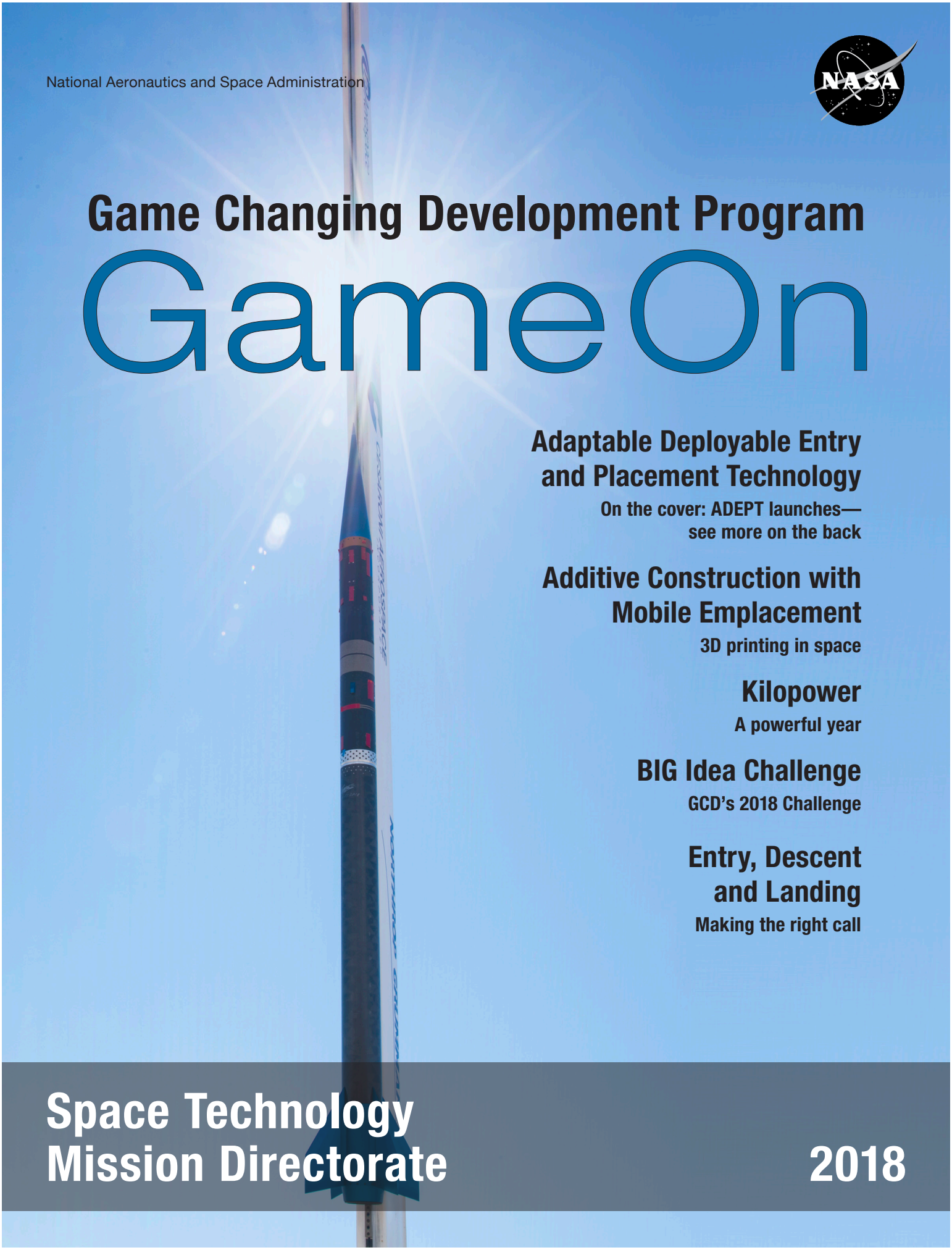
National Aeronautics and Space Administration

Game Changing Development Program

GameOn



Adaptable Deployable Entry and Placement Technology

On the cover: ADEPT launches—see more on the back

Additive Construction with Mobile Emplacement

3D printing in space

Kilopower

A powerful year

BIG Idea Challenge

GCD's 2018 Challenge

Entry, Descent and Landing

Making the right call

Space Technology Mission Directorate

2018

Well, this ends my first year as program manager for GCD. I have really enjoyed getting to know project managers, center points of contacts, principle technologists and other personnel involved in the program. Often I'm asked by others I know within and outside of NASA, "How do you like working in the Game Changing Developing program?" I usually reply, "What did I do to be assigned to this program?"….just kidding! My reply is: "It's awesome. Where else can you engage technologists and technology development projects across all of the NASA centers, small and large industry, Other Government Organizations and academia?"

In addition, the breadth, range and diversity of technologies is absolutely incredible. From the next generation space computers to automated medical diagnoses technologies, we have a portfolio of technologies that will truly enable future human space exploration and science missions.

I also would like to thank those who participated in the GCD retreat earlier this year. Your feedback was very much appreciated, and the program has incorporated many of your suggestions.

During the past year, the program has made a number of changes, such as: reducing the number of reviews from quarterly to bi-annually; changes to monthly reporting; communicating to project managers the programs monthly assessment of projects to headquarters; increased flexibility between workforce and procurement and project content documents and technical assessments.

The project content document is the precursor to development of a project plan. The intent is to produce a one or two-pager that clearly describes the goals of the technology, the technical approach and key performance parameters (KPP). Beginning in FY20, the program and projects will be evaluated on progress on KPPs as opposed to annual performance indicator (API) schedule milestones.

Finally, let's celebrate some of the many project accomplishments that occurred this year. Most recently we had the successful launch and deployment of ADEPT, a new concept for entry systems; hot fire testing of LCUSP, a technology that advanced additive manufacturing of complex propulsion system components; successful completion of the critical design review for MEDLI 2 ,which will be flying on MARS 2020 and characterizing Mars atmosphere for future missions; and completion of Extreme Environment Solar Power array phase one design enabling solar power for deep space planetary missions. This is just a subset of the numerous accomplishments by projects in the program, and I look forward to next year's technology advances.

.*Drew Hope*

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3D Printing in Space: A New Paradigm for America's Military

The ability to transport, deploy, and use a large-scale concrete 3D printer opens the door for rapid development of numerous infrastructure elements that do not have to be transported in-theater

By Michael Fiske, Jennifer Edmunson, Ph.D., John Fikes, Mallory Johnston, and Michael Case

The informal motto of Marshall Space Flight Center's In-Space Manufacturing Group is "Make It, Don't Take It." The National Aeronautics and Space Administration's (NASA) planetary habitat manufacturing and assembly technologies that incorporate in situ resources provide options for autonomous, affordable, pre-positioned habitats with radiation shielding features and protection from micrometeorite and exhaust plume debris caused by launch and landing. Without a significant atmosphere, surface dust can be accelerated and cause substantial damage to adjacent structures unless precautionary measures like a wall or berm are implemented.

Above: A B-Hut printed from the ACES-3 system at the Construction Engineering Research Laboratory in Champaign, Ill.
USACE PHOTO BY MIKE JAZDYK.

Not surprisingly, the U.S. military can realize many of these same benefits in the development of expeditionary structures. The ability to use in situ material to construct structures either autonomously or with minimum personnel will allow payloads that would otherwise make long-term Moon and Mars habitation cost-prohibitive. Equally, the ability to use local materials to construct terrestrial military expeditionary structures autonomously or with minimum personnel can reduce transport of materials in-theater and reduce waste. Additive construction provides better overall ballistic protection and thermal conditioning performance than many standard military construction techniques.

Additive Construction

On Earth, in-situ materials refer to local sources of the components of Ordinary Portland Cement-based concrete: sand, gravel, Portland cement, water, and both wet and dry additives. Using local materials minimizes the need to transport these materials in-theater. On the moon and Mars however, in-situ materials refer to the materials on the planetary surface.

This inorganic material (identified as regolith to distinguish it from organic Earth soil) will be the basis for the aggregate in any planetary cementitious material, with the goal to extract a binder from the same material. Any available water will likely be used for propulsion or life support, so a waterless binder is being pursued for these applications. Recently, NASA's Marshall Space Flight Center and Jacobs Space Exploration Group delivered a full-scale additive construction system to the U.S. Army Corps of Engineers (USACE) Construction Engineering Research Laboratory in Champaign, Ill.

The system—known as Automated Construction of Expeditionary Structures (ACES-3)—was based on prior work performed at Marshall Space Flight Center (MSFC) from 2004 to 2007, and again from 2013-2017, during the Additive Construction with Mobile Emplacement (ACME) project. Funded by USACE and NASA's Game Changing Development Program, ACME's mission was to develop a fundamental understanding additive construction, evolving from batch processing to a continuous-feed system. Work also included development of cementitious materials based on planetary (Moon and Mars) resources as well as understanding and controlling the rheological (viscosity) properties of these cementitious materials.

Contour Crafting

Contour crafting is an additive construction technology developed by Dr. Behrokh Khoshnevis of the University of Southern California and Contour Crafting Corp. Contour crafting shapes a continuously flowing bead of construction material, providing structural consistency and a more appealing aesthetic. This process has been used to build structures of gypsum, Ordinary Portland Cement-based concrete, sulfur concrete and ceramic slurries.

Contour crafting has influenced aspects of almost every additive construction technology that has been developed. USACE is interested in the technology because of its ability to support development of on-demand structures in a variety of settings using local materials. Such structures can include standard, culverts, anti-tank obstacles, and Army B-Huts (troop housing). In addition, it is expected to take less time to build a B-Hut (16-ft × 32-ft × 8-ft) than using traditional construction methods (one day compared to five days). Additive construction may need fewer construction personnel and fewer security personnel to protect construction workers. The amount of material brought into the field is reduced (a 50 percent reduction is anticipated) and can

Defining Requirements

The NASA/Jacobs team worked with USACE to define requirements for the ACES-3 system that reflected the additive construction performance goals.

- Break the system down for transportation into no more than three 8-ft × 8-ft × 20-ft volumes, consistent with a standard Army Palletized Loading System.
- Complete system setup and alignment in under 11 hours.
- Print in the X and Y axes at up to 500-in./min. concrete deposition speed with a volumetric flow rate of up to 800-in^3/min.
- Maintain absolute nozzle positional accuracy of ±1/8-in. in all three axes during printing.
- Operate entire system with no more than six personnel (long-term goal of three).
- Print concrete with aggregate up to 3/8-in. diameter.
- Include an automated dry goods storage and feed system for up to seven dry materials and an automated liquids storage and feed system for up to five liquid materials.

reduce waste from about 1-T to less than 500-lb/B-Hut. Another advantage is that if the Army has an agreement with a foreign government resulting in that government keeping the structures when the Army leaves, those structures can be designed and printed to reflect local architectures. Forward personnel would all benefit from these improvements.

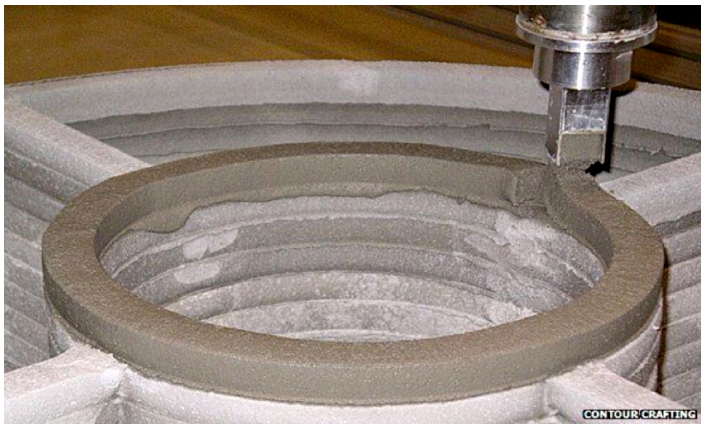
Performance Goals

In 2004, the University of Southern California delivered a contour crafting system to NASA that supported batch processing of Ordinary Portland Cement-based mixtures. The system known as ACME-1 allowed fabrication of relatively long slender walls. Typical structures fabricated with ACME-1 include a dome structure with interior walls.

Between 2004 and 2007, the NASA/Jacobs team experimented with different nozzle and trowel configurations, initial characterization of optimum rheological ("soft solids") properties, and understanding the differences between commercial off-the-shelf concrete materials and Portland cement, stucco and additives. Significant effort also was spent programming and printing various geometries and experimenting with concrete deposition speed versus concrete cure time and strength to optimize the process.

The project was inactive from 2007 until 2013 (due to funding constraints) at which point USACE contacted Marshall Space Flight Center to express interest in further development of the ACME-1, converting it from a batch process to a continuous-feed process (ACME-2). During batch placement, layers deposited on different days (wet on dry) did not adhere well. But same-day runs (wet on wet) yielded excellent bond strength. This continuous-feed system produced larger structures (though still sub-scale); eliminated poor layer-to-layer bonding; and eliminated discontinuities between the end of one batch and the beginning of the next.

As the technology advanced, preparations for the design of the full-scale system began. The evolution from ACME-2 focused on the transition from sub-scale to full-scale. Many areas requiring further development and detailed evaluation were identified, including selection of an optimized nozzle mobility system (gantry versus truck/boom arm versus robotic arm versus other); selection of components for the larger system (pump, motors, drive system) to meet print speed and volumetric flow rate requirements; hose management (minimizing vertical pumping and curves); positional accuracy; system mobility; cleaning; and assembly/disassembly.



Close-up of subscale concrete dome under construction (top) using Contour Crafting method, then completed (bottom), at MSFC Additive Construction Research and Development Laboratory.
IMAGE CREDITS: CONTOUR CRAFTING.

Toward New Heights

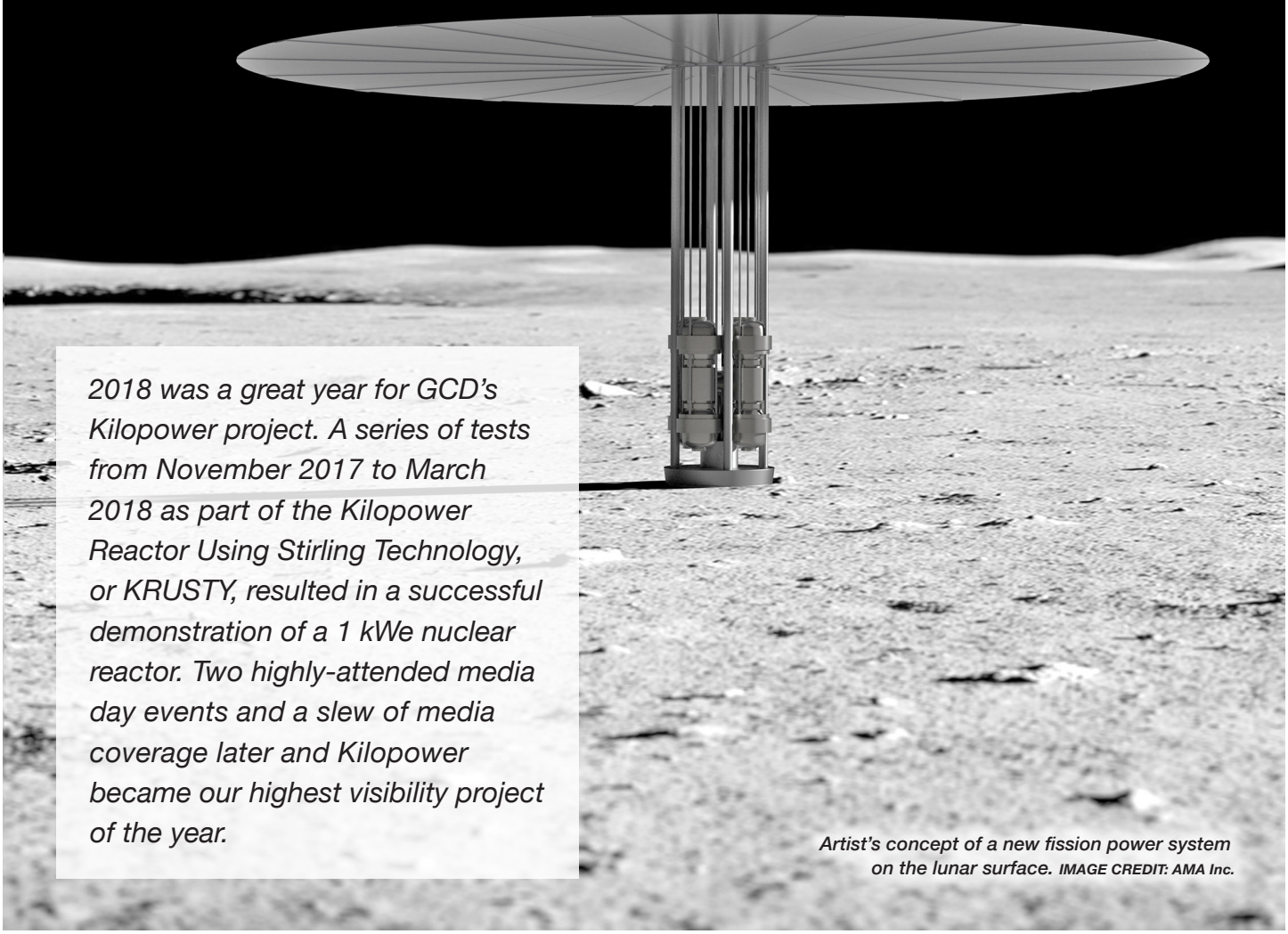
ACES-3 represents a unique asset for the U.S. military. The ability to transport, deploy, and use a large-scale concrete 3D printer opens the door for rapid development of numerous infrastructure elements that do not have to be transported in-theater.

It is expected this technology will continue to generate new applications and resources for the military engineer…and beyond.

Article first published in the July-August 2018 issue of **The Military Engineer***; Vol. 110, No. 715. Reprinted with permission of the Society of American Military Engineers.*

A powerful year:

Kilopower is the first step towards truly astounding space fission capabilities.



2018 was a great year for GCD's Kilopower project. A series of tests from November 2017 to March 2018 as part of the Kilopower Reactor Using Stirling Technology, or KRUSTY, resulted in a successful demonstration of a 1 kWe nuclear reactor. Two highly-attended media day events and a slew of media coverage later and Kilopower became our highest visibility project of the year.

Artist's concept of a new fission power system on the lunar surface. IMAGE CREDIT: AMA Inc.

Project Manager Dionne Hernandez-Lugo answers some questions about the Kilopower project.

Q: How would you describe the past year as project manager of Kilopower?

A: Exciting and challenging: the Kilopower Project in the past year has demonstrated that a fission nuclear reactor can be designed, built and tested in the United States. This year has been the conclusion of 3.5 years of hard work by this team of engineers from NASA (Glenn Research Center and Marshall Space Flight Center) and DoE (Los Alamos National Laboratory and Y12).

Q: Did you know it would garner as much attention as it did from the press/public?

A: I joined this project seven months ago as the project manager, and at the time I decided to accept this position, I knew the technology was exciting; but it came as a surprise the amount of attention this project has had in the press and in the public. All of the attention is excellent for the possible continuation of the project as a demonstration mission. However, after being here and working day to day with this team, it is not a surprise that the impact of this project and all of NASA can achieve by having a fission nuclear reactor as part of the research and technology portfolio.

Q: What do you consider the project's biggest accomplishment?

A: The biggest accomplishment by this project has been going through the engineering design and working with a multi-agency team to build of a fission nuclear reactor. It was a great example of teamwork to complete a full power nuclear test. This demonstration serves as a ground test for future flight Kilopower reactor developments.

Q Have you dealt with any negative criticism? If so, how did you handle it?

A: I would not say we have dealt with any specific negative criticism; however, we are aware that the idea of flying a nuclear reactor is a sensitive topic. People have different opinions about nuclear reactors, but with the Kilopower system one of the inherent safety features of this system is the reactor would not be turned on until in space. Regardless, we are very conscious of safety and will continue to follow all NASA safety procedures related to nuclear material.

Q. What's next for Kilopower? Can you discuss the bridge effort?

A: Kilopower in 2018 was funded to continue under STMD/Game Changing Development Program as a bridge activity to study system design options and technology development activities associated with a design for scaling up to a 10kWe system for surface power applications. The bridge will also serve as a formulation step for potential continuation under the STMD/Technology Demonstration Mission (TDM) Program as a 1-3 kWe payload on a Lunar Lander Demonstrator mission. The Kilopower TDM on the moon can potentially demonstrate a system with optimize components scalable for future human exploration and science missions. Kilopower is particularly attractive for missions to permanently shadowed locations, such as craters, where solar power is difficult to obtain and the lifetime requirements exceed battery capabilities.

Q: When will we see the concept be tested in space?

A: With the recent space policy directive for NASA to return to the Lunar surface, we are looking at a mission possibly as early as the mid-2020's. As part of the TDM, a Kilopower system could be payload on a mid-size lander to serve as power source on the surface of the Moon for Exploration and Science mission applications.

Here are the stats

- KRUSTY was the first nuclear-powered operation of a truly new fission reactor concept in the U.S. in more than 40 years.
- The testing provided valuable experience and data, which will help benchmark codes to design fission systems well beyond Kilopower.
- KRUSTY demonstrated the passive reactor operation of the Kilopower reactor class.
- KRUSTY showed that demonstrating a space reactor is not inherently expensive. (A new reactor concept was designed, fabricated and tested for less than $20 million.)
- Demonstrated a space reactor concept that can be used for near-term space science and exploration.

GCD's 2018 BIG Idea Challenge:

Power for the "Other Planetary" Experience

By Denise Stefula

In a March 2018 press release, NASA announced Norwich University as the winning team in the Game Changing Development Program's third Breakthrough, Innovative and Game-changing (BIG) Idea Challenge. The University of Colorado Boulder team was awarded second place.

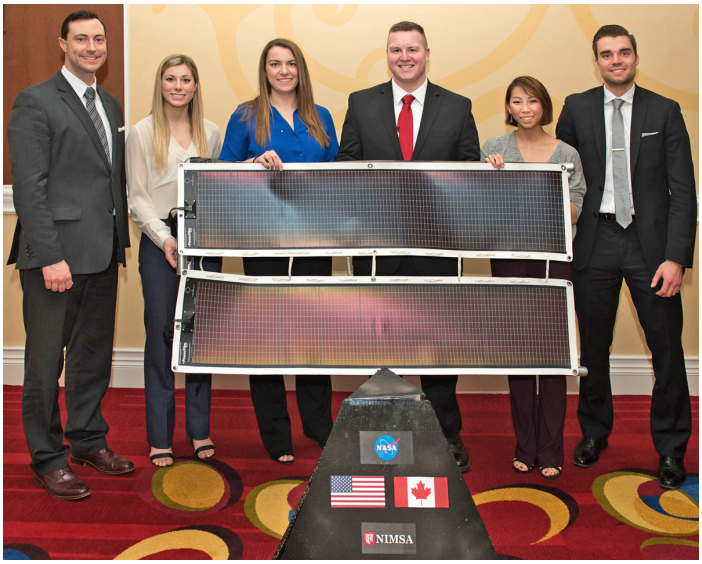
The BIG Idea Challenge is an engineering design competition during which NASA enlists university teams from across the nation to develop creative solutions to some of the agency's most relevant challenges. The most recent design competition sought innovative ideas for large power systems that can be deployed autonomously to and reside on the surface of Mars.

The five finalists each proposed completely different, unique and viable concepts. They presented their concepts in an intense design review during the 2018 BIG Idea Challenge Forum held March 6 and 7 in Cleveland, Ohio.

"This year's BIG Idea Challenge brought some fresh and exciting ideas on Mars solar arrays that gives us greater confidence to move forward toward human Mars missions," said Lee Mason after the winners were announced. Mason is principal technologist for power and energy storage with NASA's Space Technology Mission Directorate, and a BIG Idea judge. "The two winning teams provide a nice diversity in their design and operational construct: one focusing on inflatables, the other on composite booms."

Jeremiah McNatt

Jeremiah McNatt, a senior photovoltaics engineer with the Photovoltaics and Electrochemical Systems Branch at NASA's Glenn Research Center in Cleveland, Ohio, mentored students from the two winning teams. McNatt speaks fondly of having great mentors when he started out, and he feels strongly not only about paying that forward, but also about the personal reward he experiences from the interaction.



The Norwich University team, led by Dr. Brian Bradke, proposed an innovative flexible solar array design using inflatable booms to provide a compact stowed configuration and low launch mass. The team made an impressive inflatable model that validated their packing and deployment concept. IMAGE CREDIT: NASA

"I find that I get fresh perspectives on approaching technical challenges and an introduction to new technology and methods," says McNatt. "The enthusiasm of the students helps to recharge my energy and passion in projects."

While the challenge focus was for deployable solar arrays that could be used on Mars, McNatt says the internship project is to develop a high power solar array for a lunar mission.

"Because the agency is currently focusing on lunar missions, I thought having the students study lunar solar array architectures would be a great project," says McNatt. "The students were presented with a set of guidelines and then led themselves down a development path. They started by looking at various mission locations and concepts, which led them to their current design. They will continue to refine that design throughout the summer."

McNatt says the interns functioned largely as an independent team, checking in at regular intervals daily and weekly for progress updates and reviewing next steps. He described them as strong students who worked very well as a cohesive team and McNatt.

When asked what he hopes interns will take away from the experience, McNatt says, "I think the best skills that the interns can learn while here are networking and teamwork. Also, I want the interns to take away a sense of accomplishment and pride in the work that they did."

McNatt also shared his own advantages from the experience: "There are multiple benefits of having interns work on research and engineering development projects. They bring energy and new methods and technology to a project. They also bring a bit of an outsider's perspective and a curiosity, which can lead to new revelations. Many of my past interns have gone on to graduate school because of an interest in research that started during their internships."

The BIG Idea Challenge is sponsored by NASA Space Technology Mission Directorate's Game Changing Development Program, and managed by the National Institute of Aerospace.

The University of Colorado Boulder team, led by Dr. Kyri Baker, developed an autonomous foldable solar array concept that secured them the runner-up position in this highly competitive challenge. Their approach leveraged extremely lightweight/flexible composite booms that could be wrapped around a centralized hub and then unwound for deployment on the Martian surface. IMAGE CREDIT: NASA

Input from some of our interns

Though their internship is over, a few of our BIG Idea Challenge interns answered some questions about the work they are doing. Of those we spoke with, they all received their Bachelor of Science degrees in Engineering in May of this year, and are just 22 and 23 years old.

Tyler Azure is from Lino Lakes, Minn., and attended Norwich University. Azure says he became involved with the BIG Idea Challenge as part of my senior design project for my university. "Our project mirrored the requirements of the challenge and we were given the opportunity to submit our design to the competition." Azure is pleased that his work will be used to help power both lunar habitats and rovers to explore the lunar surface. "This work is important," he says, "because it will get NASA closer to manned lunar missions and missions to other planets." Azure hopes to one day be a professional design engineer.

Laurie King is from Waddington, New York, and attended Norwich. King also got involved in the BIG Idea Challenge based on a senior project. When asked what she enjoys most about the internship, King had plenty to share: "Personally I enjoy both the social and educational aspects of this opportunity. I have met some very diverse and interesting people here at NASA and enjoy getting to know them and

Above: BIG Idea interns, clockwise from bottom left, Laurie King, Eric Robinson, Nicholas Glascock-Illescas, Tyler Azure, Charlene Huyler.
IMAGE CREDIT: NASA

how they got where they are today. I think it is helpful to see that everyone has very different paths to get where they want to go. I also enjoy the educational benefits of this opportunity, during the time I was working on the original BIG Idea challenge (focused on Martian solar arrays) I was amazed from all of the research I did how many different technologies were possible and how many were already being implemented. It shows me how ideas that seem to be unachievable can actually be made possible." King grew up on a large dairy farm and wants to apply her engineering expertise in the agriculture field, making that work more efficient for farmers given the challenges she sees them facing in the future.

Charlene Huyler is from Westport, Mass., and also attended Norwich. Huyler feels their work is important because, she says, "Any proof of water on the lunar surface would be a huge milestone. We are designing and prototyping autonomously deployable solar arrays for the lunar poles. The design must incorporate power beaming to a rover to allow exploration of craters. Exploration to the bottom of Shackleton crater would allow scientists to confirm if there is frozen water at the south pole of the moon." Huyler is interested in joining the U.S. Air Force and one day reach a captain's rank, while still working and developing new and innovative technologies. After the Air Force, she's interested in working for either the Pentagon or NASA.

Eric Robinson is from Flemington, New Jersey, and attended University of Colorado, Boulder. He says from a young age, he wanted to build something that would go to space. "I love the engineering design process from brainstorming all the way to building and testing," says Robinson. "When my teammate, Nick Glascock, invited me to join him and his partners, I saw it as a great way to introduce myself to aerospace design while at the same time think of interesting, innovative solutions. Nick originally discovered the challenge and assembled a "dream team" one-by-one. I feel lucky to be a part of a team that is so creative and persistent to solve such a difficult problem." Robinson would like to design components for spacecraft or possibly do testing/systems engineering.

Huyler said she could not pinpoint any one thing she was enjoying the most about the BIG Idea Challenge internship. "I am enjoying the whole experience altogether. It's a great environment and I really like the people here. Everyone seems more than willing to help one another out with anything."

Robinson ended his interview echoing in large part what all the students expressed a sense of about the opportunity: "I enjoy the incredible technologies that I am learning about. It is an amazing opportunity to be surrounded by these scientists and engineers at NASA, people who are on the forefront of space research. I learn fascinating new things every day about the science that goes on behind every NASA project. I want to leave this experience with the motivation and desire for knowledge that I see at NASA. I get the feeling that everyone here genuinely wants to advance human knowledge and push the limits of what we can create. If I can take that attitude with me for the rest of my career, then I believe I would be incredibly successful."

Participation in the BIG Idea Challenge is open to teams of undergraduate and graduate students studying in fields applicable to human space exploration (i.e., aerospace, electrical, and mechanical engineering; and life, physical, and computer sciences). The challenge allows students to incorporate their coursework into real aerospace design concepts and work together in a team environment.
The BIG Idea Challenge is aligned with NASA's goal to increase the capabilities of the nation's future workforce through participatory, immersive educational experiences. This includes the challenge prize, which offers NASA internships to members from the winning team.

Competing Teams

First place

Norwich University
Title: Norwich Inflatable Mars Solar Array (NIMSA)
Advisor: Dr. Brian Bradke

Second place

The University of Colorado, Boulder
Title: MAFSA: Mars Autonomous and Foldable Solar Array
Advisor: Dr. Kyri Baker

Other finalists invited to compete at the BIG Idea Forum

The University of Virginia
Title: Photovoltaic Balloon for Autonomous Energy Generation on Mars
Advisor: Dr. Mool C. Gupta

Texas A&M University
Title: Solar Cell Umbrellas for Photovoltaic Power on Mars
Advisor: Dr. Magdalini Lagoudas

Princeton University
Title: Horus
Advisor: Dr. Andrej Kosmrlj

There's Science Behind Making the Right Call

By Denise Stefula

Traveling to Mars is an alluring concept for a number of reasons, the most popular of which is to answer the age-old question: Is there life on our distant cousin?

What many find most fascinating is the complicated array of technologies needed just to get off the ground, much less arrive at a planet 33.9 million miles away, what it takes to be a visitor—or potential habitant—the logistics of day-to-day existence on another orb, and sooner or later returning to Earth.

Pondering these things gives rise to many questions. What about launch and crew vehicles, space suits and other vital life support equipment, or implementing a power source? How does one communicate, where will people live and how will they get around? Just these few examples require myriad technologies working together to provide the essentials, all made up of components, hardware, software and other materials constituting whole lists and new questions of their own.

When looking for answers to these questions, who on Earth does one call?

Alicia Dwyer Cianciolo

That would be Alicia Dwyer Cianciolo, an aerospace engineer with the Atmospheric Flight and Entry Systems Branch at NASA's Langley Research Center in Hampton, Va. Cianciolo has participated in nearly every mission to Mars in the past two decades including the 2001 Odyssey orbiter, the 2003 Exploration rovers (Spirit and Opportunity), the 2005 Reconnaissance Orbiter, and the 2011 Science Laboratory Rover, Curiosity.

Much of Cianciolo's work has focused on ensuring spacecraft can safely orbit or land on the surface of Mars. She was a member of the entry, descent and landing (EDL) team that delivered the Curiosity rover to Mars' Gale Crater

in August 2012. Cianciolo's knowledge of the details and complexity of flight missions help to inform and ensure elements of reality are incorporated into concept studies—precisely why she has been involved in the Mars Architecture Study for EDL technologies.

The NASA Strategic Plan 2018 states its spaceflight objective is to "extend human presence deeper into space and to the moon for sustainable long-term exploration and utilization." An architecture study is one example of focusing efforts on specific combinations of technologies and order of operations that may enable these human missions.

"It is not the only answer," says Cianciolo, "but it attempts to combine the latest technologies with a common set of ground rules and assumptions to achieve the goal of establish ing a field station on Mars. We don't know which technologies will be right, but the key is to be open to new ones and new applications of existing ones."

Trying to determine which technologies should be selected to continue researching and developing is no easy feat, though.

Cianciolo explains that engineers are looking for commonalities among various architectures and then advocate for technology advancements (such as engine design or guidance, navigation and control systems) that benefit multiple architectures. Because most technologies under advancement with the Game Changing Development (GCD) Program have the cross-cutting potential advantageous to NASA's spaceflight objective, Cianciolo keeps an eye on several GCD projects.

"We maintain awareness of and update our assumptions based on work being done in GCD projects, including High Performance Spaceflight Computer, Kilopower, Extreme Environments Solar Panels, Entry Systems Modeling (ESM), Cryocooler, SPLICE, and MEDLI2."

Architecture studies can include anything from ground systems and rockets to space suits and living structures, and anywhere in between. NASA periodically publishes the results, with a new update anticipated for internal release late in 2018, the Mars Design Reference Architecture, or DRA6.

Recently, in conjunction with the Mars Study Capability Team (formally the Mars Architecture Team), Cianciolo has coordinated elements of several more studies. "In FY17, the Space Technology Mission Directorate's (STMD) EDL architecture study identified four EDL vehicle point designs to deliver the Mars Architecture defined payloads," says Cianciolo. "In FY18, the study was split to address specific EDL subsystems: Navigation under the GCD SPLICE project; entry guidance using direct force control under GCD ESM guidance, navigation and control project; and vehicle engine computational fluid dynamics analysis under the STMD Descent Systems Study."

While working on the humans to Mars mission concepts, Cianciolo has continued to ground advanced concepts in reality by supporting current Mars flight projects like MAVEN and InSight. She was also involved with an ISS-released small satellite project that incorporated a modulated deployable called Exo-Brake, a technology developed under GCD's ESM project.

Despite the complexities of the many varied technology architectures and paths to potential success in space exploration, it seems there is no element to meeting NASA's strategic goal for human scale EDL at Mars that Cianciolo has not touched in some way.

Alicia Dwyer Cianciolo currently works remotely from Kansas City, Mo., where she lives with her husband and four children. "When I am not trying to land people on Mars, I serve as chief cook and taxi driver."
IMAGE CREDIT: ALICIA DWYER CIANCIOLO

"This work is challenging because we often embark on analysis paths that do not lead where we think they will go," says Cianciolo. "The work is rewarding, because with every study, we learn things about the human scale Mars EDL system that we did not know before. We continue to try to move the technology along, if ever so slowly."

Support for the humans to Mars EDL projects comes from several NASA centers including Langley Research Center in Hampton, Va., Marshall Space Flight Center in Huntsville, Ala., Johnson Space Center in Houston, Texas, and Ames Research Center in Mountain View, Calif.

Where are they now?

A typical lifespan for a GCD project is anywhere between 2-5 years. The purpose and mission of the program is to be the supportive structure in what is often referred to as the "valley of death," or the mid technology readiness level in between ground testing and flight testing—where many projects get stuck.

Here's a look at some of the projects GCD helped "graduate" to the next level.

CHIEFS

CHIEFS—or Convective Heating Improvement for Emergency Fire Shelters—came into the GCD portfolio in 2014 at a technology readiness level 2. The goal of the project was for NASA to collaborate with the USDA Forest Service (USFS) and leverage each other's experiences and technologies to improve the effectiveness of emergency fire shelters for wildland firefighters ultimately saving lives.

During the project's three years within GCD, multiple shelter designs and component layups were tested in facilities ranging from small-scale propane flame rigs at NASA Langley to full-scale shelter combustion test facilities at NC State University and the University of Alberta, Edmonton, Canada. Controlled wildfire testing was also conducted in the Canadian Northwest Territories to evaluate candidate shelter designs. After a number of design improvements, a Generation 2 shelter concept was fabricated at the end of FY17.

CHIEFS project manager Josh Fody said that while the project did have other sources of funding, such as the NASA Innovation Fund, the work on the fire shelters would not have been possible without GCD.

"It has been exceptional to be a part of an effort so small and agile, which put intelligent and seasoned engineers with world-class experience to such good use, and to have such a large and tangible result to show for our efforts," said Fody.

The investment was well worth it. This summer, the USFS conducted final trials of three candidate replacement shelters; two of which are CHIEFS designs. The shelters are being carried by firefighters in the field and will be recalled this fall and inspected for wear and tear and any degradation in thermal protection. A final decision on an improved shelter will be made by the USFS after these tests.

For Fody, this has been a life-changing experience, and the best outcome would be the USFS adopting the NASA fire shelter design and lives being saved.

"Also very important to me, is that our research can hopefully be used by other entities in the U.S. that can learn from our findings and reports and help keep the U.S. economy a leader in global technology," said Fody.

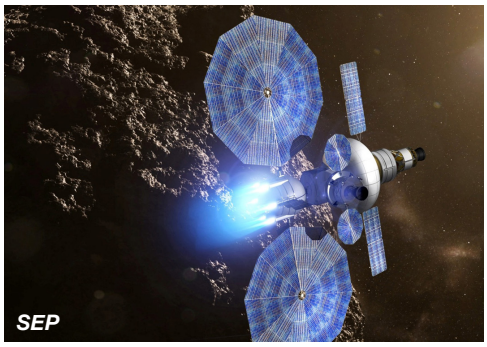
A firefighter works with a CHIEFS prototype during a training exercise near Missoula, Montana. The green pack hanging from the firefighter's backpack is the CHIEFS "Single."

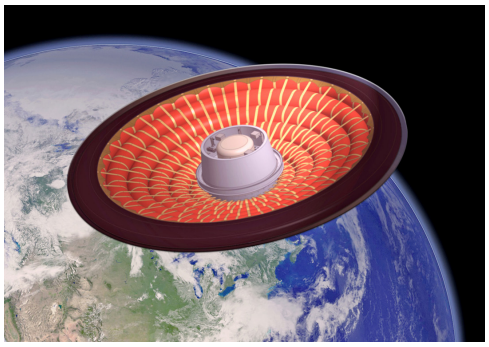
IMAGE CREDITS: IAN GROB/TONY PETRILLI MTDC (US FOREST SERVICE)

GCD "graduates" moving on to TDM

The Technology Demonstration Missions (TDM) program seeks to mature deep space optical communications systems—and a variety of other ground-breaking technologies—for infusion into government and commercial programs, dramatically extending human capabilities and opportunities in space.

Solar Electric Propulsion (SEP)
The SEP project began in GCD, developing large, flexible, radiation-resistant solar arrays that could be stowed into small, lightweight, more cost-effective packages for launch. It was a part of the GCD portfolio from 2011-2013 and during that time, it advanced from a TRL 3 to a TRL 4. The deliverables included mission concepts, interim design reviews for solar arrays and thruster design review. Within the TDM program, the project is developing critical technologies to enable government and commercial customers to extend the length and capabilities of ambitious new exploration and science missions. Technologies the project is developing and demonstrating, include advanced solar arrays, high-voltage power management and distribution, power processing units, high-power Hall thrusters and spaceflight diagnostics for measuring system performance.





Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)
LOFTID is a follow-on to the former GCD-funded technology Hypersonic Inflatable Aerodynamic Decelerator, or HIAD. The Low-Earth Orbit Flight Test of an Inflatable Decelerator, or LOFTID, is demonstrating a truly crosscutting technology for atmospheric entry. LOFTID is demonstrating a large aeroshell entry from orbit, and it is applicable to any destination with an atmosphere. Benefits of using the inflatable decelerator design for a variety of space applications include landing more mass; landing at higher altitude locations; enabling better utilization of the full volume of a launch vehicle fairing by stowing forward of the spacecraft (rather than encapsulating it within a rigid aeroshell) at launch; and enabling more access to spacecraft while integrated in the launch vehicle stack.

Deep Space Optical Communications (DSOC)
DSOC spent four years in the GCD portfolio—from FY12 to FY15—and progressed from a TRL level 2 to a TRL level 5. Its goal was to develop key technologies needed for implementing a technology demonstration of optical communications from deep space ranges. Upon closet, the project delivered the following: Isolation Pointing Assembly (IPA); Photon Counting Camera (PCC); Laser Transmitter Assembly (LTA); optical assembly and electronics needed to assemble a representative flight; and a ground photon counting detector array of a size compatible with a large aperture collector such as the Hale telescope at Palomar Mountain. In FY16, DSOC was selected for further development as part of the Technology Demonstration Missions program.

The DSOC payload, which will undergo ground validation testing in 2018-19, is scheduled to launch in 2022 aboard NASA's robotic Psyche mission. Set to study the giant metal asteroid known as "16 Psyche" in our solar system's main asteroid belt, the investigation will help scientists understand how planets and other bodies separated into layers—cores, mantles and crusts—early in their formative histories. Aided by a Mars gravity assist in 2023, Psyche will reach its destination in 2026, at which point the DSOC payload is expected to help transmit the clearest, quickest information ever obtained from an expedition into the solar system.

IMAGE CREDITS: NASA

Intern Steven Green demonstrates his progress on the technical assessment tool to Program Element Manager Stella Harrison.
IMAGE CREDIT: NASA

Game Changing Development Technical Assessment Tool

The mission of NASA's Game Changing Development (GCD) program is to identify and mature innovative and high-impact capabilities and technologies that align with Agency needs. Technologies within the GCD portfolio typically range from a Technology Readiness Level (TRL) between 3-5. This range is often referred to as the "valley of death"—where projects, in the mid-development phase, get stuck and don't progress to relevant environment testing. Periodically assessing a project's TRL is necessary to ensure the project will get to the next level and reach flight testing or mission infusion.

To make the assessment process easier, GCD program managers tasked intern Steven Green, a computer science major at Christopher Newport University in Newport News, Va., with developing a more efficient method of assessing the readiness levels of projects and their respective elements. Green developed the Game Changing Development Technical Assessment Tool, a user-friendly software application for project personnel to easily assess project technology and tasks TRLs, Software Readiness Levels (SRL) and Manufacturing Readiness Levels (MRL), along with their Advanced Degree of Difficulty (AD^2) level.

Utilizing Python's Tkinter toolkit in parallel with other modules, Green created an aesthetic graphical user interface and a flowing survey-style application that allows saving, loading, and report submission for a simple overview of the project.

GCD projects are required to complete TRL assessments at the onset of the project and typically each year they are active.

Though it isn't mandatory they use the new tool to assess their project, Stella Harrison, GCD Program Element Manager and point of contact for the app, thinks they should give it a try.

"The Technical Assessment Tool was designed to have a more methodical approach to assessing not only TRL, but Software Readiness Levels and Manufacturing Readiness Levels," said Harrison. "This allows project managers to determine their project's level of readiness in an efficient step-by-step matter."

The tool is available as a downloadable executable on SharePoint in the GCD Program dashboard.

Kilopower media events reach millions

NASA and its partners hosted a news conference Thursday, January 18, at the National Atomic Testing Museum in Las Vegas, to discuss the Kilopower project, which aims to demonstrate space fission power systems technology that has the potential to enable future crewed surface missions to the moon, Mars and beyond.

A second media day was held May 2, at NASA's Glenn Research Center. After an overview presentation, an expert panel consisting of Glenn's lead engineer, Mr. Marc Gibson, and Dr. David I. Poston, reactor designer from Los Alamos National Laboratory went over the Kilopower system design and the successful full power test of the Kilopower Reactor Using Stirling Technology (KRUSTY) experiment March 20-21. Joining the panel was Mr. Jim Reuter (right), acting associate administrator of Space Technology, and Mr. Pat Cahalane, principal deputy director of Safety, Infrastructure and Operations at the National Nuclear Safety Administration to address NASA- and Department of Energy-specific questions. STMD

Deputy AA of Programs Therese Griebel also attended. The event was covered by national and international media and reached more than 2 million people on social media. After the presentations, media personnel had the opportunity to tour the Kilopower Laboratory, Stirling Laboratory, Electric Propulsion Laboratory and the SLOPE Laboratory.

IMAGE CREDIT: NASA

GCD supports The Composites and Advanced Materials Expo

The GCD program supported The Composites and Materials Expo in Orlando, Fla., in December. The Additive Manufacturing Project sent hardware and displays and we discussed the future role NASA has in advancing materials for deep space exploration. IMAGE CREDIT: NASA

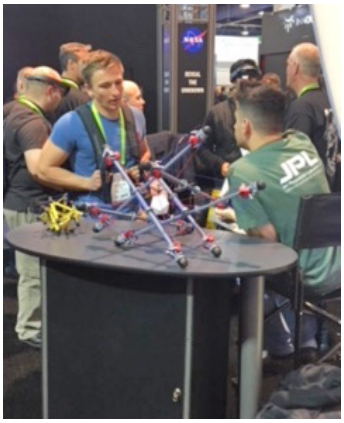
Emerging technologies showcased at NETS conference

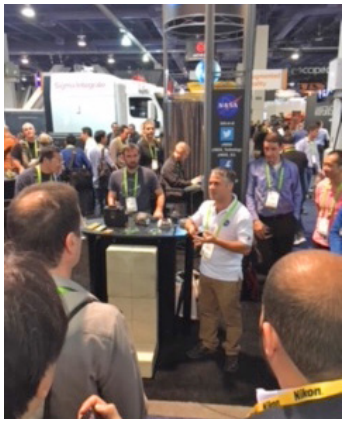
Kristen Spear (GRC), Janet Salverson (MSFC) and Amy McCluskey (Langley) staffed an exhibit at the Nuclear and Emerging Technologies for Space (NETS 2018) conference held in Las Vegas Feb. 26-28. Engineers from GCD projects Kilopower and Nuclear Thermal Propulsion presented during several track sessions. NASA STMD Principal Technologist Lee Mason and NASA STMD Chief Engineer Jeff Sheehy from HQ also presented. IMAGE CREDIT: NASA

GCD projects showcased at large events

GCD supported the Consumer Electronics Show (CES) in Las Vegas and the AIAA SciTech Conference in Kissimmee, Fla., Jan. 9-12. At CES (below), SuperBall Bot and PUFFER drew large crowds, and ADEPT was featured at SciTech. Together, the events drew 200,00 people.

IMAGE CREDIT: NASA





New exhibit featured at USEF

GCD supported the NASA Agency-level USA Science & Engineering Festival in Washington, D.C. in April. Brandon Guethe helped staff a new GCD exhibit featuring Spheros—small robots—that navigate through a maze. The exhibit was a hit and drew in many families and attendees.

IMAGE CREDIT: NASA

Crowdsourcing Expo

Program Manager Drew Hope (above) supported the NASA Crowdsourcing Expo held at NASA Headquarters in May. Hope gave a 15-minute talk describing Game Changing's successful education initiative, the Big Idea Challenge. The event was attended by NASA HQ employees. IMAGE CREDIT: NASA

AIAA Propulsion and Energy Forum

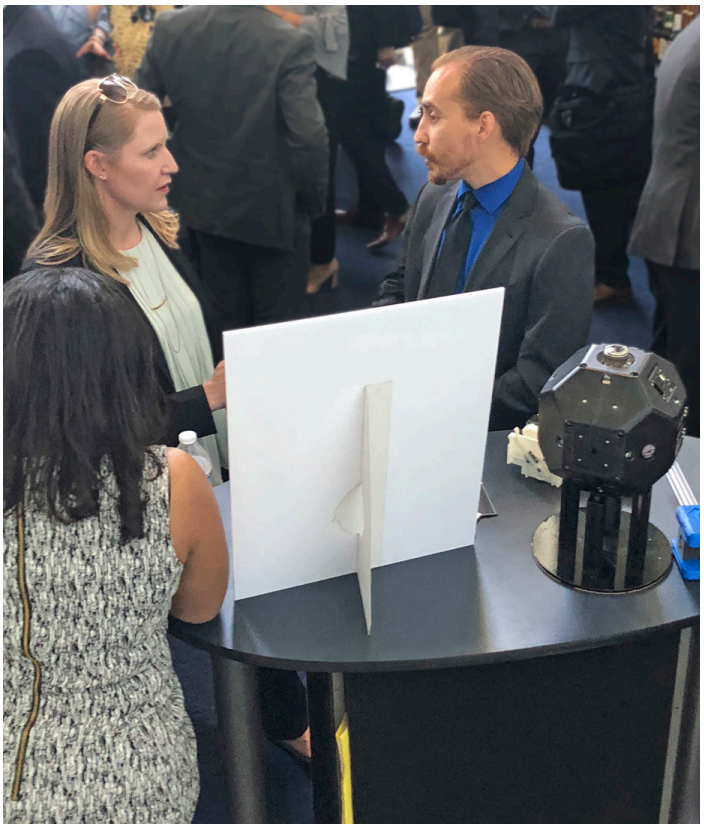
GCD's Kilopower and Nuclear Thermal Propulsion projects (left) were highlighted at the AIAA Propulsion and Energy Forum held in Cincinnati, Ohio in July. Project personnel helped staff the exhibits and presented papers at the conference.

IMAGE CREDIT: NASA

2018 Tech Day on the Hill

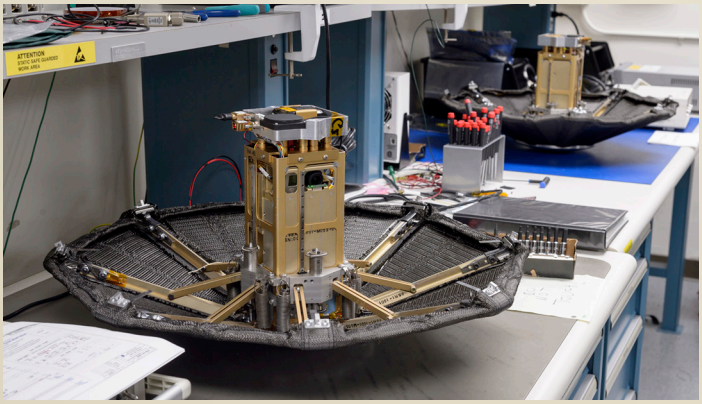
The GCD program and many of its projects supported the 2018 Tech Day on the Hill event in Washington, D.C. this past May. Projects that supported include Astrobee (right), Nuclear Thermal Propulsion, Kilopower, PUFFER (below), Additive Manufacturing Technologies, and ARMADAS.

IMAGE CREDITS: NASA



GCD supports teacher development workshop in Colorado

STMD's LaNetra Tate (from right), Trudy Kortes and Denise Stefula executed a teacher's professional development workshop April 15 at the Wings Over the Rockies Air and Space Museum in Denver, Colo. Approximately 20 teachers attended the presentation of STMD's Technology Demonstration Missions and the Game Changing Development Program. Along with obtaining knowledge of TDM and GCD programs and projects, educators also enjoyed an overview of select NASA educational resources and participated in a hands-on activity featuring GCD's Addictive Construction with Mobile Emplacement project. The lesson was developed and facilitated by April Lanotte, the museum's director of education and a Space Foundation teacher liaison and instructional designer for NASA Aeronautics and STMD. The ACME lesson required finding just the right mix to create the "martian simulant" building blocks that would subsequently be assembled into habitats or other planetary structures. Teachers remarked that the lesson was highly engaging and felt it would be a big hit with students. IMAGE CREDIT: NASA



Top: Twin ADEPT units include a flight unit for the first flight test on September 12 and a spare. IMAGE CREDIT: NASA AMES RESEARCH CENTER/DOMINIC HART

Middle: Final functional checks and power-up procedure are performed prior to close-out for the SL-12 launch. The removed access panels in the upper-left of the image reveal the stowed ADEPT in the payload module. IMAGE CREDIT: NASA

Bottom: The ADEPT and UP Aero teams pose with the ADEPT SR-1 vehicle. IMAGE CREDIT: NASA

Right: "Missile Away!" is final call before launch. IMAGE CREDIT: NASA

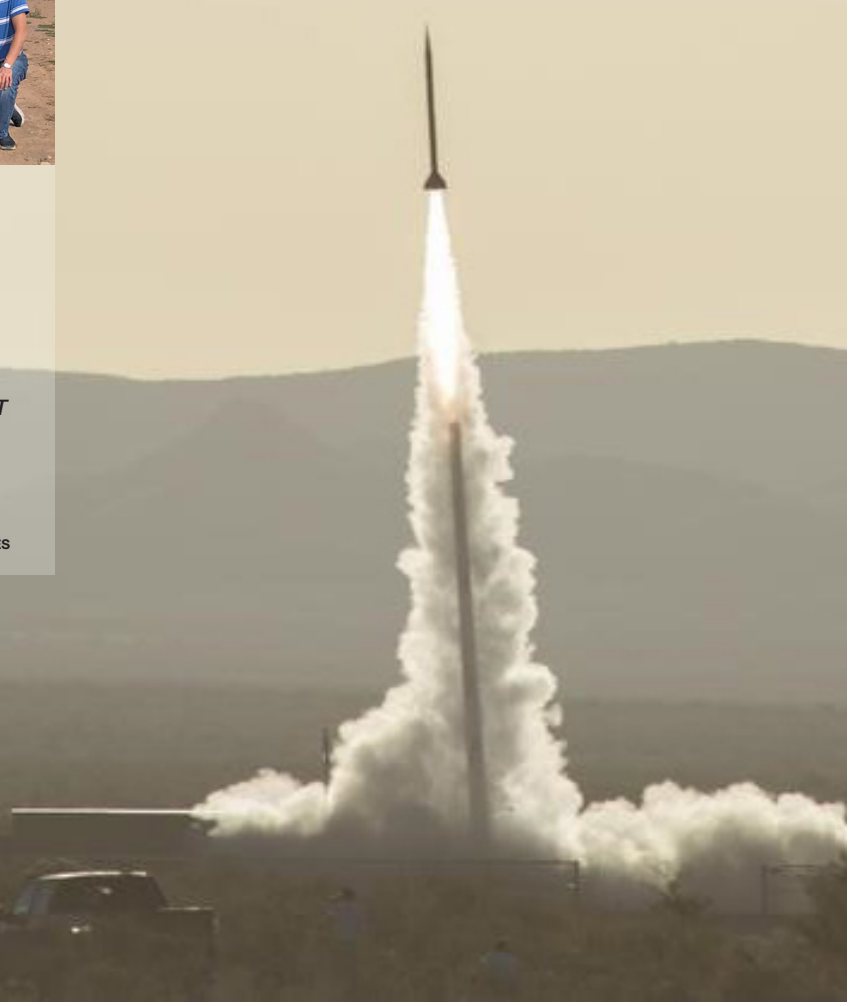
Front cover: UP Aerospace's rocket is poised to launch at Spaceport America in New Mexico. IMAGE CREDIT: NASA/LAUREN HUGHES

Truth or Consequences, N.M—On Wednesday, Sept. 12, at 7:33 a.m. MT—only three minutes after the launch window opened—UP Aerospace's SpaceLoft 12 rocket soared into the sky, carrying with it a space technology demonstration payload called Adaptable Deployable Entry and Placement Technology (ADEPT).

Developed by NASA's Ames Research Center and funded by NASA's Game Changing Development Program, ADEPT is a semi-rigid, umbrella-like heatshield that could be used for planetary lander and sample return missions. The flight tested the heat shield's deployment sequence and entry performance.

The suborbital rocket performed its job without any issues and delivered ADEPT to an altitude over 110 km. Separation and deployment of ADEPT was nominal and ground track reported the deployed ADEPT impacted at the White Sands Missile range approximately 30 miles from the launch site—14 minutes after launch.

The ADEPT payload was retrieved and brought back to launch pad by 4:00 p.m. on launch day. As expected, ADEPT did sustain some damage upon impact. It was traveling roughly 55 mph when it made impact. Three primary data sources (NGIMU, Affordable Vehicle Avionics and GoPro video) were all recovered intact and data recovery was successful for NGIMU and AVA. Over the next few months, the team will analyze the data.



For more information about GCD, please visit gameon.nasa.gov

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NP-2018-09-104-LaRC