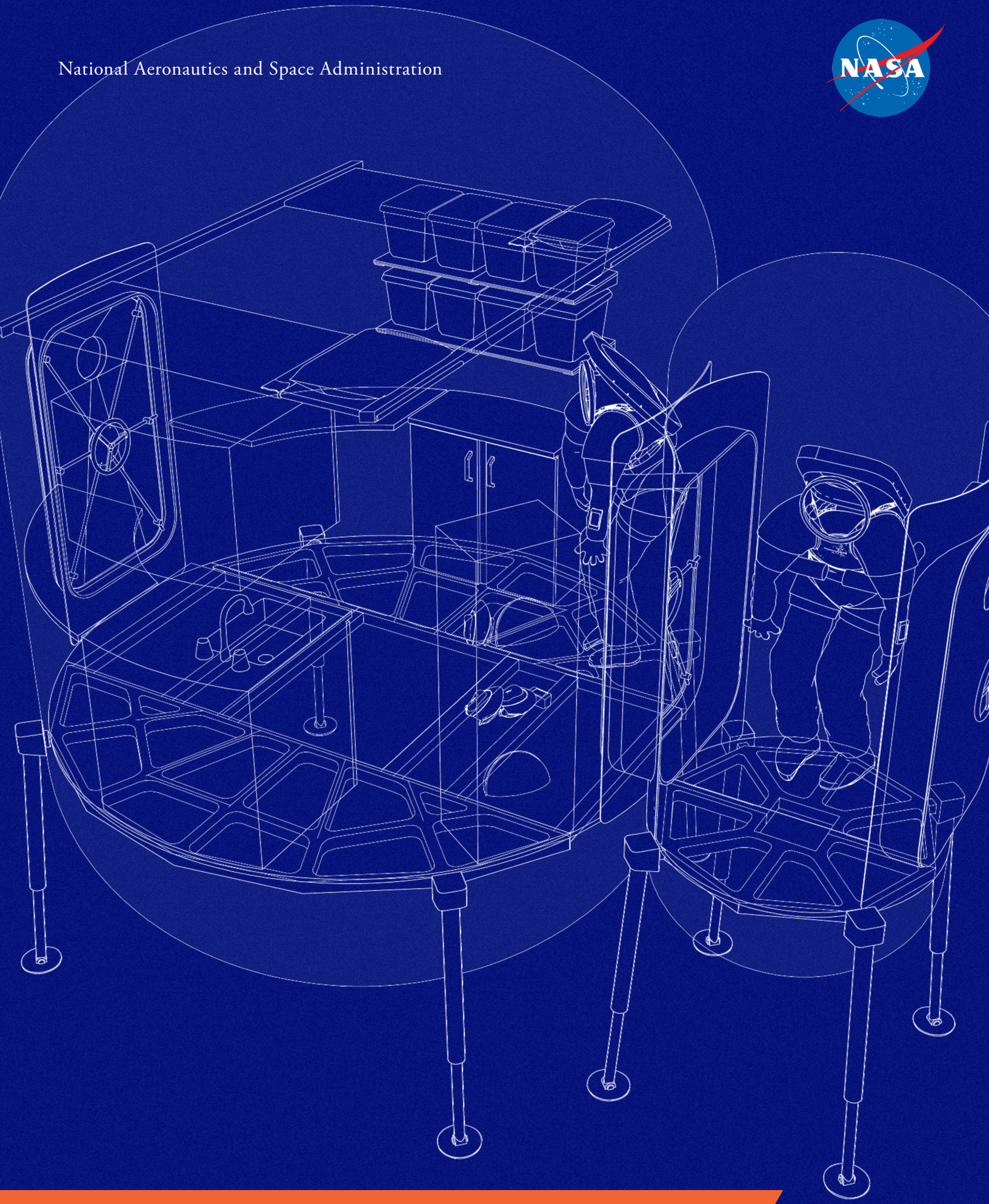
National Aeronautics and Space Administration



Annual SBIR/STTR Report 2016

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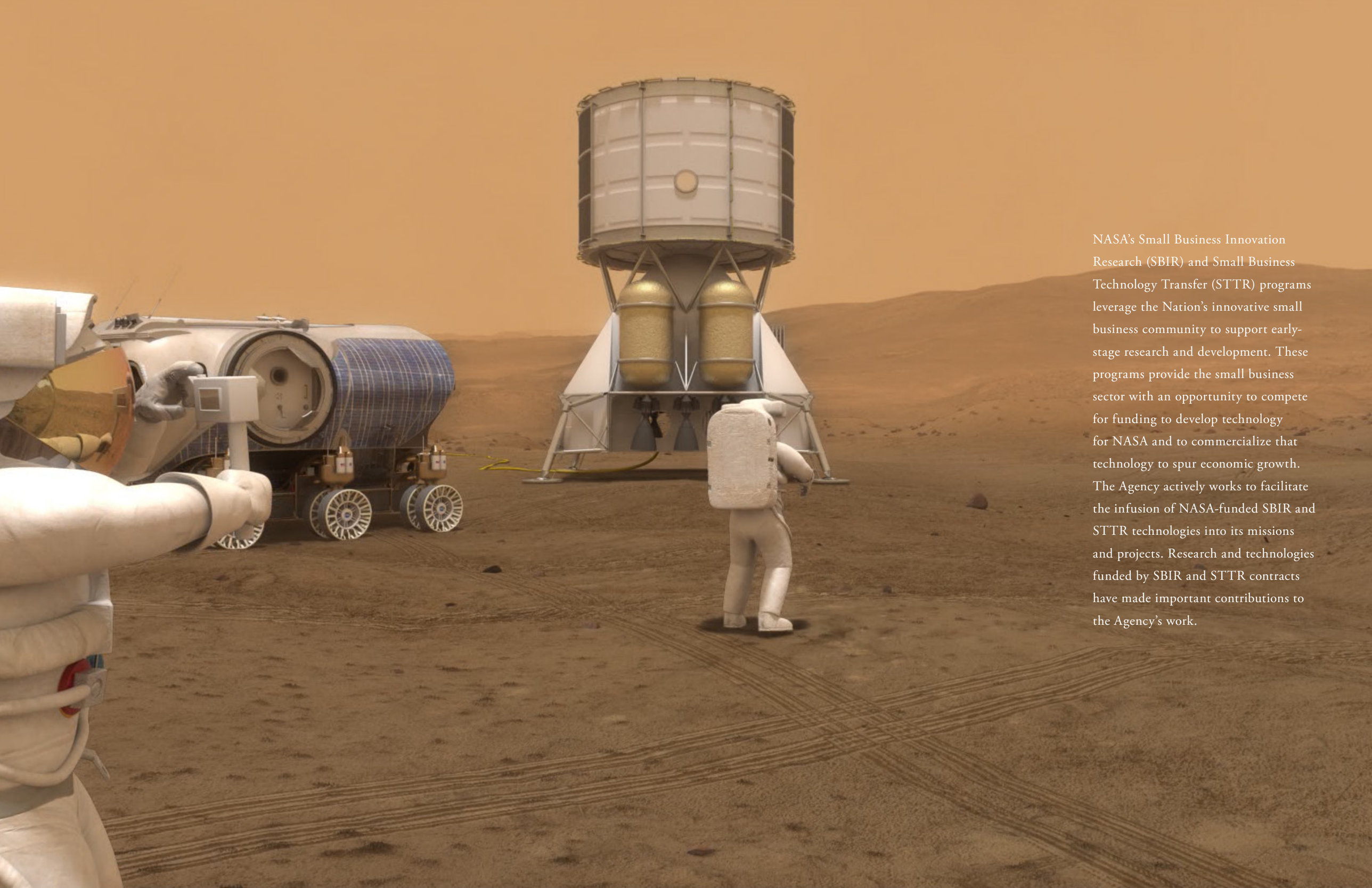
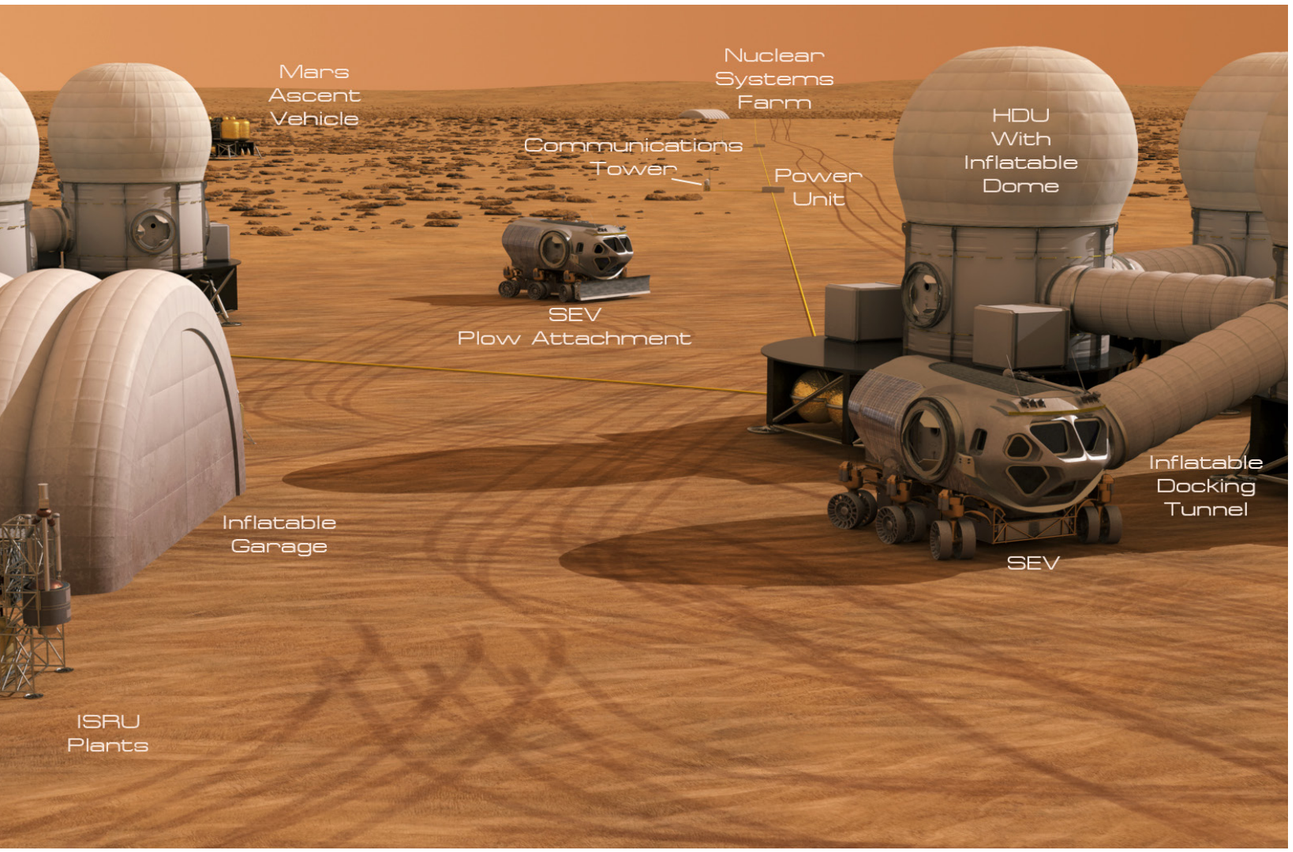


NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs leverage the Nation's innovative small business community to support early-stage research and development. These programs provide the small business sector with an opportunity to compete for funding to develop technology for NASA and to commercialize that technology to spur economic growth. The Agency actively works to facilitate the infusion of NASA-funded SBIR and STTR technologies into its missions and projects. Research and technologies funded by SBIR and STTR contracts have made important contributions to the Agency's work.



Financials & Awards

The SBIR and STTR programs reauthorization annually increases the required rate of investment for each program relative to extramural Agency Research and Development (R&D) beginning in FY 2012 and continuing through FY 2017. In accordance with the SBIR/STTR Reauthorization Act of 2011 (Public Law 112-81), NASA will continue to increase the SBIR investment by 0.21 percent to 3.0 percent of Agency extramural R&D. In addition, STTR funding increased 0.05 percent to 0.45 percent of Agency extramural R&D. Historically, the percentage of Phase I proposals to awards is approximately 13-15% for SBIR and STTR, and approximately 35-40% of the selected Phase I contracts are competitively selected for Phase II follow-on efforts.

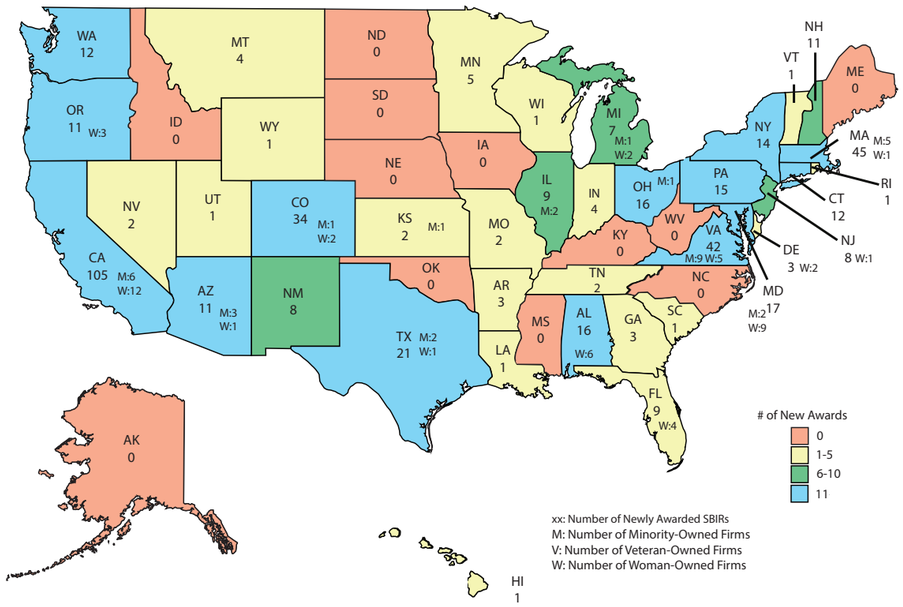
Key Statistics by Program

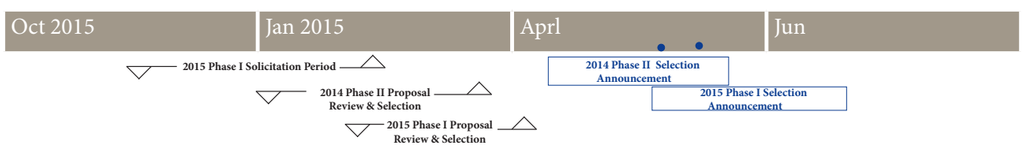
Small Business Business Innovation Research

FY 2015

$152.2M
FY 2015 Annual Budget

$151.2
Obligated



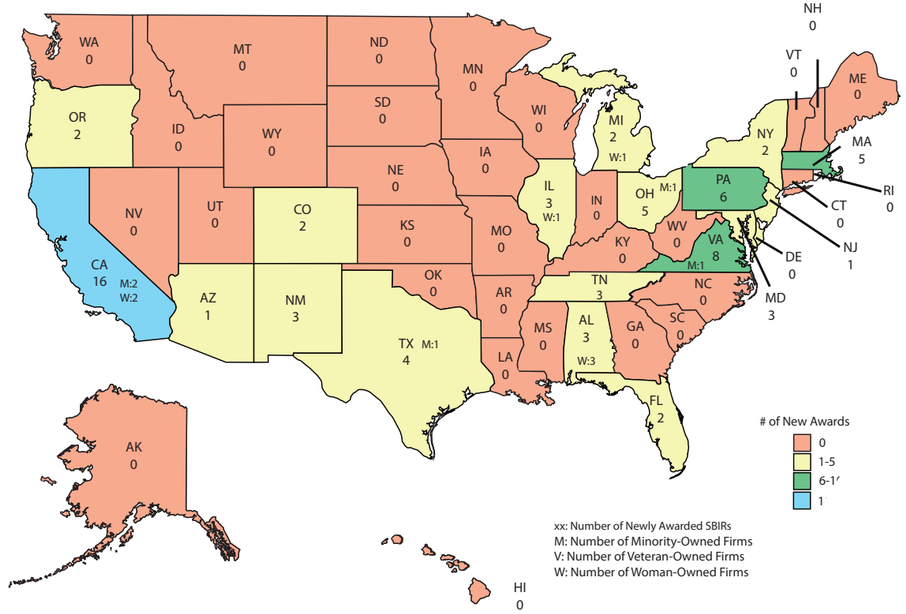


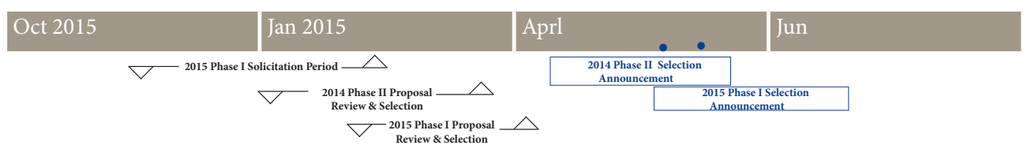
Small Business Technology TRansfer

FY 2015

$21.7M
FY 2015 Annual Budget

$22.11M
Obligated





Highlighted Successes

Success stories capture technology innovations spanning several years, involving multiple industries and dual use technologies with commercial and space applications. A success story also captures the challenging task of transitioning and commercializing their technology from an idea into the market. These companies have successfully created new approaches and solutions resulting in improved capabilities not only for NASA but also for commercial markets.

NASA issues annual SBIR and STTR program solicitations, setting forth a substantial number of topic areas open to qualified small businesses. Both the list and description of topics are sufficiently comprehensive to provide a wide range of opportunities for small business concerns, research institutions, and universities to participate in NASA's research and development programs. SBIR and STTR funding awards are divided into three phases. Phase I awards give small businesses the opportunity to establish the scientific, technical and commercial merit, and feasibility of the proposed innovation in fulfillment of NASA needs. The most promising Phase I projects are awarded Phase II contracts through a competitive selection process, based on scientific and technical merit, expected value to NASA, and commercialization potential. Phase II awards focus on the development, demonstration, and delivery of the proposed innovation. Phase III is the commercialization of innovative technologies, products, and services resulting from a Phase I or Phase II contract. Commercialization includes further development of technologies for transition into NASA programs, other Government agencies, or the private sector. Phase III contracts receive funding from sources other than the SBIR and STTR programs and may be awarded without further competition.

MADE IN SPACE, INC.

While the average consumer is still coming to grips with the mere concept of 3D printing, Made In Space is already miles beyond this seemingly new trend. 220 miles beyond Earth's atmosphere to be exact – where astronauts and NASA personnel at the International Space Station (ISS) are printing tools and other necessities in zero gravity that will open up an entirely new era of off-world additive manufacturing.

PHASE III SUCCESS
$1,493,506 – Phase 1 on-orbit operations complete. Hardware delivered and performed nominally on ISS. Testing specimens returned to Earth and awaiting analysis.

AGENCIES
NASA

SNAPSHOT
The first company to successfully manufacture in space, Made In Space is partnering with NASA to bring 3-D printing and plastics reuse and recycling to the International Space Station. Started with 2 employees. Up to 24 currently.

MADE IN SPACE, INC.
NASA Research Park
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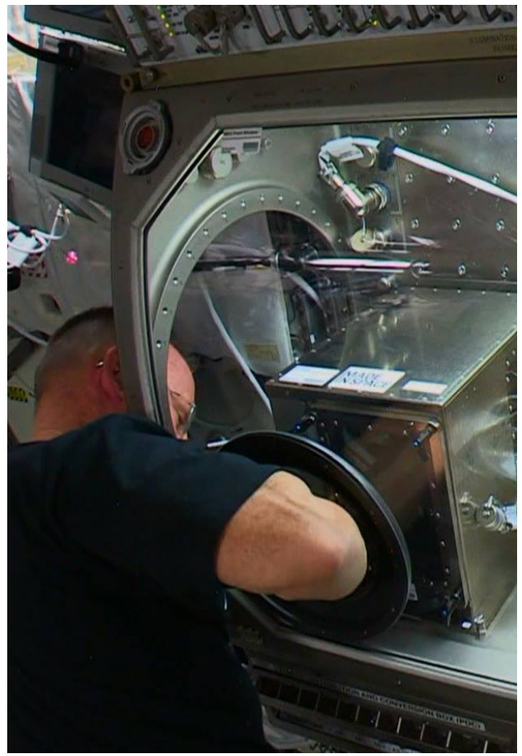
Building 153
Moffett Field, CA 94035

madeinspace.us

Made In Space's Zero-G Printer was launched to the ISS on September 21st, 2014, under a partnership agreement with NASA Marshall Space Flight Center. This accelerated path to success for the California-based company founded in 2010 can be somewhat attributed to its young and naively ambitious staff whose futuristic visions can't help but spread excitement and awe. But it can also be attributed to NASA's Small Business Innovation Research (SBIR) program. With a Phase I and subsequent Phase II award to build an Additive Manufacturing Facility (AMF) for on-demand fabrication in space, Made In Space successfully deployed its innovation and became the first company to manufacture in zero gravity.

"We asked ourselves, what is the fastest, cheapest way to bring manufacturing to space?" explains Made In Space Chief Engineer Mike Snyder. "We spent weeks testing hardware and commercial printers, and flight testing and learning how to make a printer gravity independent. We soon discovered that it was easier and more efficient to build from the ground up."

The realization that they had to construct hardware that can build what is needed in space, as opposed to launching it from Earth, helped the company accelerate its own technology and broaden space development while simultaneously opening up the opportunity for people on Earth to use in-space capabilities. Made In Space's Additive Manufacturing Facility, which utilized these lessons learned, will demo on the ISS this year as part of a recent Phase III contract with NASA as well as be made available to a variety of commercial entities for a broad range of potential applications. And although reaching a Phase III milestone is a huge success even for longstanding companies, Made In Space is not about to stop there.



LEFT: Made In Space's 3D printer being installed on the International Space Station. *Photo courtesy of NASA.*
RIGHT: Aaron Kemmer of Made In Space stares through the windows of the Microgravity Science Glovebox with the Zero-G 3D Printer enclosed.

To understand the direction of the company, one must first grasp the vision of its creators.

"Our overall goal as a company is to help humanity colonize space," adds Snyder. "This is how biology works – we spread like a rapid virus to everywhere we can live. Space is no different. Whether it's the moon, Mars, other moons and solar systems, or free floating on an asteroid, that is the goal of our species."

To this end, the company's innovations all have the common, interwoven theme of utility and practicality in other worlds.

"Obviously you need manufacturing for this to happen, so we tackled that first, as an entry point," says Snyder. "This is the cornerstone of our future work – the things that help colonization. Our first closed loop building system will be the material reclaimer we are working on, so that the material from a 3D printed object can be reused once the original objects breaks or becomes obsolete."

Named the R3DO, this plastic recycling system for creating 3D printer feedstock on-orbit also began as a NASA SBIR project. Made In Space has since flown a prototype on several microgravity flights to verify that it is capable of recycling ABS plastic and extruding feedstock in microgravity. The extruded feedstock was then used to successfully print parts using Made In Space 3D printers. The company hopes to support ISS activities with this technology, as well as several other in-space missions that will significantly enable and improve NASA's exploration efforts.

Across the federal agencies, Made In Space hopes to partner with the US Navy regarding the integration of the R3DO system into Naval operations and logistics. As for commercial potential, the development of a high quality, reliable, and safe recycler will be highly useful to the commercial 3D printing market, which continues to grow exponentially.

The Space Shuttle Discovery housed Techshot's very first innovation – "Chix in Space." The payload was sent into space on the STS-29 mission March 13, 1989.

TECHSHOT, INC.

What is the best way to send chicken embryos into space? Eighth grade student John Vellinger asked himself this very question and soon started building a science fair project to find the answer. This project would not only gain the attention of NASA, but would spawn a company that continues to bring cutting edge solutions to the world of space travel. Vellinger, who would eventually become the Co-Founder of Techshot, entered his concept of a space-based incubator capable of caring for growing chicken embryos, and took home the top prize. Since that fateful science fair project over 30 years ago, the Indiana-based company has been developing complex payloads for microgravity research professionals. Techshot devices have flown aboard parabolic-flight aircraft, sub-orbital rockets, space shuttles, the SpaceX Dragon and are currently in use at the International Space Station (ISS).

PHASE III SUCCESS:
Yearly revenues of $5-8 million

AGENCIES
NASA, DOD (ARMY, NAVY, AIR FORCE, MARINES), DARPA, NIH, NSF

SNAPSHOT
Through a new Phase III contract with NASA, Techshot will become the operators of equipment permanently housed aboard the International Space Station, including an X-ray machine and a high throughput device for conducting research on plants and cell culturing.

TECHSHOT, INC.
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Greenville, IN 47124

www.techshot.com
812.728.8136

The success of the company can be attributed to both the remarkable tenacity of Vellinger and Co-Founder & CEO Mark Deuser, as well as the initial seed money provided by NASA when they needed to get off the ground.

Let's rewind a bit. January 28, 1986. The day was set to be a milestone for Vellinger and Deuser, who were situated in the viewing area at Cape Canaveral, Florida, as the Challenger launch was being watched by the world. For the two young men, this was the day their innovation "Chix in Space" – that same science project John had been perfecting for the past 5 years – would be sent into space. Instead, 73 seconds after liftoff, the disaster that transpired shook the entire world. The devastating loss of the crew and the shuttle was a huge blow to the space industry, and sent the two men back to their respective work. Vellinger was a student at Purdue, while Deuser had been working as an engineer for the Kentucky Fried Chicken headquarters in Louisville, KY. Although the promise of their technology flourishing in space seemed to vanish with the orbiter, Vellinger and Deuser continued to develop their incubator with the promise that they would get a chance to re-fly the payload. On November 1, 1988, they decided to form their company, Techshot, and prepared to send their new and improved "Chix in Space" on the space shuttle Discovery. The STS-29 mission, along with the Chix payload, was successfully launched and executed on March 13, 1989. Techshot was in business.

LEFT: Techshot's Analytical Containment Transfer Tools (ACT2) being packed up and sent out to NASA for launch to the International Space Station (ISS) in June 2015.
RIGHT: Payload Specialist John Glenn works with Techshot's ADSEP hardware aboard Space Shuttle Discovery on STS-95. Photo courtesy of NASA

Not long thereafter, the company learned of the SBIR program.

"It was a great opportunity to satisfy some of NASA's interests and continue to conduct research and create an opportunity to really launch the company," explains Rich Boling, Vice President of Corporate Advancement. "Throughout the program, we were then able to identify military needs and other potential applications for our technology."

Techshot went on to develop its Advanced Space Experiment Processor (ADSEP), which operates in low gravity. The technology provides cell culturing and biphasic, electrophoretic, and magnetic separation capabilities. It shot to fame when Astronaut John Glenn was captured using the technology aboard the Space Shuttle Discovery STS-95. Because of the success, Techshot spun off IKOTECH LLC to further develop the technology, and is today being used in stem cell and diabetes therapeutics.

Another recent spinoff is Techshot Lighting, which produces LED tent lighting for all branches of the military. Other solutions include mechanical, electrical, and software solutions that offer widespread defense applications. For the aerospace industry in which it got its start, Techshot continues to develop microgravity research, processing and analysis solutions.

"We essentially created an innovation engine from the SBIR program," added Boling. "Had we not had help developing some of that risky technology, our products could never have been built. To have that agency help is a really valuable tool, and other small businesses can use that as well."

Today, Techshot is experiencing unprecedented growth. Through a new Phase III contract with NASA, they will become the operators of equipment permanently housed aboard the ISS, including an X-ray machine and a high throughput device for conducting research on plants and cell culturing. Through a payload operations control center on the ground, Techshot will have a staff that mans these consoles to communicate directly with the astronauts using its equipment.

Techshot occupies a 22,000 square foot facility in Greenville, Indiana, approximately 10 miles north of Louisville, Kentucky. The company employs 40 team members, most of whom are mechanical, electrical chemical or software engineers. The high degree of talent graduating from local universities such as Purdue University and The University of Louisville ensures a continued pipeline of employees for the company. Everything the company manufactures, from space hardware, to lighting, to circuit boards, is made in-house, or in the state of Indiana.

"As a small business working so closely with NASA, it's interesting that we're not located in Houston, or in Florida where NASA has operations," says Boling. "Yet we are more capable than ever to deliver solutions."

MAINSTREAM ENGINEERING

Nearly thirty years ago, brand new Florida-based Mainstream Engineering received two small SBIR awards from the U.S. Air Force for the development of spacecraft heat rejection systems. But Dr. Robert P. Scaringe, President and Founder, already had transition on his mind long before that.

PHASE III SUCCESS
$100 million in development contracts from the Army; $20 million/year in revenue from commercial sales.

AGENCIES
NASA, DOD, DOE, DOT & USDA

AWARDS
- 2014 SBA Tibbetts Award for Commercialization
- 2013 Florida Excellence Award by the Small Business Institute for Excellence in Commerce
- Winner 2013 Florida Companies to Watch
- SBA's Prime Contractor of the Year for SE U.S.
- State of Florida Governor's New Product Award
- SBA's Administrator's Award for Excellence

MAINSTREAM ENGINEERING
200 Yellow Place
Rockledge, FL 32955

www.mainstream-engr.com

"Taking a product to market is always the goal for us," explains Scaringe. "Even before we begin the proposal, we are examining the market side of things."

Fast forward to today, and Mainstream Engineering is posting revenues in excess of $20 million a year, and continues to supply solutions to NASA, DOD, DOE, DOT, USDA and the commercial industry with its vast product lines of advanced thermal control and energy conversion technologies.

Mainstream's air conditioning product line – QwikProducts™, which includes dozens of specialized and patented products used in the air conditioning and refrigeration industry, were all originally developed under SBIRs. In 2001, EPA regulations brought about the need to find alternatives for the R-11 and R-113 flushing agents that were used to clean pilots' oxygen breathing systems. When the Air Force released a solicitation to find the solution, Mainstream's response was a biodegradable, non-toxic flushing agent with no long-term environmental or health risks. The flushing solution, trademarked as Qwik System Flush®, found its niche in both the military and commercial sectors and is currently sold by air conditioning trade wholesalers all over the world. Similarly, Mainstream's QwikBoost®, originally developed to improve the performance of NASA thermal control systems, is sold in automobile supply houses around the world (as an ingredient in R-134a+) to boost the cooling capacity of auto air conditioning systems. Mainstream recently signed both a $40 million production contract to produce the military's Tricon Refrigerated Containers (TRCS program) and a $60 million production contract to produce the military's Improved Environmental Control Units (IECUs). While both were competitively awarded without any SBIR preference, these efforts were directly derived from Mainstream's SBIR efforts.

That's not to say, though, the path to commercialization is always an easy one. While its products in the refrigeration industry found high demand and praise, it has been Mainstream's more risky ventures that are a testament to its perseverance.

The company recently developed the world's smallest 3-cylinder diesel engine, the AMD45™, which uses automotive design principles coupled with durability enhancements for demanding military applications. The project was met with skepticism and was denied a Phase I award. After three attempts, they were eventually awarded a Phase I/II award. The AMD45/3-cylinder, 1.25 L Turbodiesel for Demanding Military Applications was successfully completed and manufactured in-house. This new, lightweight diesel power plant will be supplied to off-road vehicle manufacturers allowing them to make high-powered diesel versions of their off-road vehicles for military JP-8 fueled applications. The company is pursuing the development of extremely lightweight diesel generator sets from this compact lightweight diesel engine. Along the way, Rivian Automotive was spun off to run with innovations in automotive manufacturing and represents a tremendously successful new car startup.

"It's very rare if you have a great idea, for people to say, 'Hey that's a great idea!'" added Scaringe. "Usually they say, 'Well why hasn't anybody thought of that before?' You have to be passionate about it and keep pushing until you prove it's a great idea."

Another one of those ideas the team is working to bring to market is their Biomass project, which involves traveling to the landfill and parking an 18-wheeler which will process organic waste and turn it into number 6 fuel on site. This solves the problem of transporting waste long distances, which is not economically viable. The completely self-contained truck converts 10 tons of waste a day into 1,300 gallons a fuel. Once the fuel is made, a tanker truck can deliver the fuel directly to the customer. This type of fuel, which is generally used to power ships or power plants, can be profitably and quickly produced. Mainstream received follow-on funding from the Army as a method to get rid of waste. They currently have a tenth scale prototype which produces 130 gallons of fuel a day and are developing full-scale prototypes to get on the road shortly.

"With any SBIR award, the mindset should be…the government is helping pay for our development – you can't always expect them to pay for all of your development. However, any help is better than none, if you are really serious about getting the product to market. If you get a Phase II, or Phase III, that's all the better, but if you look at it like you have to get government money to get the product completed, then that is the wrong attitude," explains Scaringe. "The government is here to help you develop a product that they want. They want you to get to market, and we want to get to market. We don't care about only minimally satisfying the contract – we want much more, we want a successful commercialization. Maybe if we get 100K from an SBIR, we will invest 200K of our own money. You have to get to the finish line."

That attitude is the reason Mainstream Engineering has a 100 percent commercialization index rating for the DOD, and the reason why many products have gone right from the Phase I or Phase II to a commercial shelf. Mainstream was also the recipient of two Tibbetts Awards, for excellence in commercializing SBIR-funded technologies, winning the most recent award in 2014.

SBIR·STTR
America's Seed Fund™
POWERED BY NASA

Geocent's technology, OpenCOP, is an open-source, open-architecture integration platform that allows emergency managers to better operate in critical situations and to share situational awareness. OpenCOP was used during the BP oil spill cleanup in the Gulf of Mexico.

GEOCENT

Emergency management teams often cite communication issues as their biggest challenge during natural disasters. This was never more transparent than during the devastation of Hurricane Katrina on the city of New Orleans. First responders, military personnel, federal agencies, FEMA, municipalities, city officials and state governments were all trying, unsuccessfully, to get on the same page as to where assets were located, where troops were stationed, who needed emergency medical attention, which roads and exit routes were blocked or destroyed, and other critical logistics.

PHASE III SUCCESS
2014 revenue of $28M; recently signed a $10M contract with the U.S. Navy to deliver software and systems engineering solutions and an additional contract with SPAWAR.

AGENCIES
DHS, DOD, NASA, USDA

SNAPSHOT
Founded in 1992, Louisiana-based Geocent is a classic example of an SBIR success – the company utilized several SBIR awards through multiple agencies to deliver sought-after solutions to a broad range of government and commercial clients.

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Louisiana-based Geocent knew that if these organizations could somehow share geospatial information on a map that could work with each team's own tools, communication would be greatly enhanced. This led the company to respond to a Small Business Innovation Research (SBIR) solicitation from the Department of Homeland Security (DHS) on how to support emergency response capabilities. The result was a technology that could be used across multiple agencies for a more comprehensive common operating picture.

"Through this SBIR, we built our Open Common Operating Picture, or OpenCOP, which is an open-source, open-architecture integration platform for enabling the dissemination of complex geospatial data," explains Keith Alphonso, Chief Technology Officer of Geocent. "It is a platform that allows emergency managers to better operate in critical situations and to share situational awareness. We received follow-on funding from Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) and used this technology during the BP oil spill, Hurricane Isaac and Superstorm Sandy as well."

Geocent then used that core technology for its Navy customers to integrate weather data. Multiple Phase III contracts with the Navy soon followed, including a $22.1 million award from SPAWAR to work with the agency in San Diego on command and control technologies, capabilities and Internet operations. Additionally, Geocent was awarded an SBIR Phase III competitive contract to provide the Naval Oceanographic Office (NAVOCEANO) the ability to display their forecasted ocean weather data and observations of current ocean weather data on a geospatial map so that it can be viewed on tools such as Google Earth and other Open Geospatial Consortium based map viewers.

For its Department of Homeland Security customers, Geocent is continuing to provide Geospatial Technical Support Services (GTSS) under a Blanket Purchase Agreement worth $98 million – which was awarded to Geocent and three other small businesses. Through this agreement, DHS will secure geospatial technology services to produce maps of natural hazards such as floodplains, as well as assess critical infrastructure risk and vulnerabilities. DHS also has a goal to use the technology to track and monitor law enforcement activities and support reconnaissance operations, conduct urban search and rescue operations to recover survivors affected by disasters, plan security operations for special events, and facilitate vessel and cargo tracking and inspection.

Geocent's hugely successful stint in the SBIR arena is a testament to its team, who looks beyond the initial award and sees what potential exists in the marketplace for a particular technology.

"Commercialization is something we look for in SBIRs and in fact Phase III is a big thing for us to strive for," explains Ridge Bourgeois, Federal IT Sector Director for Geocent. "The SBIR program has been a cornerstone of where we live and operate in terms of the innovation perspective, and we still try to be on the cutting edge and to solve the technical solutions that otherwise would fall to the wayside without the program. As a small business, you are busy in operations and maintenance of things, but with SBIRs we can continue to expand in our core competencies of software engineering and data integration and push the envelope."

Continuing on its SBIR journey, this year Geocent was awarded a NASA SBIR to develop earth science data processing algorithms in the cloud. This ties in two of the company's core capabilities – data processing and geospatial data. Since NASA collects a great deal of earth science data with satellites, they want to make this information readily available to the public.

"What we are doing is instead of just having data in the cloud, you can also have processing in the cloud," adds Alphonso. "Raw data is one thing, but to have the ability to process that data for specific purposes is the value that we are bringing. Maybe you want to take an image of the coastline and compare that image to one taken five years ago to assess coastal erosion. Those are the types of things the algorithms can provide."

The state of Louisiana also continues to be a great customer for Geocent, who was honored with several awards in 2014. In addition to the coveted 2014 Tibbetts Award from the U.S. Small Business Administration, Geocent received the Boeing Performance Excellence Award, along with the Marshall Space Flight Center Small Business Subcontractor Excellence Award. With the government's demand to increase its technology platforms each month, 2015 is shaping up to be the biggest year yet for Geocent.

Geocent's OpenCOP was inspired by Hurricane Katrina in light of the need for better communication among emergecy management teams.

Ask any major U.S. defense prime contractor how the company got started, and chances are, "in a basement of an old monastery," won't be an answer you hear. Yet, this was precisely the case with Touchstone Research Laboratory, which flourished from such humble beginnings. With just $100 that purchased a scanning electron microscope the founders rebuilt, the company began its journey to become one of the preeminent suppliers of next-generation materials and products for a broad array of government and commercial clients.

PHASE III SUCCESS
Over $55.7 million in contracts with the DOD; 25% of annual revenue stems from government contracts, while 75% is derived from commercial sales.

AGENCIES
DOD, NASA, NSF, DOE

SNAPSHOT
Founded in 1980, West Virginia-based Touchstone Research Laboratory is a 3-time Tibbetts Award recipient for its broad-based product development research philosophy, which focuses on the development of next-generation, over the horizon materials and products.

TOUCHSTONE RESEARCH LABORATORY
The Millennium Centre
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In the beginning, the government wasn't exactly a target client. It was the Challenger Space Shuttle accident that brought a great deal of materials qualification work to Touchstone, which opened the company up to government programs.

In the late 1990's, during a visit to another very successful SBIR company, Composite Optics (now Orbital/ATK), one of Touchstone's founders conceived the idea to aggressively focus on the SBIR program.

Today the company has a steady and long-standing relationship with many agencies across the Department of Defense, NASA, the Department of Energy, and the National Science Foundation.

The company has utilized the Small Business Innovation Research (SBIR) program to invent dozens of new materials and products and has generated a large intellectual property portfolio.

One of these SBIR projects was the development of a fireproof carbon foam to build walls for Navy ships. This resulted in one of the company's most successful products to date - CFOAM® carbon foam, a structural material made from coal. CFOAM is lightweight, fireproof, impact absorbing, can be produced either thermally insulating or conducting, and can also be made to absorb radar.

Over the past few years the CFOAM carbon foam manufacturing processes have been refined and the manufacturing has been expanded to supply both the commercial aerospace and government aerospace markets.

CFOAM expands and contracts with changes in temperature almost identically to aerospace carbon fiber composite parts. This characteristic makes CFOAM an excellent material to use as the basic structure of the molds for these parts. It has subsequently driven the manufacturing of composite molds to become the leading market for CFOAM.

Currently, Touchstone is spinning out two businesses, one to manufacture CFOAM on a very large scale and the other to manufacture the composite molds for the aerospace industry. In the composites industry, these molds are called composite tools.

"As we commercialized our SBIR technologies, our original vision was to go directly into the commercial marketplace," explains Brian L. Gordon, Laboratory Director at Touchstone Research Laboratory. "But because the government is often willing to take more risks with new technologies, we found a great deal of the initial sales were to the Federal Government. The commercial markets have opened up a little slower but now dominate the sales of our SBIR related products."

Composite molds are not the only market for CFOAM. It has been used in thermal protection systems (like Space Shuttle tiles) as well as nozzles for rockets, as fireproof wall systems, as well as in energy absorbing applications. The uses for fireproof, strong foam are nearly endless.

CFOAM abounds with unique properties, allowing Touchstone to continue to leverage this new material in amazing applications. Recently, Touchstone completed a program for the Missile Defense Agency (MDA) to develop an electrically conductive thermal protection system that will protect rockets from lightning strikes as they pass through the atmosphere. And for the Marines, Touchstone is developing a non-metal exhaust system for a new amphibious assault vehicle. Excluding metal eliminates corrosion problems and the weight associated with metal exhaust systems.

CFOAM technology has given rise to another product, CSTONE™, for which Touchstone has also won an R&D 100 Award. CSTONE is like CFOAM without the porosity, and is strong and high temperature like CFOAM. It can be used industrially to make crucibles and kiln furniture or in the military to produce rocket nozzles and vertical take-off and landing pads.

Another of the company's innovations to win an R&D 100 award is MetPreg™, a lightweight, fiber-enhanced aluminum that is three times stronger than traditional aluminum alloys. It can also be used in temperature ranges far higher than traditional aluminum. MetPreg is a true metal matrix composite (MMC) that makes use of all traditional composite-processing techniques. MetPreg has all the advantages of metals and composites and works well with adhesives, soldering, brazing and welding.

At NASA, Touchstone is working with the agency to advance its metal matrix composite technology. Since launch vehicles are made from aluminum, Touchstone's material can be added to strategic locations to reduce the overall weight of the vehicle and improve performance.

Touchstone was the 27th company in the nation, and one of only two in West Virginia, selected to take part in the Defense Production Act Title III Program. The program aims to ensure a domestic production capability that is critical for the nation's defense programs and includes areas such as technology items, components, and industrial resources. The company has worked with its local economic development – the Regional Economic Development Partnership – to build a world-class research and manufacturing park that includes 4 buildings on about 10 acres. Today, Touchstone employs about 40 individuals with advanced degrees in physics, engineering, chemistry, and material science.

Touchstone will continue its efforts to leverage the SBIR program to develop innovative products and materials, spin out businesses to advance the local and national manufacturing base, and provide technical solutions to Americans and the federal government.

"The SBIR program is tremendous in terms of start-up funding to explore the feasibility of your technology," says Gordon. "Once you've demonstrated that, then you're able to scale up and get additional funding from the program to get to a more mature technology level. Without SBIR we could not have accomplished all that has been done here at Touchstone."

Touchstone Research Laboratory has just completed the installation of 8 test machines for specialized testing in its mechanical testing laboratory. These machines utilize full digital control with software developed by Touchstone for material testing up to 1300ºC.

Radiance Technologies' patented WeaponWatch® technology is used on the Army's AH-64D Apache helicopter (pictured here). The technology can display threat type and location, cue imaging systems and weapons, and support a common operating picture in real-time using existing tactical radios and other military communications systems.

RADIANCE TECHNOLOGIES, INC.

The story reads almost like a case study. How does a three-person team leverage ingenuity and government funding to become a major U.S. defense prime contractor signing billion dollar contracts? Radiance Technologies has the answer. The key is the Alabama-based company's ability to design, develop, fabricate, integrate, and test components and systems. This end-to-end capability, supported by a strong operational team, enables Radiance to provide innovative solutions to not only the Department of Defense (DOD), but to customers across the U.S. government. Because of this, Radiance has experienced significant growth since its founding in 1999.

PHASE III SUCCESS
Yearly sales exceed $115M; Radiance was awarded an IDIQ contract with the U.S. Air Force totaling nearly $1 billion in 2014.

AGENCIES
DOD, DHS, NASA, USDA

SNAPSHOT
Huntsville-based Radiance Technologies is an employee owned, engineering and technology company providing solutions to the Department of Defense. Went from 3 employees in 1999 to 454 employees today across the globe, including 180 in Alabama.

RADIANCE TECHNOLOGIES, INC.
350 Wynn Drive
Huntsville, AL 35805

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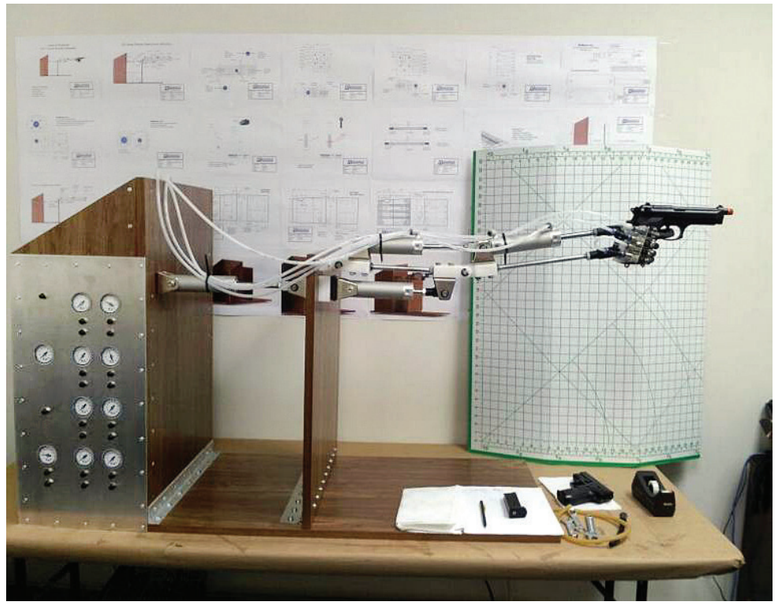
"Our first work involved collecting data from sensors," explains William Bailey, Strategic Initiatives Analyst for Radiance Technologies. "We evolved into sensor exploitation; we provide Intel analysis and algorithms over a large variety of sensors; perform R&D, and create software applications to help analysts use sensors more efficiently. We integrate prototype systems where sensors are central components, and reverse engineer when necessary."

Sensors continue to be a critical core competency for Radiance, though its broad expertise has enabled the company to venture into new territory. The company is currently working with the Army to implement a broad area hostile fire sensing architecture that uses lower cost discrete sensors, which do not require cryogenic cooling assemblies, and therefore greatly reduce the life cycle cost of hostile fire sensor payloads for both manned and unmanned aerial vehicles. One of Radiance's largest customers is U.S. Army Intelligence & Security Command (INSCOM), for which the company provides around 160 analysts to date. Over at the Department of Homeland Security (DHS), Radiance is designing, developing and testing a 6 degree-of-freedom (DOF) device, which will fully simulate the recoil reactions of a wide range of human shooters, handguns, and ammunition types.

At NASA, Radiance is helping the agency to integrate three unique energy harvesting technologies that utilize the company's existing research strengths that are of interest and utility to NASA applications and environmental conditions. By developing multiple technologies, NASA will soon be able to harvest energy from multiple waste energy sources, including environmental vibrations, thermal energy, and solar flux. With no prior experience with NASA, Radiance beat out large, incumbent contractors to win the Marshall Space Flight Center's (MSFC) new Engineering Solutions and Prototyping (ESP) full and open Delivery Order contract worth $350 million. Radiance hopes to evolve its capabilities through this award as well as increase its capabilities for its sensor solutions.

Radiance's relationship with its government clientele began with several Small Business Innovation Research (SBIR) contracts, both with the DOD and the United States Department of Agriculture (USDA) that gave the company the platform to showcase its capabilities. The company soon became the Systems Engineering and Technical Assistance Contract (SETAC) Prime Contractor of Choice through the U.S. Army Space and Missile Defense Command and the U.S. Army Forces Strategic Command – a contract with a ceiling of $997 million that extends through 2016. In 2012, Radiance was awarded a $300 million Agile Cyber Technology contract through the Air Force Research Lab (AFRL) to develop cyber hardware and software tools that would allow the fleet to dominate in the cyber environment. With 86 Phase I and II SBIR projects awarded since 2001, the company has perfected the art of leveraging government funds to commercialize its projects.

"We have this broad array of capabilities, but SBIR has been critical for us in that it allows us to take a concept and prototype and integrate it, as well as perform the testing and evaluation," says Bailey. "We can carry that all the way through to a fielded prototype for our customer, and no other small businesses can do that without this support. It has allowed us to provide diverse solutions for our customers."



Radiance is currently working on an SBIR Phase II project with the Department of Homeland Security (DHS) to design, develop and test a 6 degree-of-freedom (DOF) device, which will fully simulate the recoil reactions of a wide range of human shooters, handguns, and ammunition types.

SBIR was the driving force behind one of Radiances' most advanced technologies - WeaponWatch® - which provides a highly reliable, wide area surveillance capability for the real-time detection, classification, and location of direct and indirect hostile weapon fire with a very high probability of detection and a very low false alarm rate. WeaponWatch is currently in use on the Army's AH-64D Apache helicopter. In late 2014, Radiance announced its largest contract to date – serving as one of three prime contractors on a $960 million indefinite-delivery/indefinite-quantity contract for services in support of the Advanced Technical Exploitation Program II (ATEP II). Radiance, along with its Dayton partners will perform research, development, system sustainment, and intelligence production activities utilizing geospatial-intelligence and non-nuclear measurement and signature intelligence data at the National Air and Space Intelligence Center (NASIC), at Wright-Patterson Air Force Base outside of Dayton, Ohio. Approximately 50 new employees were hired near Wright-Patterson to accommodate this contract.

Looking to the future, Radiance wants to continue its research and development on its sensors for use in weapon signatures, from small arms fire to missiles. By figuring out how to collect various signatures, Radiance hopes to use this information to develop an entire host of technologies that can detect weapons systems and provide decision makers with the intelligence needed to respond appropriately. The company credits its location in the great state of Alabama as a driving factor in its recent success.
"You have an amazingly diverse array of military customers, as well as NASA, right here in Huntsville," adds Bailey. "There is a huge demand for these technologies, along with very supportive congressional leadership. Add that to the low cost of living and the high quality of life, and you have the perfect environment for innovation."

FRONTIER TECHNOLOGY, INC.

When the Department of Defense (DOD) needs to analyze a lot of data in a very short period of time, the organization relies on analytical software to help it make the most informed decisions possible. By providing the data-rich DOD and its end customers with software solutions that interact seamlessly with those pools of information, FTI has made a name for itself in the complex realm of engineering analysis.

PHASE III SUCCESS
$120M in awards including a $65M GSA Phase III contract and a $50M Army Phase III contract

AGENCIES
DOD, NASA, DOE

SNAPSHOT
2015 Tibbetts Award recipient; Ohio-based Frontier Technology, Inc. (FTI) assists its government clients with engineering analysis solutions to help improve decision-making; grew organically from 2 founders to over 100 employees.

FRONTIER TECHNOLOGY, INC.
4141 Colonel Glenn Highway
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Beavercreek, Ohio 45431

www.fti-net.com
(937) 429-3302

Logistically, the technology aims to dissect the decisions we make everyday with facets of our left brain and right brain. FTI's complex tools and algorithms can find patterns in the data that enable users to make informed resolutions that go far beyond "gut feelings." With massive amounts of data to analyze, FTI realized that people want to get educated before they make a major decision that affects many areas of a DOD organization.

With the goal to provide customized DOD operational and acquisition decision-making software products, FTI began by focusing on its government customers first and foremost. In doing so, the company got its start with the Small Business Innovation Research and Small Business Technology Transfer programs (SBIR/STTR) in the late 80s, just a few years after it was founded in 1985, and used those programs as a launching pad to commercialize these sought-after, albeit riskier technologies.

"To commercialize SBIR technologies, you often have to show potential customers that the core technology they need has already been paid for through the SBIR program, and yet it will work for them as well," explains Ron Shroder, CEO and President of FTI. "That removes the risk for our customers, and often they would be willing to invest additional resources to make it more robust. Once a few customers lined up with investments, FTI soon had a full product suite of these decision aids."

This type of commercialization success was demonstrated as the Army G3/G5/G7 put a Phase III in place to leverage prior investment in logistics and planning by the USAF and the Navy funded the first of several task orders.

That product suite includes decision-making aids such as FTI's Integrated Cost Estimation, or ICE™, which simplifies the process of building system cost estimates and determining the return on investment for a program or technology. ICE™ integrates a whole suite of budget and cost assessment tools. Another FTI product, known as NormNet®, enables the DOD to implement condition-based maintenance and other contemporary system maintenance strategies. NormNet® assists operational decision makers by modeling normal system operations and predicting future performance without requiring physical models or lists of failure modes. FTI's ELAPS® - Extensible Load-Adaptive Processing System software suite is designed to increase the efficiency of high volume data processing by addressing the core requirements of automation, scalability, and extensibility.

FTI was recently awarded a Phase III contract by the Air Force to support enterprise assessment and resource investment planning and related sustainment and logistics decision processes. As part of this contract, FTI will identify and apply decision support methods and tools resulting from an earlier Phase I and Phase II award to develop capabilities for enterprise level analyses. These enhanced analytical capabilities will identify and quantify cost-effective improvements, verify operational performance, and guide materiel investment strategies through long-term materiel war gaming.

For its Navy customers, FTI is currently creating an integrated Navy Fuel Efficiency Conservation Dashboard and Optimization System Prototype. The prototype will support a structured comparison of investments in technology, the documentation of the business case, and return on investment of specific technologies. This prototype will be used within the fleet in support of the Navy's energy efforts, and specifically support energy usage, efficiency, and readiness initiatives. FTI is also characterizing the benefits of the ELAPS® data management architecture to support the Navy's energy conservation data as part of several Missile Defense Agency (MDA) pilot efforts. This core MDA technology has already been installed at one operational MDA site and has been demonstrated to allow operators to format satellite data in minutes as opposed to hours. Based on the success of these pilot efforts, MDA is planning to award a Phase III SBIR in Sep 2015 to enable multiple services to continue to mature and apply this core data management architecture.

Although the company was founded in California, Shroder and many of FTI's analysts and developers with rich aviation backgrounds sit near Wright Patterson Air Force Base (WPAFB) in Ohio, where he feels the company has a majority of its initial SBIR roots.

"Ohio is the birthplace of aviation and it has always been an incredibly powerful research and development (R&D) community with people who truly understand the culture of aviation here," adds Shroder. "There are amazing government researchers here who see the real benefit of these technologies. We are fortunate to be able to interact with them face to face. We start with their passion, develop solutions, and then adapt them to other organizations because their problems aren't unique to WPAFB – they impact DOD organizations throughout the country."

Another key to the company's success – hiring the right mix of bright, young developers, engineers, and mathematicians (many with Ph.D.'s), as well as retired military personnel. As an employee-owned company, each staff member has a vested interest in helping the company to flourish.

A recipient of the 2015 Tibbetts Award, Shroder and FTI proudly accepted the honor at the White House this spring.

"FTI's goal continues to be the use of these decision aid technologies to empower our clients through data driven decisions," said Shroder after the ceremony. "Our passion aligns with the Congressional intent of the SBIR Program, which is to commercialize these technologies through the use of the sole source Phase III strategies. We hope that our customers' recent awarding of over one hundred million dollars of Phase III contracts is just the beginning of an aggressive growth period for our company and its employee owners."

Ron Shroder, CEO and President of FTI, accepts the 2015 Tibbetts Award from the U.S. Small Business Administration Office.

EXPERT MICROSYSTEMS

Since 1995, Expert Microsystems has made a place for itself in the niche market of prognostics and health management for critical equipment. In the aerospace and power generation realm, this translated to precise techniques for monitoring the sensors of engines, power plants, and other infrastructure using specialized software. The company's patented SureSense® system provided the means to monitor automatically a complex system such as a power plant, from a remote location. The plant data is accessed using a distributed SCADA – Supervisory Control and Data Acquisition – system that is essentially a communications and control network that can open and close valves, operate pumps, and give other commands. The thought process then turned to the SCADA systems themselves – instead of monitoring just the plant equipment, why not monitor the control systems and ensure they are also of optimal health?

PHASE III SUCCESS
Over $6.58 million in related revenues

AGENCIES
DHS, DOE, NASA, USAF

SNAPSHOT
Expert Microsystems SureSense® software has been deployed across federal agencies as well as the commercial marketplace in the electric power generation, aerospace, cyber security, electronic and industrial process control industries.

EXPERT MICROSYSTEMS
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Orangevale, CA 95662

www.expmicrosys.com

With this in mind, Expert Microsystems embarked on an SBIR project with the Department of Homeland Security (DHS) to apply these same proven principles to intrusion detection with the goal of making the control infrastructure – which can be vulnerable to threats – more secure. During the Phase II portion of the project, Expert Microsystems demonstrated the feasibility of this new defense by actually hacking into a SCADA system at the Idaho National Laboratory (INL) and demonstrating the ability to identify the attack even while the conventional intrusion detection systems – commonly used today – did not. The INL-provided SCADA system provided an opportunity for testing where no real damage to public infrastructure could be caused by the testing.

"In doing this project, we added a whole set of new and useful capabilities to our core technologies for prognostics and health management," explains Randy Bickford, Founder and President of Expert Microsystems. "Our original goal was to apply our PHM techniques to the problem of intrusion detection in control systems, and we successfully proved that this core technology has an extended applicability across a wide range of other computing platforms as well."

The work the Sacramento-based company did in 2006 with DHS is continuing to come to fruition – in early 2014, Expert Microsystems was awarded a U.S. patent for its asset surveillance methods, which were based off of the same technology developed under the SBIR sponsorship. This patent, in combination with twelve related patents for the company's core PHM technology, demonstrate a long history of successful innovation.

The path of success led Expert Microsystems to the commercial marketplace. The company chose to pursue opportunities in the computer networking and server industry. This entailed applying the same techniques of PHM to a computer server and monitoring both hardware and software within a network infrastructure. This is especially important for financial or security institutions which engage in high-end transactions. Whether a threat might compromise the server hardware or software, detection of the problem is critical to prevent a server crash. Ultimately, this technology was licensed to one of the largest software manufacturers in the world, and they have been successful in applying the technology to database and transaction servers. Here, the technology has several advantages over existing products including fewer false positives, the ability to analyze very large data sets and variables from multiple sources, and the ability to monitor cyber networks automatically in multiple and differing environments.

In addition to licensing the technology, Expert Microsystems won a follow-on Phase II contract with the Department of Energy (DOE), and most notably, a Phase III designated procurement contract with NASA. Using its SureSense® software package, Expert Microsystems demonstrated the ability to accurately detect and diagnose sensor faults and identify anomalous system operating states in a wide variety of power plant and spacecraft equipment. The SureSense® package is also being embedded in other computer programs and control systems for providing real-time data analytics.

Today, Expert Microsystems is combining its SureSense® product line with a newer and complimentary product that they are developing for the Electric Power Research Institute (EPRI) and DOE. This Fleet-wide PHM Suite combines the output from SureSense® with other plant information, such as results from inspections or maintenance actions, to further refine the diagnosis based on the instrument data processed through SureSense®.

New applications are broad and Expert Microsystems is actively seeking licensing opportunities with a global player in the power generation space. There is also interest on the part of DHS to monitor first responders and from the Department of Defense to monitor soldiers. While their core technology is essentially a "doctor" for machines, this same prognostic principle can apply to the health of individuals. New uniforms are currently being constructed for firefighters that sense the wearer's vital signs. The sensors have a wireless link to a local station – either on the truck or an office – and the interest is in knowing which person is healthy and which is in distress? If a firefighter is down, vital signs information can be monitored in real-time and medical personnel can be alerted automatically with precise diagnostic information about the firefighter's condition.

Contrary to what people may conclude, this software does not and will not replace the human expert. In fact, it is quite the opposite. Rather than have the doctor seek out and analyze data to find the abnormal condition, the software does the early work - it finds the problem, and synthesizes the data to an initial diagnosis. What is does not do is decide the necessary course of action and treatment. The goal is to enable the human expert to implement the most effective response at the earliest possible time.

"Letting problems accumulate in both machines and humans has the same detrimental effect on the overall health of the unit," says Bickford. "So whether we are dealing with equipment, or the "human" machines of the heart and other vital organs, longevity through continued prognostics and maintenance is what we are seeking."

Square One's Protein Crystal Imaging System used by medical researchers.

SQUARE ONE SYSTEMS DESIGN

When South Korean-based electronics giant Samsung was looking for the perfect robot to fit its needs, it went far beyond its borders in technology-rich Asia. It went all the way to Jackson, Wyoming. That's where Square One Systems Design spearheads its development of innovative automated systems, precision positioning devices, and robots for diverse industries. The company has utilized the Small Business Innovation Research (SBIR) program to not only gain insight into worldwide applications, but to increase its own visibility in the vast global marketplace.

PHASE III SUCCESS
Over $3 million in revenue resulting from technologies originally funded by the SBIR program.

AGENCIES
DOE, NSF, NASA, HHS (NIH)

SNAPSHOT
Wyoming-based Square One Systems Design is a world leader in robotic automation inspired by the surrounding natural beauty of Yellowstone and Grand Teton National Parks.

SQUARE ONE SYSTEMS DESIGN
3500 South Park Drive
Jackson, WY 83001

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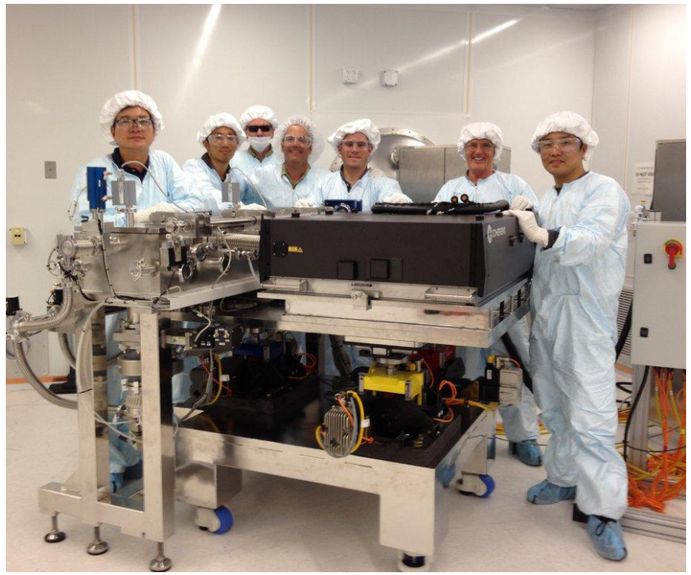
"One of the great things about SBIR is that the opportunities come to you," says Bob Viola, Director of Engineering for Square One Systems Design. "Solicitations are published online and we can locate opportunities that align with our expertise, so for a company like ours, which is located remotely from the end user, the SBIR program offers that advantage for exposure and that has been huge for us."

After successfully completing SBIR projects with various U.S. agencies including DOE, DOD, NSF, NASA and NIH, Square One has developed a full suite of robotic applications. The company's first SBIR project with DOE enabled the development of an innovative six-axis robot, masquerading as an inanimate object.

"We developed our 'Tri-Sphere' parallel robot, which is actually a table that can be moved and positioned in all six degrees-of-freedom, and can hold 5,000 pounds," explained Viola. "We envisioned it would be used in DOE laboratories. We were lucky enough to partner with Lawrence Berkeley National Laboratory in a partnership with Samsung, and we've used additional SBIRs to refine the design. Now we have what we hoped for – a portfolio of technologies."

The Tri-Sphere Positioning System, developed under SBIR funding, is a fundamentally new type of positioning technology specifically designed to meet the stringent requirements of 3rd and 4th generation synchrotron light sources. The mechanisms used to support and position mirrors, monochromators, and other beam conditioning components are critical to the performance of synchrotron beamlines. However, the performance of these mechanisms is often not equal to the demands placed upon them by modern synchrotron designs. This results in temperamental beamlines that are difficult to align, and are susceptible to vibrational and thermal disruptions, and incapable of achieving operational goals.



LEFT Square One's employee Charlie Hagen installing the company's patented Sample Exchange Robot.
RIGHT The team at Square One Systems Design showcases its Tri-Sphere Positioning System – this SBIR-funded technology is an innovative six degrees-of-freedom precision alignment system specifically tailored for synchrotron applications.

The Tri-Sphere, by contrast, delivers precision adjustment in all six degrees-of-freedom while providing rock solid stability. While derived from the same class of mechanisms as hexapods, the Tri-Sphere's innovative design allows it to transcend the limitations of conventional six-axis positioners. Comprised exclusively of prismatic actuators, the Tri-Sphere is almost infinitely scalable and can generate large, highly asymmetric work envelopes.

Square One sold several units of its Tri-Sphere Positioning System to Samsung and traveled to South Korea to install the devices, where Samsung is using it to position very powerful lasers.

Another bread and butter device for the company is its Sample Exchange Robot. Current generation synchrotron light sources provide X-ray beams of unprecedented brightness, allowing experimental data sets to be gathered in a matter of minutes. However, fresh samples are still generally loaded manually; a time-consuming process that compromises the productivity of valuable X-ray resources. Square One's fully automated Sample Exchange Workcell provides a fast, reliable solution by pulling a selected sample from the magazine, reading its barcode, and correctly orienting it and transferring to the experiment.

Another powerful innovation is Square One's Detector Positioning Robot – an advanced 6-axis device offering a new approach for positioning detectors. Under robot control, a detector can be rapidly repositioned throughout an exceptionally large detection volume. This system delivers accuracies and repeatability equal to that of hard-tooled detector positioning mechanisms. However, unlike these mechanisms, the robot's center of rotation can be instantly re-defined when a sample's location changes. This results in systems that provide maximum operational flexibility.

Although the SBIR program has had a crucial hand in the company's success, Viola is quick to point out that its location in the great state of Wyoming has had instrumental impact on the growth of Square One.

"The state is very uniquely suited for a smart technology start up, because unlike some states, Wyoming runs a multi billion dollar surplus," adds Viola. "There is a very active program called the Wyoming SBIR/STTR Initiative, or WSSI for short. It offers all sorts of resources and support for companies that want to play in the SBIR arena. It deals with how to write winning proposals."

The state also has a Phase 0 Program where companies come to the WSSI and put together mini proposals. Experts at the University of Wyoming then review proposals, and winners receive up to $5,000 to help offset the inevitable costs with putting together a Phase I SBIR proposal. For a state with only 500,000 people, Viola feels Wyoming attracts the best of the best of high-tech entrepreneurs with a drive to succeed. Part of the vision of the company is to assemble the best minds in the business in an idyllic location, equip them with the latest design tools, and then turn them loose on the most challenging automation projects. The leaders at Square One believe their unconventional setting fosters original thinking and collaborators, which include ONR and Stanford University, always enjoy their visits.

The next sector to conquer according to Viola is the auto assembly industry, although any commercial product that is assembled using automation would be a target opportunity. Square One's niche market of physics research and semi conductor manufacturing is continuing to grow exponentially so there are no shortage of opportunities for this highly innovative and results driven company.

The STJ X-ray Spectrometer is the culmination of several SBIR awards through the Department of Energy.

STAR CRYOELECTRONICS

X-ray spectroscopy is a widely used experimental technique for studying the composition and chemistry of materials and is used across a broad range of scientific fields including condensed matter physics, materials science, chemistry and biology. Through a current Phase IIB grant with the Department of Energy, STAR Cryoelectronics is developing a complete, turnkey X-ray spectrometer that will be easy to use by researchers at synchrotron facilities, both in the U.S. and abroad, for X-ray absorption spectroscopy (XAS).

PHASE III SUCCESS
$6 million through commercial and government contracts; customer base is approximately 60% commercial and 40% government

AGENCIES
DOE, NASA, DOC (NIST)

SNAPSHOT
New Mexico-based STAR Cryoelectronics has branched out from developing superconducting sensors for NASA to assisting the Department of Energy with the development of a high-resolution X-ray spectrometer for use by researchers at synchrotron facilities in the U.S. and overseas.

STAR CRYOELECTRONICS
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Santa Fe, NM 87508-1338

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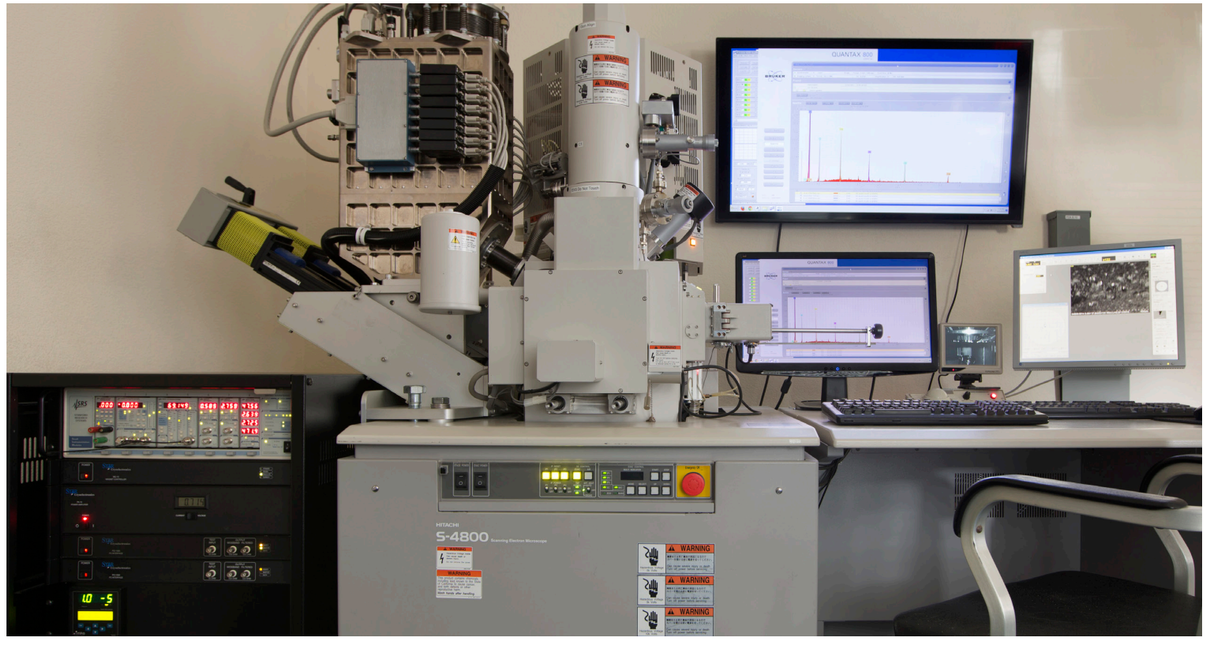
The company has also developed a second type of spectrometer through SBIR grants with the Department of Commerce for X-ray microanalysis in conjunction with a scanning electron microscope. This machine combines the ease of use of conventional energy dispersive spectrometers with the high-energy resolution of wavelength dispersive spectrometers into one instrument, allowing researchers to more efficiently and more accurately analyze samples on a nanometer scale. This new 2-in-1 X-ray spectrometer, named the MICA-1600, will meet compelling needs for improved tools for X-ray microanalysis, in particular for the semiconductor industry.

"We got our start in 1999 with the help of several SBIRs from NASA to develop our superconducting sensors and related control electronics products," said Dr. Robin Cantor, President and Founder of STAR Cryoelectronics. "Over the years, with the help of the SBIR program, we have branched out beyond our core technology infrastructure and leveraged that infrastructure to develop full turnkey systems."

When Cantor decided to start the company, not many others shared his vision at the time. Cantor worked for Conductus Inc., a California company that specialized in superconducting electronics applications including SQUIDs – Superconducting Quantum Interference Devices. As the Manager of the SQUID Technology Group, Cantor was passionate about his work, but corporate officials decided to focus on more mainstream application areas that had much larger perceived market potential, and ultimately dropped the SQUID division from its platform. Cantor took a job as a technical staff member at the Los Alamos National Laboratory (LANL), but never lost sight of his goals. A year later, Cantor decided to buy that defunct division from Conductus, knowing there would be a customer base for the products, and believing that he could grow the business. Seventeen years later, the supply chain has matured and Cantor and STAR are selling devices and offering custom services to customers around the world.



STAR Cryoelectronics' MICA-1600 installed on a scanning electron microscope.

The ultra-sensitive SQUID sensors available from STAR Cryoelectronics are based on Low-Temperature Superconductor and High-Temperature Superconductor technologies. An extensive range of standard and custom SQUID sensors and packaging options is available for applications in biomedical imaging, non-destructive testing of materials, geophysical exploration, and basic research. The company's dc SQUIDs and advanced PC-based SQUID control electronics products – sold under the name pcSQUID™ - are in use at major universities, government and corporate research laboratories in the U.S., Europe, Asia and Australia for a variety of basic and applied research applications.

Supplementing this technology is Mr. SQUID®, the Educational Demonstration System for Superconductivity, which has been sold to over 300 colleges and universities worldwide.

Although the company does have a handful of competitors around the globe, Cantor attributes the success and competitive advantage of the company to the SBIR program and the company's location.

"We are fortunate enough to be located right by two of the best national laboratories in the country – Sandia National Laboratories and Los Alamos National Lab; both of which have small business assistance programs that we have relied on over the years for technical support and assistance," adds Cantor. "As a small company, we can't afford to develop the infrastructure that is available at these labs, so having these small business assistance programs has been invaluable to us – we would not have been able to compete in the world market otherwise."

Cantor adds that many of his overseas competitors also have national labs in their home countries, and they use these labs for commercial production. Having access to the expertise at LANL and Sandia helps level the playing field.

In the commercial marketplace, STAR continues to sell superconducting sensor components, readout electronics and various accessories that were all developed under its original SBIR projects with NASA. The company is also doing business in the biomedical imaging industry, providing thousands of sensors for sophisticated brain imaging systems to record and localize the magnetic signals associated with neuronal activity in the human brain. This magnetoencephalography system is an essential tool for mapping functional brain activity and may be superposed with MRI data in order to correlate the localized activity in the brain with anatomical information, providing doctors with essential data for pre-operative surgical planning.

STAR currently employs seven individuals at its headquarters in Santa Fe, and all final assembly, testing, and system integration are done in-house. With the application range for sensing products quite large, STAR Cryoelectronics has a busy few years ahead in developing new types of sensors and continually improving its component product line. With a collaboration with the University of New Mexico to develop a new class of X-ray detectors and ultra-high resolution cryogenic thermometers, STAR is an exemplary small business success, both in the state of New Mexico, and far beyond its borders.

IMAGE COURTESY | **U.S. NAVY**

The Navy flight deck is one of the noisiest environments to work on, resulting in billions of dollars in hearing loss claims each year. ITAC is a key solutions provider and is helping the U.S. Navy to predict and identify noise in jets in order to design quieter, more efficient engines.

INNOVATIVE TECHNOLOGY APPLICATIONS CO. (ITAC), LLC

The Veterans Administration (VA) estimates that more than 1.5 million veterans receive compensation for hearing loss suffered during their careers. Everyday, Navy personnel and Marines work on aircraft carriers where noise levels exceed the levels at which current hearing protection devices are effective. Beyond the long-term hearing loss, heightened noise on the deck renders communication difficult. Jet noise from supersonic aircraft represents the most severe hearing hazard on aircraft carriers. The Navy is taking a proactive approach by trying to identify the regions within jets that contribute to the noise in order to more efficiently reduce noise.

PHASE III SUCCESS
$2.5 million in Phase III revenue resulting from DoD STTR-funded technologies; additional Phase III contract in collaboration with Illinois Institute of Technology (IIT)-led DOE project for $8.2 million for advancing wind turbine technology

AGENCIES
DOD, DARPA, NASA

SNAPSHOT
Missouri-based Innovative Technology Applications Co. has leveraged several SBIR and STTR awards to provide the military with critical technologies, including efficient noise prediction for supersonic jets.

INNOVATIVE TECHNOLOGY APPLICATIONS CO. (ITAC), LLC
PO Box 6971
Chesterfield, MO 63006-6971

www.itacllc.com
(314) 373-3311

With this end goal in mind, the agency reached out to the small business community via a Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) solicitation. Missouri-based Innovative Technology Applications Co. (ITAC) swiftly responded, and went on to develop a high-demand process that is garnering praise across the U.S. Navy and other federal agencies.

“If you want to design something that reduces noise, you first have to predict the noise that is created,” explains Dr. Alan B. Cain, President and Founder of ITAC. “We develop tools that allow engine companies to design highly efficient jet engines by guiding them to quieter designs. The details we generate provide significantly more information than what can be measured on an aircraft carrier deck.”

ITAC, in collaboration with Penn State University, developed this particular technology under an STTR award. The end goal is a software and analysis tool for accurate prediction and control of noise emitted from the engines on fighter jets. While high-speed jet engines are the focus of the project, the ultimate objective is to create a broadly capable software system that can accurately predict aerodynamic noise from the aircraft - fans, jets, turbo machinery, engine cores, prop fans, propellers, and airframe components. This technology is available to support government and industry, as well as academic institutions in their efforts to design and develop future generations of efficient, environmentally acceptable air vehicles. The company credits NAVAIR in playing a pivotal role in ensuring success of this collaborative effort between ITAC, Penn State, and the U.S. Navy.

In a different Phase II STTR collaboration with the U.S. Air Force and researchers at the University of Notre Dame, ITAC developed an advanced mathematical model with neural networks to improve control of complex facility systems. The program goal is to significantly

ITAC is currently working with the U.S. Department of Energy to investigate the aero-acoustics of wind turbines using advanced numerical simulations and phased array technology to help identify dominant acoustic source locations to aid in the development of noise reduction devices for wind turbines.

improve the control, operation, and efficiency of large wind tunnel facilities. The capabilities that ITAC and Notre Dame developed in this effort can also improve the safety of operating wind tunnel facilities through operator training. ITAC recently completed an initial Phase III effort to advance commercialization, and is currently in discussions with multiple agencies that are looking to acquire the technology. Within the commercial sector, this technology is applicable to large-scale facility control systems, offering a vast potential of possibilities. Personnel at Air Force Office of Scientific Research (AFOSR) provided important support and guidance to ITAC in advancing this technology.

In another Phase III effort, funded by the Office of Naval Research (ONR), ITAC advanced an innovative phased array microphone technology to improve the processing of aero-acoustic test measurements. These arrays have been instrumental in developing methods for quieting aircraft and other systems. This technology has been demonstrated to be an improvement in the measurement of supersonic jet noise.

These multiple STTR projects, along with several other SBIR awards from the DOD and NASA, have resulted in Phase III successes for the 6-person team at ITAC. “Our approach is unique and different from our competitors,” says Dr. Cain. “Instead of using a large number of processors that generally drive up costs rapidly, we identify the range of scales that are most important and that contribute to the highest amplitudes. By forgoing the lower amplitudes, we obtain a good prediction of the dominant sources of loud noises. Our customers find our approach to be cost effective with sufficiently high fidelity to help designers and engineers make decisions quickly, while conducting parametric studies which otherwise seem cost prohibitive.”

Dr. Cain, who worked for Boeing and McDonnell Douglas in the 80s and 90s, started ITAC in 1999. He leveraged the SCORE program within the state of Missouri to help launch his company, as well as the SBIR program just one year later, in 2000, and continues to leverage the program to this day.

“I think the SBIR/STTR program is a great way to test new concepts, and move fundamental technologies into the commercial marketplace,” he added. “And we’ve done just that.”

Techshot's Analytical Containment Transfer Tool (ACT²) was developed to contain and transfer samples in a safe manner for real-time analysis. Previously, samples had to be collected in space and flown back down to Earth for post-flight analysis

TECHSHOT, INC.

Handling E. coli within the confines of the International Space Station might not have been what most astronauts had in mind when they signed up for their missions. After all, this is not exactly a healthy and common bacteria we seek to handle on Earth, let alone in space. But with a newly developed and government funded Analytical Containment Transfer Tool (ACT²) developed by Techshot, Inc., astronauts can now safely handle these specimens, enabling NASA to launch an entirely new era of off-world DNA research and analysis.

PROJECT
Analytical Containment Transfer Tool (ACT²)

MISSION DIRECTORATE
Science

PHASE III SUCCESS
$9.5 million IDIQ contract with NASA

SNAPSHOT
3-time Tibbetts Award winner Techshot supplies tools and machinery to the International Space Station and has built a name for itself developing complex payloads for microgravity for commercial and U.S. government clients

TECHSHOT, INC.
7200 Highway 150
Greenville, IN 47124

"The goal with the E. coli experiment is to see how it performs in microgravity," explains Techshot Vice President Rich Boling. "Genes have distinct expressions and behave differently in certain environments. By analyzing the E. coli out of its natural element, we can begin to see all sorts of new patterns and eventually learn how biological specimens and DNA behave in space."

ACT² was Techshot's answer to a Small Business Innovation Research (SBIR) solicitation posed by NASA back in 2010. At the time, the agency's ability to analyze the DNA of biospecimens in space was more limited. Samples typically were collected, frozen, and analyzed post-flight. Since return capsules didn't exist, the samples had to be sent back down with the crew. In addition, separate tools were needed for collection and analysis – creating a potentially hazardous situation when it came time to transfer from the shuttle to the laboratory. As a small business predominantly serving the U.S. government – mostly by developing complex payloads for microgravity research – Techshot knew it could develop a solution.

The resulting ACT² is a device that both contains and transfers samples in a safe manner from unique experiment-specific, spaceflight hardware to on-orbit analytical tools for real-time analysis. There is no need to send the sample back down to Earth, which was the previous protocol. NASA understood the ability to do this was a crucial step for performing in-flight analysis. It's not only safer to use than the previous combination of tools, but because it is disposable, it is cost effective as well.

"We are a solutions company, and I don't use that term in just the marketing sense," explains Boling. Some companies are built around one technology and they are looking for government uses; we take the opposite approach and say, 'what do you need?' The ACT² transpired from that mentality."

LEFT The team at Techshot poses with several spaceflight-qualified copies of the ACT² before they are flown to the International Space Station

RIGHT Although Techshot is based in Greenville, Indiana, team members regularly communicate with astronauts aboard the International Space Station via its Payload Operations Control Center

"When NASA says they have a problem – we raise our hands and say we have a solution – and the best solution always wins. We love that."

TECHSHOT
VICE PRESIDENT
RICH BOLING

In March 2016, several ACT² devices loaded with frozen E. coli, and a suite of equipment collectively known as Wetlab-2, will launch to the ISS aboard a SpaceX Cargo Dragon. Built by NASA Ames Research Center, Wetlab-2 along with ACT², collectively provide a research platform for conducting real-time quantitative gene expression analysis aboard the station.

For a company that was founded thirty years ago by an eighth grade science fair participant focused on sending chicken embryos into space, the team has hit its stride recently with a suite of technologies being utilized on the ISS.

Techshot is currently developing a Multi-purpose Variable-G Platform for Life and Microgravity Sciences Research (MVP) set for deployment in 2017. The MVP is a single locker sized dual-centrifuge facility for life and microgravity sciences research and it will enable the study of cells, plants, fruit flies and organisms on the ISS. This will join the company's Bone Densitometer – another SBIR funded project – which is already in use on the ISS by biotech companies such as Novartis and, soon, by Eli Lilly and Company in its research on the station.

Techshot was recently awarded an Indefinite Delivery Indefinite Quantity contract by NASA valued at nearly $10 million. Spanning a period of five years, the agreement essentially is a menu of services and hardware, such as ACT², that the agency can buy from the company at pre-negotiated rates.

Techshot has effectively developed a spin-off strategy to commercialize new products originally intended for its government clients. One of Techshot's most successful endeavors was its Advanced Space Experiment Processor (ADSEP), which operates in low gravity and provides cell culturing and biphasic, electrophoretic, and magnetic separation capabilities. Techshot spun off IKOTECH LLC to market this technology, and it is currently being used in stem cell and diabetes therapeutics research. Techshot Lighting LLC was created when Techshot produced highly rugged and energy efficient LED lighting that is used in Afghanistan by the Marines and in many Army and Air Force bases across that country. While spanning industries, these innovations all have one thing in common; their derivation from the SBIR program.

"The SBIR program is a terrific field leveler," adds Boling. "We're not near any NASA center – yet we compete with businesses all over the country and other technical hubs. When NASA says they have a problem – we raise our hands and say we have a solution – and the best solution always wins. We love that."

And although the team at Techshot might be far removed geographically from its NASA customers, the team is closer than ever to astronauts on the ISS thanks to its Payload Operations Control Center, which enables real-time communication with the crew operating its hardware.

"We have this perfect storm right now of working with the best people, and providing the best solutions. In the shuttle era, you built a single experiment – you launched it, and you returned it," reflected Boling. "Now we have equipment permanently onboard the International Space Station, and we're continuing to add to that catalog with the help of the SBIR program."

The bright pink lights of the VEGGIE system undergoing testing inside the International Space Station Environmental Simulator chamber at the Space Station Processing Facility (SSPF) at NASA's Kennedy Space Center
// PHOTO COURTESY OF NASA //

ORBITAL TECHNOLOGY CORPORATION (ORBITEC)

A standard six-month mission to the International Space Station can certainly have its life changing and awe-inspiring moments for the crew. Mealtime, however, is not one of those moments. Astronauts have come to rely on prepackaged, freeze-dried foods to nourish them during these lengthy expeditions.

PROJECT
Deployable Vegetable Production Unit (VEGGIE)

MISSION DIRECTORATE
Human Exploration and Operations

PHASE III SUCCESS
$1.34 million directly related to VEGGIE; additional multimillion dollar contracts for technologies that stemmed from the VEGGIE SBIR project

SNAPSHOT
Through the NASA SBIR program, ORBITEC developed VEGGIE, which is currently in use aboard the ISS to grow fresh vegetables, plants and flowers. A second VEGGIE unit is set to join its counterpart in 2016

ORBITAL TECHNOLOGIES CORPORATION (ORBITEC)
Space Center
1212 Fourier Drive
Madison, WI 53717

Although modern science has come a long way in providing nutrient-rich foods to astronauts, whole foods like vegetables and leafy greens were not available on-orbit. That is, until Orbital Technologies Corporation (ORBITEC) introduced the Vegetable Production System (VEGGIE) – a game-changing technology that enables the growth of plants and vegetables in space. With support from NASA's Small Business Innovation Research (SBIR) program, VEGGIE grew from an idea envisioned by a team of horticulturists and engineers, to a system in use today aboard the ISS and one that is redefining NASA's new era of space exploration.

"Based on past research, we believed there was a significant physiological advantage to having fresh food available to the crew," recalls Robert Morrow, Senior Scientist at ORBITEC. "So we proposed a simplified plant growth system for food supplementation, and eventually received an SBIR award to help further develop that concept."

The team at ORBITEC dove into their vision – a vision that did not fully come to fruition until 18 years after the concept was developed. This first-of-its-kind system had to meet some stringent requirements; it needed a light source that could sufficiently produce crops, a compressible nutrient and water delivery system, and it would require a semi-passive atmospheric control system that minimizes water use without limiting air flow around the plants. VEGGIE would also need to run on low power and utilize the cabin environment for temperature control and as a source of CO_2. The end result was a system that operated with only 70 watts of power, which is equivalent to a standard light bulb.

ORBITEC, based in Madison, Wisconsin, won a Phase II award worth $600,000 just one year after its Phase I, to continue this promising development and meet all of these objectives. After several high-fidelity prototypes were built by ORBITEC, and tested by both ORBITEC and NASA Kennedy Space Center (KSC) scientists, VEGGIE made its debut onboard the ISS in 2014 when it launched on the Space X Dragon 4 capsule.

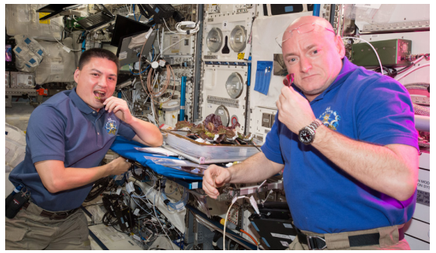
Bolden, Dr. Marshall Porterfield, and Mr. Angel Otero supported the VEGGIE effort, with a display at NASA HQ in Washington DC

UPPER RIGHT Astronauts Lindgren and Kelly enjoying fresh lettuce grown in the ISS

BOTTOM LEFT NASA's "one-year astronaut" Scott Kelly tweeted this flower that was grown on VEGGIE – marking the very first time an ornamental flower was grown in space

BOTTOM RIGHT NASA Astronaut Steve Swanson activates the VEGGIE machine aboard the ISS

// PHOTOS COURTESY OF NASA //



Seeds for romaine lettuce and zinnia flowers also accompanied the system for the astronauts to grow in space. Expedition 39 flight engineer Steve Swanson started the lettuce seeds in May 2014. Thirty-three days later, the plants were harvested and flown back to Earth where they were tested for food safety at KSC. Soon thereafter, the second round of plants were activated by astronaut Scott Kelly – but this time, the crew enjoyed eating the romaine lettuce. The zinnia flower had also bloomed, marking the very first ornamental flower that was grown in space.

"The crew was so excited to have fresh food onboard," says Robert Richter, Program Manager for Veggie at ORBITEC. "Some of the best feedback we got was from Astronaut Kjell Lindgren. He said the ISS is a very sterile environment and just having plants near him provided the color and relaxation that he had been missing."

> "The funding we received for BPS enabled us to develop VEGGIE and supported us to where we are today. Without the SBIR program, we literally would not have gotten off the ground."
>
> ORBITEC
> PROGRAM MANAGER FOR VEGGIE
> ROBERT RICHTER

The implications of VEGGIE go far beyond providing sustenance and relief to the crew of the ISS. The ability to grow food in space is important for NASA's anticipated long duration missions to Mars and other planetary expeditions, where astronauts could be away from Earth for years at a time.

VEGGIE came on the heels of another highly successful ORBITEC project – the Biomass Production System (BPS). Concurrently with the initial development of VEGGIE, ORBITEC was developing the Plant Research Unit (PRU) which was awarded the largest NASA follow-on contract ever at the time. Today, ORBITEC is working on two other large-scale projects, which utilize some of the same technology developed under BPS and VEGGIE, including an Advanced Plant Habitat and a NextSTEP Hybrid Life Support System. The company is looking at hybrid life support systems which incorporate both biological and physical-chemical systems and looking at testing larger plant growth systems to improve these technologies for long duration space missions.

"VEGGIE is a stepping stone for long duration systems focused on life support," adds Morrow. "This feeds into a number of scientific aspects; but they all lean toward plant biology in space."

The overall vision of the company attracted Sierra Nevada Corporation – the top woman-owned federal contractor in the United States, which acquired ORBITEC in 2014. Sierra Nevada wanted to add to its Space Systems capabilities, and through this acquisition, was able to add to its technology portfolio in the areas of strong liquid rocket propulsion systems, human space flight life support and thermal systems, automated life science systems, and fire suppression systems. ORBITEC, which began as a 3-person team, will continue to operate out of its Wisconsin headquarters, where it has built a name for itself in the international aerospace community.

"The NASA SBIR program played a key role to our commercial success, and the eventual acquisition by Sierra Nevada Corporation," says Richter. "The funding we received for BPS enabled us to develop VEGGIE and supported us to where we are today. Without the SBIR program, we literally would not have gotten off the ground."

The second VEGGIE system is set to join its counterpart on the ISS with the launch of SpaceX 14 in 2016.

WORLDWINDS, INC.

The aftermath of Hurricane Katrina on the greater New Orleans area resulted in over $81 billion in property damage. Since the U.S. government underwrites all flood insurance policies, months of subsequent debates occurred on whether destruction was caused by wind or water – because each fall under separate policies. The U.S. government uses specialized flood maps and computer models to assess risk and set premiums for flood insurance policies. Updates to the Gulf Coast maps and computer models were certainly needed after Katrina, and the ability to effectively and efficiently generate more accurate flood models became crucial.

PROJECT
Web-Based Hurricane Storm Surge and Flood Forecasting Using Optimized IFSAR Bald Earth DEMS

MISSION DIRECTORATE
Science

PHASE III SUCCESS
$1 million in subcontracts with FEMA

SNAPSHOT
While developing specialized hurricane flood atlases for the coastal regions using space-based radar information under a NASA SBIR project, WorldWinds helps to develop new flood maps for FEMA post-Hurricane Katrina

WORLDWINDS, INC.
1103 Balch Blvd.
Stennis Space Center, MS 39529

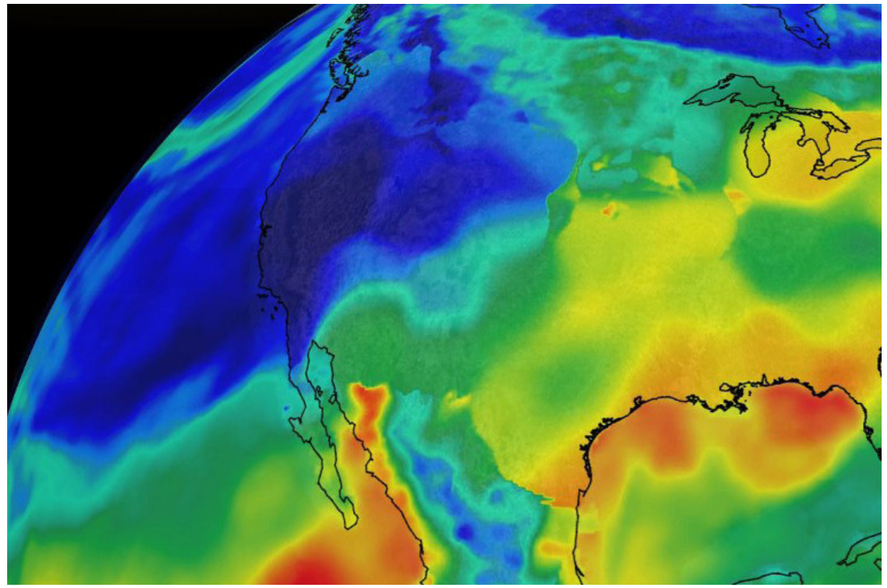
Three years prior to Katrina, a Mississippi-based small business, WorldWinds, Inc., was embarking on a Phase I Small Business Innovation Research (SBIR) project for NASA aimed at developing hurricane flood atlases for the coastal regions using space-based radar information. NASA had an interest in looking at hurricane storm surge forecasts using highly accurate digital elevation models to improve forecasting near coastlines; and WorldWinds' SBIR work centered on atlases that would include high-resolution storm surge simulations and rainfall effects. When Hurricane Katrina hit land, the need for such a technology was expedited, and suddenly WorldWinds was fulfilling demand across government agencies.

"We were working on our Phase II SBIR project with NASA, where we were applying the Interferometric Synthetic Aperture Radar (IFSAR) data from the space shuttle collection and developing high resolution storm surge atlases," explained Elizabeth Valenti, President/Owner at WorldWinds, Inc. "Toward the end of the Phase II project, Hurricane Katrina happened, and suddenly we were proving this process in real-time, in a brand new situation."

The work on the NASA SBIR project opened up the doors to working with the Federal Emergency Management Agency (FEMA) on a project called FEMA Risk MAP. Risk MAP provides high quality flood maps and information along with tools to better assess the risk from flooding and planning in an effort to reduce or mitigate flood risk.

PREVIOUS PAGE The aftermath of Hurricane Katrina on the Gulf Coast expedited a need for updated flood maps and corresponding risk. FEMA used WorldWinds' technology developed under the NASA SBIR program to update its Risk MAP across the region and other U.S. states

RIGHT WorldWinds is delivering commercial weather display products for TV broadcasters across the United States



WorldWinds' technology powers this map by running storm surge simulations for historical and hypothetical hurricanes. A 852 processor core supercomputer, one of the largest in Louisiana and located at WorldWinds' headquarters, is used for efficiently running the ADCIRC hydrodynamic model.

ADCIRC is a system of computer programs for solving time dependent, free surface circulation and transport problems in two and three dimensions. WorldWinds' hydrodynamic model estimates the water level at each 30-meter grid point (on average) every 15 minutes, given the characteristics of a hurricane. Post Hurricane Katrina, new maps were produced for many southern states, while maps for other areas are in the process of being generated.

> "Toward the end of the Phase II project, Hurricane Katrina happened, and suddenly we were proving this process in real-time, in a brand new situation."
>
> WORLDWINDS, INC.
> PRESIDENT/OWNER
> ELIZABETH VALENTI

"The NASA SBIR program really opened up the doors for us to most of our other work with agencies and within the commercial sector," adds Valenti. "In Phase II, we learned how to use the storm surge model, and we were able to purchase the parallel processing supercomputer equipment required. That allowed us to do the processing work for FEMA, since they were looking for an existing capability. We had the personnel, the hardware and the expertise for the Risk MAP project."

With its experience in developing and leveraging weather prediction and hindcasting services, WorldWinds has also found commercial success that has derived from its original SBIR-funded technologies. Using the same ADCIRC hydrodynamic modeling storm surge technology, WorldWinds is working with a private company to produce products that serve the TV weather broadcast market.

The company receives data from NASA and the National Oceanic Atmospheric Administration (NOAA) and processes this information around the clock by WorldWinds servers in 4 different states. After passing through WorldWinds' retrieval and processing algorithms, the results are formatted by Baron Services – a national weather forecasting service – and showcased on Baron's graphical display systems several times a day for use by client television stations across the United States, Canada and Spain, and most recently, by Accuweather's 24-hour weather news channel.

For NASA, the interest lies in understanding climate change and the rising sea levels. The agency is looking at potential increases in storm surges with the interest of protecting NASA infrastructure, both on the Gulf, and in communities where a risk may not have been previously anticipated. With offices at NASA's Stennis Space Center in Mississippi and Slidell, LA, WorldWinds is positioned to provide continued solutions to NASA's growing weather prediction needs both along the Gulf Coast and across the country.

ESAero's ECO-150 concept was developed using both superconducting and non-superconducting electric distributed propulsion systems which were funded under the NASA SBIR program

EMPIRICAL SYSTEMS AEROSPACE, INC.

While most people equate NASA with space exploration, the agency actually sets standards across the general aviation industry and influences how Americans fly everyday. One of the most pressing objectives is the need to increase efficiency across all commercial aircraft, thus decreasing both fuel costs and harmful emissions; a goal that is shared by Empirical Systems Aerospace, Inc. (ESAero).

PROJECT
SCEPTOR Distributed Electric Propulsion Aircraft

MISSION DIRECTORATE
Aeronautics Research

PHASE III SUCCESS
$8 million in Phase III contracts from NASA

SNAPSHOT
California-based ESAero has a rich history with the NASA SBIR program and has tied together several Phase I and II projects to deliver a new suite of electric aircraft propulsion system designs and tools to its government clients

EMPIRICAL SYSTEMS AEROSPACE, INC.
P.O. Box 595
Pismo Beach, CA 93448

"We believed early on that investments needed to be made in electric aircraft propulsion," says Andrew Gibson, President of ESAero. "We already had a history in this area and had proven that electric aircraft brought benefits; we felt we could meet NASA's goals for future aircraft."

This belief led the Central California-based team at ESAero to pursue funding from the NASA Small Business Innovation Research (SBIR) program. After a successful SBIR stint in 2009 with NASA Glenn looking at hybrid electric aircraft, which utilize cooled liquid hydrogen to cool superconducting generators, ESAero began to focus on non-superconducting technologies, which they felt better aligned with the current supply chain. A few years later, SCEPTOR took form – Scalable Convergent Electric Propulsion Technology Operations Research – and it is allowing NASA to explore the next generation of electric aircraft designs.

SCEPTOR, with which ESAero is working in tandem with Armstrong Flight Research Center, Langley Research Center, and partner small businesses, serves as an electric propulsion testbed designed to test new distributed electric propulsion concepts in flight. Through a follow on Phase III contract with ESAero, Armstrong purchased an airframe for modification that is currently being built. SCEPTOR provides NASA with flight data on distributed electric propulsion, allowing the comparison of computer modeling and simulation data with actual in-flight performance data.

"The SBIR program helps small businesses to better compete with larger companies - this is work that a large prime contractor could do, but because it is so far off and such a low TRL, they are not making the investments," explains Gibson. "Through SBIR, small businesses can be cutting edge and put their stake in the ground. Eventually this development, once created for NASA, will go mainstream. And that is the ultimate commercialization."

ESAero's Scalable Convergent Electric Propulsion Technology Operations Research (SCEPTOR) technology is being used by NASA to explore the system level impacts of distributed electric propulsion
// Photo courtesy of NASA //

NASA has high hopes for SCEPTOR, and they are expecting the technology to result in 3 ½-5 times less energy use, 25-30% less gas use, more fuel efficiency, and better aerodynamic performance. Since NASA invests in much of the early research and development work in aviation, meeting these milestones paves the way for others in the industry to conform. Reducing carbon emissions is also an end goal and NASA realizes to get there, they must convert to hybrid or electric.

> "Through SBIR, small businesses can be cutting edge and put their stake in the ground. Eventually this development, once created for NASA, will go mainstream. And that is the ultimate commercialization."
>
> ESAERO PRESIDENT ANDREW GIBSON

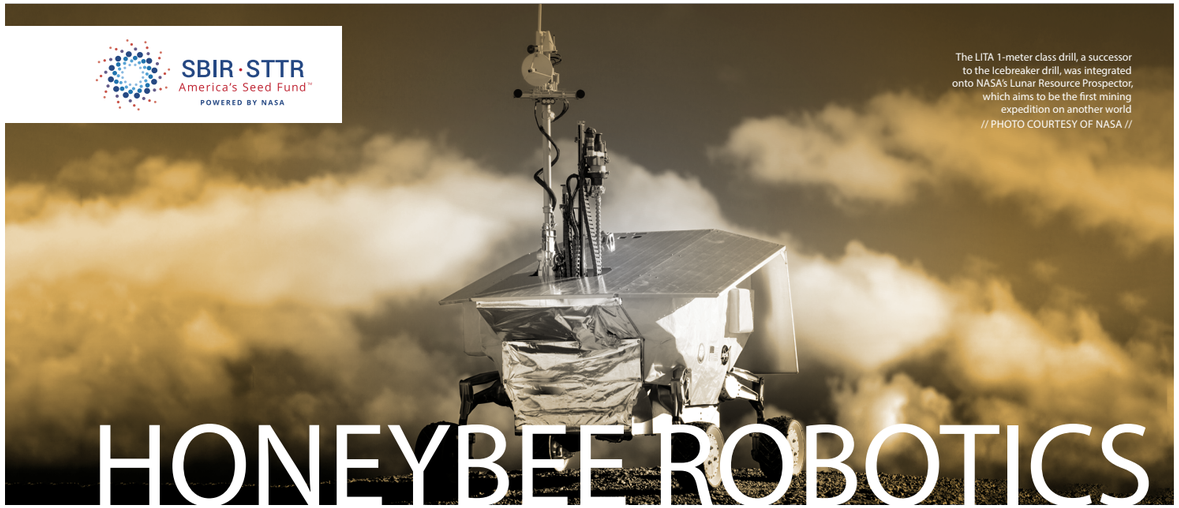
SCEPTOR came on the heels of another successful SBIR technology belonging to ESAero. PANTHER (Propulsion Airframe iNTegration for Hybrid Electric Research), also developed with NASA funding across several Phase Is and internal development, is a tool suite for the sizing and performance of electric and hybrid electric air vehicles. The company's focus is to innovate in the area of electric aircraft design and integration, which has applicability across many branches of the government and in the commercial aviation sector as well.

Another follow on Phase III contract awarded to ESAero saw the development of a ground test capability called the HEIST (Hybrid Electric Integration System Testbed), which involved the utilization of the LEAPTech (Leading Edge Propeller Technology) wing. The LEAPTech wing utilizes a different form of distributed propulsion, in that it distributes propellers across the leading edge of a wing rather than in ducts. This is a more near term application for electric distributed propulsion.

Wanting to fully understand how things work at the component level and studying how electric motors perform, ESAero received an award for another NASA SBIR project to better comprehend failure as it relates to the rest of the propulsion system. This SBIR Phase II project focuses on intelligent prognostics and health management (PHM) systems, which monitor aircraft performance. It is being designed and executed by ESAero for HEIST. By teaming with General Atomics Intelligent Systems, ESAero is creating the ability to monitor the degradation of a subsystem in real-time, so that self-repair decisions are possible.

With two NASA follow on Phase III contracts worth $8 million, subcontracts with the Department of Defense, and increasing work with many of the nation's top prime contractors, ESAero is staking its claim in the area of innovative and futuristic electric aircraft design.

"Electric vehicles are a game changer – how you design aircraft, how you approach a mission; the problem is being redefined and nobody understands how to integrate it," adds Gibson. "This opens up the design space so much. We are just beginning to understand and have those capabilities, as a community. We want to be a leader in that area and maintain the lead."



The LITA 1-meter class drill, a successor to the Icebreaker drill, was integrated onto NASA's Lunar Resource Prospector, which aims to be the first mining expedition on another world
// PHOTO COURTESY OF NASA //

HONEYBEE ROBOTICS

In the search to find extraterrestrial life, one mantra says it all: Follow the water. Wherever water flows on Earth, one can be sure to find life – and that principle may well transcend to other worlds. NASA has been investing in technology that can go beyond what one can assess from the surface; drills that can reach meters below the surface to more habitable environments, or hundreds of meters below ground into large water-bearing formations. By aligning with NASA and setting its sights on Mars, Honeybee is hoping to reach new depths during planetary exploration that were previously untouched.

PROJECT
Compact Lightweight Sampling Drill for Planetary Exploration

MISSION DIRECTORATE
Exploration Systems

PHASE III SUCCESS
More than $3 million in follow-on contracts with NASA, DOD, and private companies

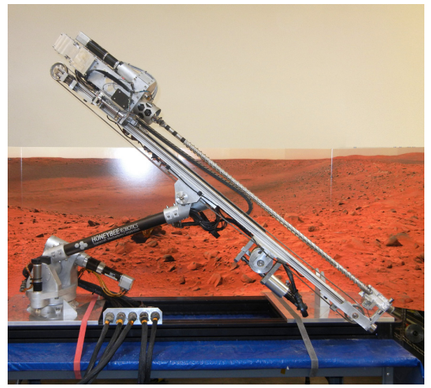
SNAPSHOT
Honeybee Robotics has developed advanced robotic and electromechanical systems that operate in challenging environments in space and on Earth. Since 2003, every NASA spacecraft to land on the Martian surface has utilized technology built by Honeybee.

HONEYBEE ROBOTICS
Brooklyn Navy Yard
Building 3, Suite 1005
63 Flushing Avenue
Brooklyn, NY 11205

Brooklyn, New York-based Honeybee Robotics has spent over fifteen years developing advanced robotics systems and planetary drills that allow scientists to explore planets in three dimensions. The company's meter-class drill extraction systems were originally intended for lunar missions. Honeybee had a vision of sustaining a human or robotic presence on the Moon to mine local resources from a central base, thus decreasing the cost and wait times associated with sending them up from Earth.

"Water is one of the most precious resources in space," explains Kris Zacny, Vice President of Honeybee Robotics and Director of Exploration Technology. "Once you get water you can sustain human presence; you can break down the molecules into hydrogen and oxygen so astronauts can breathe, without the need to bring extra tanks. Hydrogen and oxygen can also be utilized as a propellant to either come back or to explore farther. It extends the life of all missions."

Although the drill's objectives were originally intended for the Moon, NASA switched gears and set its sights on Mars – where with similar performance the drill could potentially meet the same resource-collection goals while also aiding the search for life beyond Earth. Honeybee got its break to help NASA address this exploration goal when it began applying for NASA Small Business Innovation Research (SBIR) awards to refine its lunar drill system and make it suitable for Mars missions. Magnetic fields protect planets from charged particles in space. Since the magnetic field of Mars is only a fraction of what it is on Earth, anything on the surface or slightly below would likely be sterilized or killed by charged particle radiation or UV light penetrating Mars' thin atmosphere. The Icebreaker, as it was eventually named, was designed to drill 1–2 meters, which has never before been achieved on Mars. The system would also have to be autonomous and would need to be comprised of the right materials in order to withstand the sterilization requirements for planetary protection.



LEFT The 1-meter class Icebreaker drill, shown on a deployment boom prior to testing at the Honeybee Robotics laboratory

RIGHT The Icebreaker drill shown during field testing in the Dry Valleys of Antarctica, an analog environment to the cryogenic ice found in the Mars polar regions

"This particular SBIR project was really the turning point for us," reflected Zacny. "The technology developed under this program has been integrated in every single drill system that we have developed since."

Serendipitously, the SBIR and STTR Reauthorization Act of 2012 gave Honeybee and NASA the opportunity to expedite this technology, with the implementation of the Commercialization Readiness Program (CRP). With SBIR alone, NASA invests in early research and development for technology they eventually need, even though NASA may not be ready to infuse it into a specific mission. CRP is designed to help make the SBIR technology more ready for commercial applications, including infusion into NASA's missions. CRP allows for funding additional work, until the mission is ready to infuse the technology; enabling that infusion to be expedited. With CRP, small businesses like Honeybee can provide component technologies that large prime contractors utilize while helping small businesses become a vital part of the supply chain.

> "The technology developed under this program has been integrated in every single drill system that we have developed since."
>
> HONEYBEE ROBOTICS
> VICE PRESIDENT
> DIRECTOR OF EXPLORATION TECHNOLOGY
> KRIS ZACNY

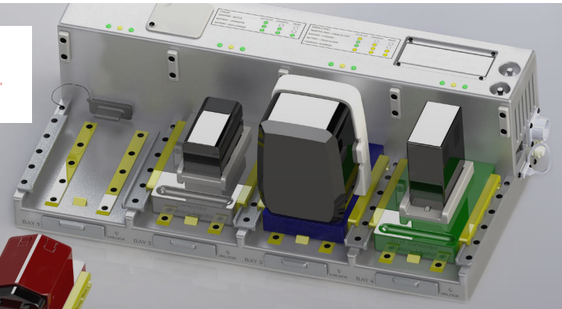
These solutions include systems designed for drilling, coring, and physical sampling of Mars, the Moon, Venus, Europa, comets, and asteroids. Mining resources from asteroids is an on-going project for Honeybee through technologies such as its Asteroid Water Extractor, both to gather water resources to refuel orbiters around the Earth and to support human spaceflight.

Among other planetary exploration technologies, Honeybee is currently improving its Planetary Deep Drill, which could penetrate hundreds of meters into the water-rich Mars polar ice caps and Jupiter's moon Europa. The four-meter Planetary Deep Drill contains all of the motors, electronics and sensors required for operations while using an efficient rotary percussive drilling technology. The current drill can operate on as little as 250 Watts of power – less than many consumer-grade drills you could buy at Home Depot.

Although Honeybee's work on the 1-meter class drills transitioned to the newer systems designed primarily for Mars, NASA didn't want to give up its lunar missions. Focused within the polar regions of the Moon, NASA is planning to collect and analyze samples of water and other volatiles from one-meter depth through a follow-on Phase III contract with Honeybee worth approximately $1 million.

Commercially, Honeybee is exploring opportunities in the energy sector thanks to its early R&D work with NASA. The company has just received funding from one of the largest oil and gas contractors in the world to develop a specialized percussive system, which uses cam spring technology to generate blows of constant energy independent of blow frequency while operating in a vacuum environment. This is an alternative to conventional hammer systems, which provide higher energies at higher frequencies. Another follow-on Phase III contract with the Department of Defense involves the development of a robotic geotechnical system, which also stemmed from its SBIR-funded technology through NASA. The geotechnical tool performs all actions related to driving a rod into the ground, depth measuring, and data processing autonomously.

"We wouldn't be where we are right now without the CRP and SBIR programs," says John Abrashkin, Director of Marketing at Honeybee Robotics. "It has essentially enabled us to build systems that can go to the Moon and to Mars and even Europa. We are developing critical technology that nobody else wants to invest in; it's risky. But if they pay off, as they have, they allow NASA and other government agencies to procure needed technological innovations and set their sights on new missions that were never before possible."



CAD image of the Universal Battery Charger showing four separate battery types

AURORA FLIGHT SCIENCES CORPORATION

From camcorders and digital cameras, to science experiments, to drills, the International Space Station is home to a handful of tech gadgets and power tools that constantly need to be charged. Just like on Earth, all of these things require their own dedicated chargers. While the obvious inconvenience of lugging dozens of various adapters to space might seem like reason enough to invest in a universal battery charger, the driving force is actually the cost. The estimated total to launch 1 kg (a little over 2 pounds) of equipment into orbit is over $10,000. Although the newer launch vehicles may drive that figure down, it will still cost thousands of dollars to send equipment into space – necessitating a simpler, cost-effective system for use on the ISS.

PROJECT
ISS Universal Battery Charger (UBC)

MISSION DIRECTORATE
Human Exploration and Operations

PHASE III SUCCESS
Recent Phase III follow-on contracts with NASA worth $200K to supply the UBC to the Internatwional Space Station; technology results in costs savings of $2 million per launch.

SNAPSHOT
Aurora Flight Sciences has utilized the NASA SBIR program to develop a Universal Battery Charger for use on the ISS capable of interfacing with the most commonly used batteries on board.

AURORA FLIGHT SCIENCES CORPORATION
90 Broadway
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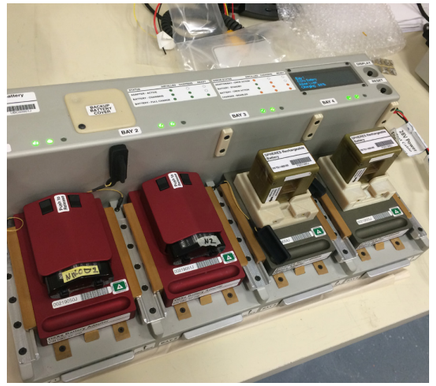
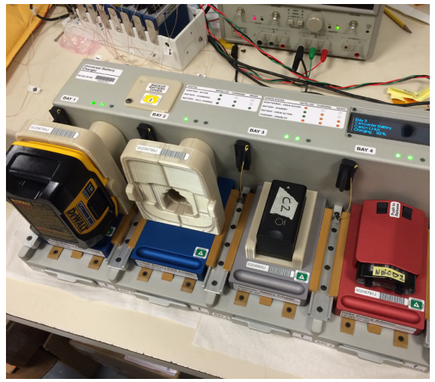
Aurora Flight Sciences had been developing payloads for use on the ISS spanning several decades. One of its ISS payloads, SPHERES, which is a collection of miniaturized satellites used for experiments, was burning through large amounts of non-rechargeable alkaline batteries. This equated to a few million dollars in launch costs. A 2010 NASA Small Business Innovation Research (SBIR) solicitation sought the development of a rechargeable battery for SPHERES. Familiar with NASA's needs, Aurora responded to the solicitation, but brought a whole other idea to the table.

"We originally thought we would build this rechargeable system for our payload under this SBIR," recalls John Merk, Space Systems Group Lead for Aurora Flight Sciences. "But we felt that satisfying our own needs wasn't enough. We ended up pitching a universal battery charging system for the ISS that could accommodate much more than SPHERES. It would be capable of charging most of the commonly used batteries on board the ISS."

Aurora won a Phase I SBIR award from NASA and began to work on the conceptual design for what would soon be called the Universal Battery Charger (UBC). The company began looking at every type of rechargeable battery currently in use on the station. Since different batteries require different voltages and charging schemes, solutions were brainstormed to account for these differences. The ISS is also limited when it comes to power sources, similar to how there are never enough wall outlets in a bedroom. When Aurora won a subsequent Phase II award to begin building a more detailed design, the company was well on its way to turning their idea into a tangible system.





TOP LEFT Universal Battery Charger base system, charging (2) Nikon li-ion batteries and (2) custom SPHERES li-ion batteries

TOP RIGHT Universal BatteryChargerundergoing testing at Aurora's R&D Center, charging several different battery types (colored indicators and screen show status of batteries being charged)

BOTTOM Aurora Flight Sciences, along with MIT and Pratt & Whitney, are developing the next generation of electric aircraft. Pictured here is the D8 "Double Bubble" design concept

"We were able to say we have this great idea, and we want to turn it into a flight program," says Merk. "NASA really wanted to see it happen. We were engaged with the ISS vehicle office, and they agreed to be a Phase III sponsor – the SBIR helped us turn this into a real program."

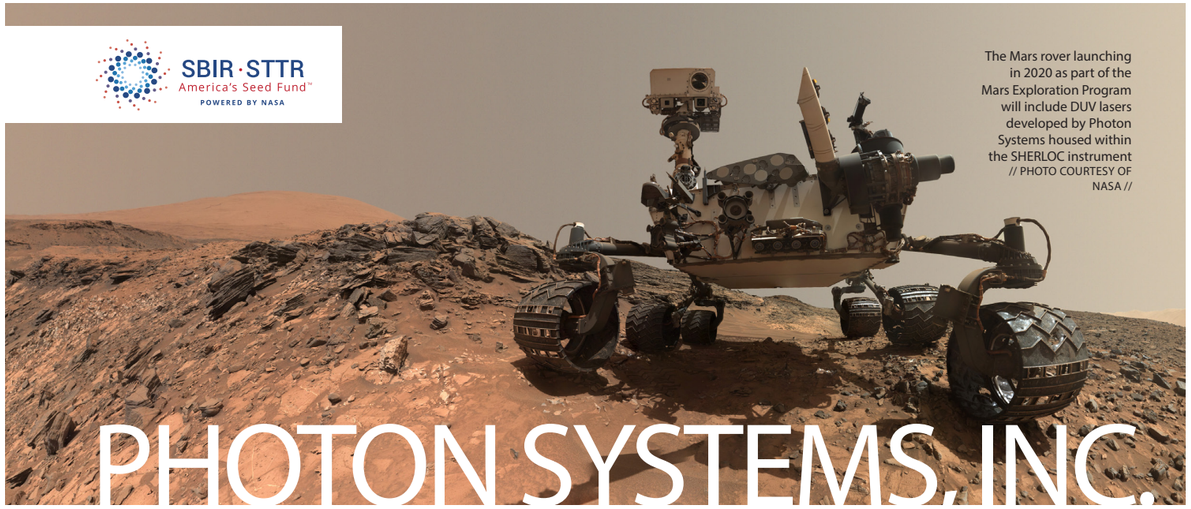
> "As a small R&D firm, you have to go after these higher risk, cutting edge technologies that are only funded under SBIR."
>
> AURORA FLIGHT SCIENCES SPACE SYSTEMS GROUP LEAD JOHN MERK

The resulting design utilizes a four-channel base unit and sliding, removable battery adapters for a more savvy and space-saving design. Each adapter is specific to one battery type and contains all the information required to safely charge the batteries. Since every charger that makes its way onto the ISS has to pass stringent safety tests, creating a one-size-fits-all charger reduces the manpower and hours needed to perform multiple tests on different units.

Follow-on contracts with NASA soon followed worth $200K to supply UBC units to the ISS, which are set to make a debut with the launch of Space X 8 in 2016. Aurora has a rich history with the NASA SBIR program, dating back to 1986. Current projects that supplement the UBC include the development of a new-age spacesuit for NASA astronauts, building hybrid nanocomposites for future aircraft, and developing electric drive for vertical lifts. Aurora is also concurrently serving as the prime contractor on one of NASA's most anticipated projects – the D8 "Double Bubble" future aircraft series. In tandem with MIT and Pratt & Whitney, this project involves the revolutionary design of future aircraft through physics-based modeling across multiple engineering disciplines. The D8 has the potential of achieving a 71% reduction in fuel burn, a 60 EPNdB reduction in noise, and an 87% reduction in emissions.

For the Department of Defense, Aurora is currently in discussions regarding an internal rechargable battery on one of the agency's small satellites that would be launched from the ISS. Additional applications are being developed that involve a custom battery for an Extravehicular Activity application.

"For us, the NASA SBIR program has been invaluable," says Merk. "As a small R&D center, you have to go after these higher risk, cutting edge technologies that are only funded under SBIR. But you develop them and grow them into actual products. And many of our SBIRs have been integrated somehow into Aurora's larger portfolio."



The Mars rover launching in 2020 as part of the Mars Exploration Program will include DUV lasers developed by Photon Systems housed within the SHERLOC instrument
// PHOTO COURTESY OF NASA //

PHOTON SYSTEMS, INC.

The 2020 Mars Rover is already one of the most highly anticipated robotic missions in NASA's history. As part of the Mars Exploration Program, this rover is designed to address key questions about the potential for life on the Red Planet and to gauge the challenges of future human exploration. One way to accomplish this is by using specialized ultraviolet (UV) lasers developed by Photon Systems to trace miniscule amounts of organics, such as amino acids; the building blocks of life.

PROJECT
Deep Ultraviolet (UV) Laser for Mars 2020 SHERLOC Instrument

MISSION DIRECTORATE
Science

PHASE III SUCCESS
Contracts with NASA worth $3 million; additional contracts with the DOD worth $4 million and commercial contracts worth $8 million

SNAPSHOT
The 11-person team at Photon Systems has been working with NASA since the late 90s to develop a DUV laser and the related resonance Raman and fluorescence spectrometer that will be instrumental in exploring Mars in 2020.

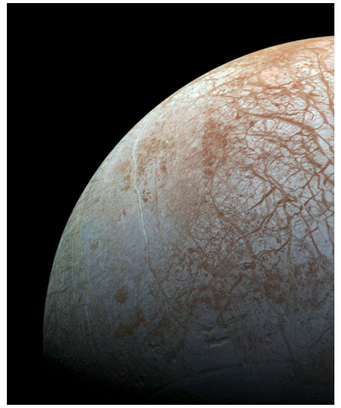
PHOTON SYSTEMS, INC.
1512 Industrial Park Street
Covina, CA 91722

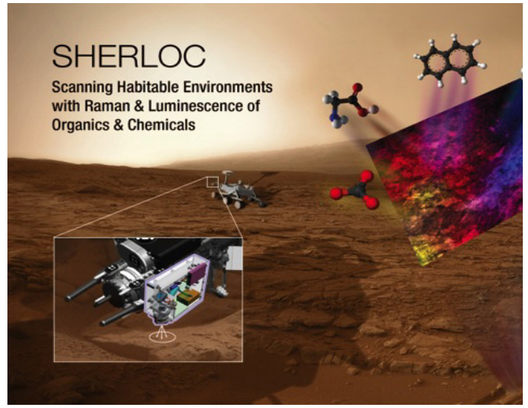
These Deep Ultraviolet (DUV) lasers are housed within one of the key pieces of equipment on the rover – SHERLOC – Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals. Through a contract with NASA's Jet Propulsion Laboratory (JPL), and several Small Business Innovation Research (SBIR) awards, Photon Systems is perfecting its laser and the ability to utilize deep UV methods for detecting organics.

Since anything designed for Mars has to go through decades of development, Photon Systems has been working closely with NASA since 1997 on all of the facets required for the highly ambitious task of planetary exploration. This evolved into using deep UV laser based technology to analyze trace amounts of other organic and inorganic materials as well as minerals. NASA hopes to create a detailed chemical/spatial map of portions of the Martian surface that will identify potential signs of ancient Martian conditions and perhaps even potential biosignatures within a rock.

"We had an idea for a small laser that was lightweight, with a low power consumption that could detect and characterize trace small amount of organics," recalls Dr. Bill Hug, Chairman and CEO of Photon Systems, Inc. "Through additional SBIRs focused on detecting amino acids and other prebiotic materials, this led to our current work on SHERLOC on developing a mini laser that enables mini-deep UV spectroscopic methods."

Photon's ultraviolet light lasers – which weigh about 1 pound – will be stationed on the robotic arm of the Mars rover and will use two types of ultraviolet-light spectroscopy to help search for signs of potential life on Mars. Interesting samples will be collected for possible return to Earth on a future mission. SHERLOC aims the UV laser light at a specific target and looks at the spectral signature coming back. In the first type of spectroscopy, a distinct fluorescence spectral





LEFT Europa, Jupiter's smallest moon, could be home to various life forms due to its many oceans. NASA has plans to use Photon Systems' patented UV laser technology to eventually explore the surface of Europa
// PHOTOS COURTESY OF NASA //

signature is emitted from molecules that contain rings of carbon atoms; clues that shine light on the potential for past life. The SHERLOC instrument hovers about 5 cm above the ground and ensures anything it measures remains sterile, which is important for planetary protection.

The second type of spectroscopy is called Raman scattering, which identifies certain minerals borne from salty water as well as other organic and inorganic compounds. This dual-use instrument is the first of its kind, and allows for the powerful analysis of many different compounds that were never before achievable. With an input power less than 10 W and emission wavelength at 248 nm, these lasers are smaller, lighter, and use less power than other lasers emitting in the deep UV, which are needed for the type of spectroscopy being employed in SHERLOC. These lasers have demonstrated the ability to operate at the extremes of temperature, from minus 130 Celsius to plus 70 Celsius; a necessity for operation on the rover arm of the Mars 2020 lander. This was previously unattainable.

> "The NASA SBIR program has enabled a very complicated technology to be developed that if it were left to private enterprise, never would have been built."
>
> PHOTON SYSTEMS, INC.
> CHAIRMAN AND CEO
> DR. BILL HUG

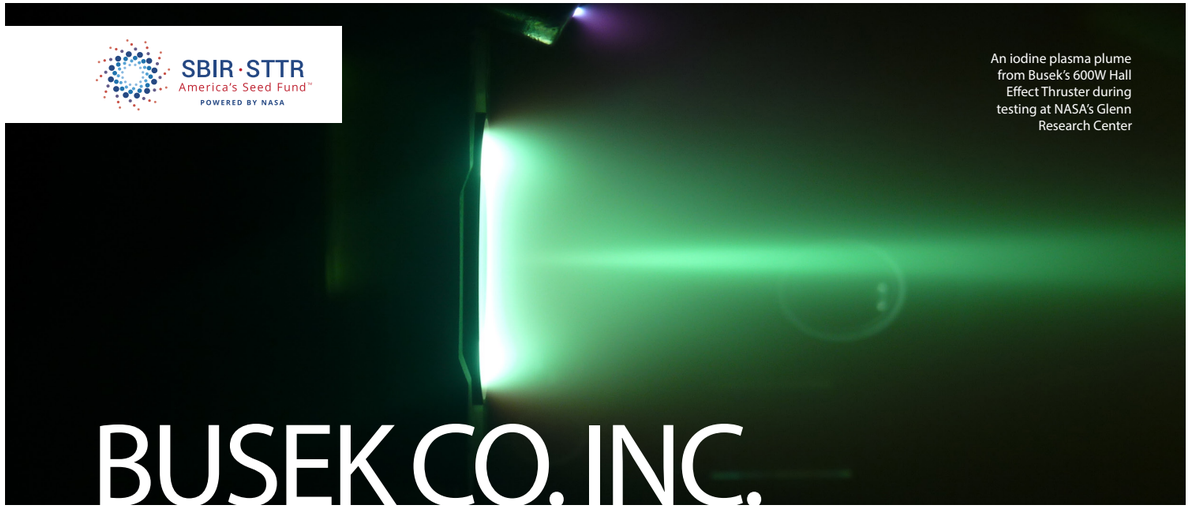
The beauty of such a laser is that it is capable of generating strong signals from organic materials that enables ultrahigh sensitivities. Just as the technology can pick up the detection of trace organic species on a planetary surface, that same principle can be applied to other sorts of detection, including chemical, biological and explosive weapons, as well as crime scene investigations. Photon Systems has contracts in place with the Department of Defense worth $4 million that utilize the same technology originally developed under the NASA SBIR project.

"The NASA SBIR program has enabled a very complicated technology to be developed that if it were left to private enterprise, never would have been built," adds Hug. "We believe we are at the forefront of a large number of commercial and government applications, both with the DOD, NASA, EPA, NIOSH, etc. but it has taken 17 years. No venture capitalist would have waited that long."

In the commercial sector, Photon Systems is working with both Pfizer and DuPont on contracts that involve the validation for manufacturing equipment and looking for trace amounts of containments in manufactured pills and food products. Additional applications in the pharmaceutical and food safety industry are also being explored. Commercial revenue stemming from the SBIR-funded technology has exceeded $8 million.

As for NASA, the agency has plans beyond the Mars 2020 mission to explore Titan, the largest of Saturn's moons; Enceladus, the active moon of Saturn; and Europa, a moon of Jupiter. All of these celestial bodies are high priority targets. Titan, because of the wealth of organic species present on the surface; Enceladus, because of liquid water in the subsurface that is being flung into space; and Europa, due to its under ice ocean that contains twice as much water as there is on Earth. These reasons make all three of them the best possible candidates for future exploration beyond Mars.

With just eleven employees and missions extending into the outer realms of our solar system, Photon Systems is just beginning to break ground in the buzzed-about deep UV territory. With concurrent projects right here on Earth utilizing the same futuristic technology, Photon Systems may be one of the few companies that can honestly say it has cornered the universal market.



An iodine plasma plume from Busek's 600W Hall Effect Thruster during testing at NASA's Glenn Research Center

BUSEK CO. INC.

A modern spacecraft performing interplanetary missions may change velocity by more than 20,000 miles per hour (32,000 km/hr). To achieve these speeds, Hall Effect Thrusters and other forms of ion propulsion may be used. For decades, xenon has been the gas of choice for most of NASA's solar electric propulsion (SEP) systems. However, alternate propellants are needed for future missions. The high-pressure storage requirements of xenon gas coupled with fluctuating costs due to limited availability have prompted scientists to seek out alternative propellants and compatible propulsion systems.

PROJECT
Iodine Hall Thruster for Space Exploration

MISSION DIRECTORATE
Space Technology

PHASE III SUCCESS
Over $3 million in Phase III and follow-on contracts with NASA and the USAF

SNAPSHOT
Busek has revolutionized solar electric propulsion technology by pioneering the use of iodine propellant, resulting in efficient, compact, low mass and high performance space propulsion systems.

BUSEK CO. INC.
11 Tech Circle
Natick, MA 01760

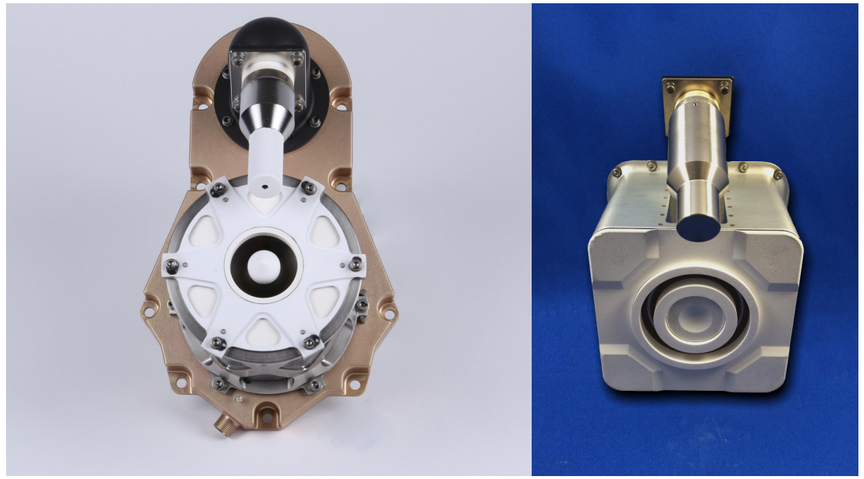
www.busek.com

Busek Co. Inc., which has been developing state of the art Hall thrusters and solar electric propulsion systems for over two decades, had a vision that iodine would provide all of the known benefits of xenon without the inherent challenges.

"Iodine was a complete change in approach for Hall thrusters," says Dr. James Szabo, Chief Scientist for Hall Thrusters at Busek. "Because you can launch at a much lower cost with fewer volume restrictions, this isn't just mission enhancement – it's mission enabling."

Iodine offers NASA immense benefits when compared to xenon including mass and cost savings. Iodine may be stored as a solid in low volume, low mass, low cost propellant tanks – an attractive feature when volume capacity on a spacecraft is extremely limited. This is in contrast to the high pressure, high mass, high cost tanks required for xenon Hall thruster systems. However, the team at Busek had to be sure that performance was not compromised by the use of iodine.

In 2010, the first ever demonstration of an iodine fueled Hall thruster occurred at Busek with Air Force funding. It was discovered that thruster efficiency and exhaust velocity were equal to what was achieved with xenon on Busek's thruster designs. With this new knowledge in hand, the Natick, Massachusetts-based company responded to a NASA Small Business Innovation Research (SBIR) solicitation and proposed an iodine Hall thruster for the agency's specialized missions. Busek won a Phase I award and aligned with NASA Glenn Research Center.



LEFT The Busek BHT-200 was the first U.S. developed Hall Effect Thruster to fly in space (TacSat-2, 2006)

RIGHT An iodine compatible 600 W Hall Effect Thruster (BHT-600-I) was an SBIR Phase II deliverable

While the Phase I project tested a very large thruster at power levels up to and exceeding 10 kilowatts, a Phase II objective was to scale down the system. The thruster was transitioned to a 600 Watt system, which is better sized for future Discovery Class missions. The Phase II project also saw the development of an iodine compatible hollow cathode, a power processing unit (PPU), and an improved iodine feed system (IFS).

> "SBIR has been invaluable, enabling us to do this groundbreaking research and development. We were given funding to take risks and do research in the lab that a bigger corporation wouldn't be able to do."
>
> BUSEK CO. INC.
> CHIEF SCIENTIST FOR HALL THRUSTERS
> DR. JAMES SZABO

The project has since led to numerous additional contracts including awards to develop a 200-watt iodine fueled Hall thruster system for the iSAT (Iodine Satellite) mission. Glenn Research Center (GRC), Marshall Space Flight Center (MSFC), and USAF Space and Missile Systems Center (SMC) are playing critical roles in this program which targets launch readiness in Spring of 2017.

Busek has also been working with a spacecraft launch provider and NASA Ames Research Center to develop small spacecraft delivery systems that would benefit from the availability of iodine Hall thrusters.

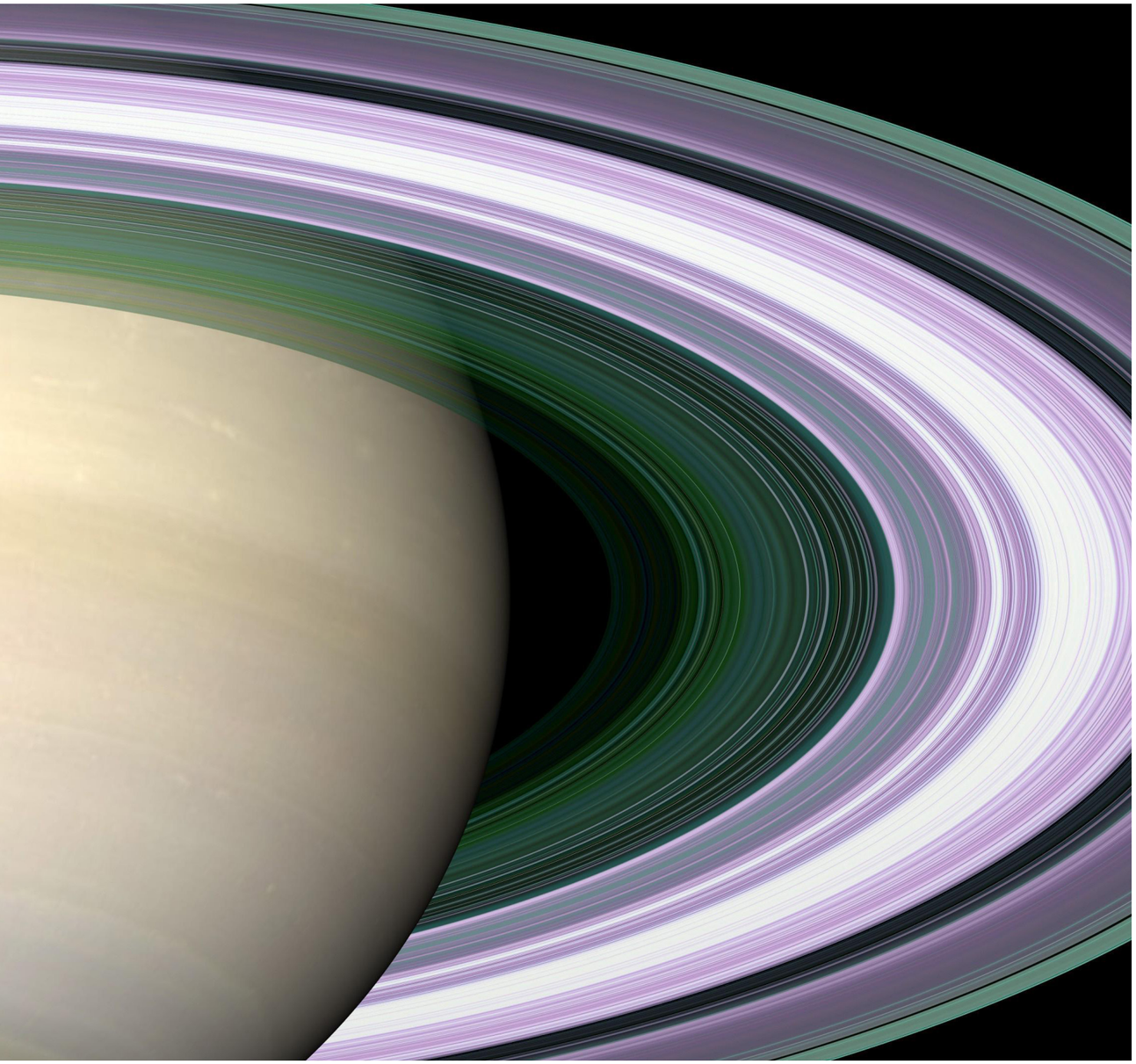
"A lot of credit goes to the NASA SBIR program, which enables cost-effective innovation and risk-taking in R&D. Busek developed the first U.S. Hall thrusters to fly in space and alternate propellant research is an extension of that work," adds Szabo. Taking concepts from the drawing board to flight is what we do."

Iodine Hall thruster systems can fill a wide range of spacecraft and missions, ranging from CubeSats (small satellites) up to large geostationary satellites and interplanetary probes.

Iodine fuel is also attractive for gridded ion engines – a sister technology to Hall Effect Thrusters. Busek is contracted to build iodine fueled Radio Frequency (RF) gridded ion engines for Morehead State University's Lunar IceCube and Arizona State University's LunaH-Map space probes. These 6U spacecraft will launch on the first flight of NASA's Space Launch System (SLS) in 2018. Exploration Mission 1 will carry 13 CubeSats to test innovative technologies that will ultimately enable future Mars missions.

Busek also believes its iodine Hall thrusters are an excellent fit for LEO, MEO and GEO applications as well as planetary exploration and asteroid redirect missions. Another important use for the technology is de-orbiting spacecraft at end of life, mitigating the risk of space debris.

As with many of NASA's end goals, iodine Hall thrusters are designed to make space exploration more feasible, compact, and cost effective, with the immediate goal of getting to Mars. The agency believes iodine can find a nice niche in the space market, allowing them to plan for multiple missions at a fraction of the cost.



Mission Directorate & Technology Area Investments

NASA's SBIR & STTR Programs invest in many different research areas. The following tables break down the program's Phase II investments into 4 views:

1. Mission Directorate Investments by Technology Area
   FY 2011-2015 (see note about ARMD below)
2. SBIR Combined Investments by Technology Area
   FY 2011-2015 (HEOMD, SMD, and STMD)
3. Mission Directorate Investments by Technology Area
   FY 2015 (see note about ARMD below)
4. SBIR Combined Investments by Technology Area
   FY 2015 (HEOMD, SMD, & STMD)

The past 5 years have brought about programmatic changes as noted below:

- Space Technology Mission Directorate (STMD) is a newly created Mission Directorate (MD).
- Prior MDs, Space Operations Mission Directorate (SOMD) and Exploration Systems Mission Directorate (ESMD), have merged to form Human Exploration and Operations Mission Directorate (HEOMD).
- The Aeronautics Mission Directorate (ARMD) does not fall under any TA, therefore, ARMD is broken down by SBIR's solicitation topic/subtopic areas and not included in the SBIR Combined Investments tables.

HEOMD Investments by Technology Area

FY 2011- 2015 Phase I & II Awards

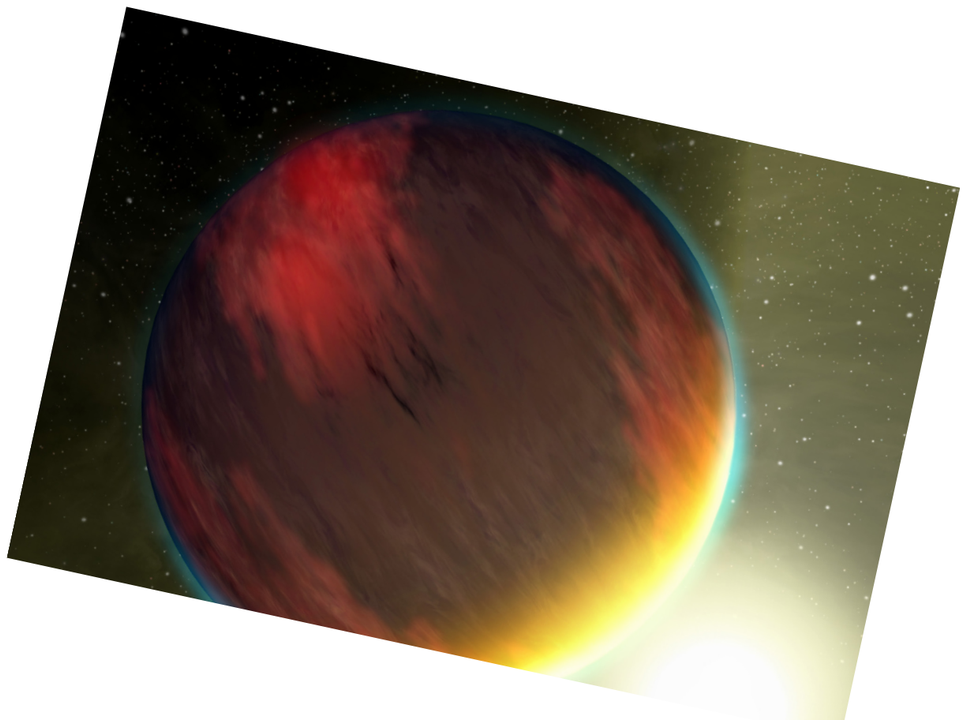
Level 1 TA	Level 2 TA	Number of Awards	Award Amount
1.0.0 Launch Propulsion Systems		31	**$9,169,328**
	1.1.0 Solid Rocket Propulsion Systems	4	$1,049,885
	1.2.0 Liquid Rocket Propulsion Systems	18	$6,582,563
	1.4.0 Ancillary Propulsion Systems	5	$1,037,405
	1.5.0 Unconventional/Other Propulsion Systems	4	$499,475
2.0.0 In-Space Propulsion Technologies		104	**$32,482,125**
	2.1.0 Chemical Propulsion	39	$11,079,550
	2.2.0 Non-Chemical Propulsion	36	$11,940,747
	2.3.0 Advanced (TRL <3) Propulsion Technologies	4	$1,049,898
	2.4.0 Supporting Technologies	25	$8,411,930
3.0.0 Space Power and Energy Storage		82	**$23,519,321**
	3.1.0 Power Generation	46	$15,254,245
	3.2.0 Energy Storage	30	$6,640,664
	3.3.0 Power Management and Distribution	6	$1,624,412
4.0.0 Robotics, Telerobotics and Autonomous Systems		73	**$24,407,960**
	4.1.0 Sensing & Perception	6	$738,642
	4.2.0 Mobility	5	$1,224,984
	4.3.0 Manipulation	12	$5,381,937
	4.4.0 Human-Systems Integration	14	$5,316,878
	4.5.0 Autonomy	20	$7,071,055
	4.6.0 Autonomous Rendezvous and Docking	2	$874,991
	4.7.0 RTA Systems Engineering	14	$3,799,473
5.0.0 Communication and Navigation		104	**$31,942,903**
	5.1.0 Optical Comm. And Navigation	30	$9,748,157
	5.2.0 Radio Frequency Communications	24	$6,590,064
	5.3.0 Internetworking	3	$972,743
	5.4.0 Position, Navigation, and Timing	26	$8,799,131
	5.5.0 Integrated Technologies	16	$4,648,454
	5.6.0 Revolutionary Concepts	5	$1,184,354
6.0.0 Human Health, Life Support and Habitation Systems		205	**$57,458,792**
	6.1.0 Environmental Control Life Support & Habitatio	63	$16,032,640
	6.2.0 Extravehicular Activity Systems	36	$7,844,986

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
6.0.0 Human Health, Life Support and Habitation Systems		205	**$57,458,792**
	6.1.0 Environmental Control Life Support & Habitatio	63	$16,032,640
	6.2.0 Extravehicular Activity Systems	36	$7,844,986
	6.3.0 Human Health and Performance	62	$21,229,892
	6.4.0 Environmental Monitoring and Safety	27	$7,952,343
	6.5.0 Radiation	17	$4,398,931
7.0.0 Human Exploration Destination Systems		69	**$19,142,161**
	7.1.0 In-Situ Resource Utilization	47	$11,879,055
	7.2.0 Sustainability & Supportability	10	$3,656,051
	7.3.0 Advanced Human Mobility Systems	2	$1,498,698
	7.4.0 Advanced Habitat Systems	2	$249,863
	7.5.0 Mission Operations & Safety	5	$571,693
	7.6.0 Cross-Cutting Systems	3	$1,286,801
8.0.0 Science Instruments, Observatories & Sensor Systems		16	**$5,597,980**
	8.1.0 Science Instruments	10	$4,223,035
	8.2.0 Observations	1	$600,000
	8.3.0 Sensor Systems	5	$774,945
9.0.0 Entry, Descent and Landing Systems		39	**$10,652,968**
	9.1.0 Aeroassist & Entry	31	$8,604,565
	9.2.0 Descent	3	$973,430
	9.4.0 Vehicle Systems Technology	5	$1,074,973
10.0.0 Nanotechnology		10	**$3,501,852**
	10.1.0 Engineered Materials and Structures	2	$699,934
	10.4.0 Electronics, Sensors and Devices	8	$2,801,918
11.0.0 Modeling, Simulation, Information Technology and Processing		16	**$6,032,183**
	11.1.0 Computing	4	$1,118,404
	11.2.0 Modeling	9	$3,289,296
	11.3.0 Simulation	1	$124,823
	11.4.0 Information Processing	2	$1,499,660
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		108	**$29,350,872**
	12.1.0 Materials	33	$6,521,349
	12.2.0 Structures	29	$7,451,637

HEOMD Investments by Technology Area

FY 2011- 2015 Phase I & II Awards

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		108	**$29,350,872**
	12.1.0 Materials	33	$6,521,349
	12.2.0 Structures	29	$7,451,637
	12.3.0 Mechanical Systems	8	$3,174,028
	12.4.0 Manufacturing	24	$7,590,690
	12.5.0 Cross-Cutting	14	$4,613,168
13.0.0 Ground and Launch Systems Processing		21	**$5,483,164**
	13.1.0 Technologies to Optimize the Operational Life	1	$124,966
	13.2.0 Environmental and Green Technologies	2	$824,996
	13.3.0 Technologies to Increase Reliability and Missi	11	$3,597,068
	13.4.0 Technologies to Improve Mission Safety/Missi	7	$936,134
14.0.0 Thermal Management Systems		32	**$8,240,886**
	14.1.0 Cryogenic Systems	11	$2,524,289
	14.2.0 Thermal Control Systems	20	$5,616,683
	14.3.0 Thermal Protection Systems	1	$99,914
Total		**910**	**$266,982,495**



SMD Investments by Technology Area

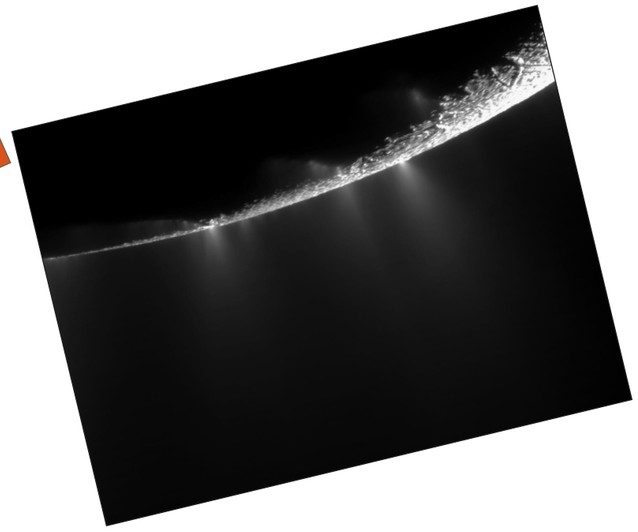
FY 2011- 2015 Phase I & II Awards

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
1.0.0 Launch Propulsion Systems		4	**$1,918,449**
	1.1.0 Solid Rocket Propulsion Systems	2	$724,674
	1.4.0 Ancillary Propulsion Systems	1	$594,202
	1.5.0 Unconventional/Other Propulsion Systems	1	$599,573
2.0.0 In-Space Propulsion Technologies		57	**$20,657,328**
	2.1.0 Chemical Propulsion	29	$6,983,909
	2.2.0 Non-Chemical Propulsion	22	$11,624,407
	2.4.0 Supporting Technologies	6	$2,049,012
3.0.0 Space Power and Energy Storage		46	**$14,807,296**
	3.1.0 Power Generation	26	$9,697,709
	3.2.0 Energy Storage	6	$717,108
	3.3.0 Power Management and Distribution	14	$4,392,479
4.0.0 Robotics, Telerobotics and Autonomous Systems		36	**$12,730,581**
	4.1.0 Sensing & Perception	4	$499,555
	4.2.0 Mobility	11	$2,390,024
	4.3.0 Manipulation	6	$2,802,124
	4.4.0 Human-Systems Integration	1	$124,783
	4.5.0 Autonomy	8	$3,186,313
	4.6.0 Autonomous Rendezvous and Docking	4	$3,479,384
	4.7.0 RTA Systems Engineering	2	$248,398
5.0.0 Communication and Navigation		18	**$5,538,148**
	5.2.0 Radio Frequency Communications	2	$248,196
	5.4.0 Position, Navigation, and Timing	14	$4,451,357
	5.5.0 Integrated Technologies	2	$838,595
7.0.0 Human Exploration Destination Systems		1	**$115,520**
	7.5.0 Mission Operations & Safety	1	$115,520
8.0.0 Science Instruments, Observatories & Sensor Systems		301	**$110,581,109**
	8.1.0 Science Instruments	192	$71,751,689
	8.2.0 Observations	41	$15,733,284
	8.3.0 Sensor Systems	67	$22,971,136
	Not Mapped	1	$125,000

SMD Investments by Technology Area

FY 2011- 2015 Phase I & II Awards

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
9.0.0 Entry, Descent and Landing Systems		11	**$4,253,280**
	9.1.0 Aeroassist & Entry	1	$124,997
	9.3.0 Landing	3	$939,359
	9.4.0 Vehicle Systems Technology	7	$3,188,924
10.0.0 Nanotechnology		1	**$699,821**
	10.4.0 Electronics, Sensors and Devices	1	$699,821
11.0.0 Modeling, Simulation, Information Technology and Processing		50	**$18,046,139**
	11.1.0 Computing	9	$3,599,877
	11.2.0 Modeling	16	$4,873,152
	11.3.0 Simulation	5	$1,723,980
	11.4.0 Information Processing	20	$7,849,130
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		9	**$1,733,207**
	12.1.0 Materials	2	$229,010
	12.3.0 Mechanical Systems	2	$879,750
	12.4.0 Manufacturing	5	$624,447
13.0.0 Ground and Launch Systems Processing		2	**$874,037**
	13.1.0 Technologies to Optimize the Operational Life	1	$750,000
	13.3.0 Technologies to Increase Reliability and Missi	1	$124,037
14.0.0 Thermal Management Systems		31	**$10,090,876**
	14.1.0 Cryogenic Systems	13	$4,872,911
	14.2.0 Thermal Control Systems	18	$5,217,965
	Total	**567**	**$202,045,791**



Level 1 TA	Level 2 TA	Number of Awards	Award Amount
2.0.0 In-Space Propulsion Technologies		5	**$1,993,882**
	2.2.0 Non-Chemical Propulsion	4	$1,868,955
	2.4.0 Supporting Technologies	1	$124,927
3.0.0 Space Power and Energy Storage		22	**$5,890,581**
	3.1.0 Power Generation	11	$2,627,074
	3.2.0 Energy Storage	10	$2,513,551
	3.4.0 Cross Cutting Technology	1	$749,956
4.0.0 Robotics, Telerobotics and Autonomous Systems		3	**$374,571**
	4.3.0 Manipulation	3	$374,571
5.0.0 Communication and Navigation		5	**$1,996,952**
	5.1.0 Optical Comm. And Navigation	2	$1,622,965
	5.4.0 Position, Navigation, and Timing	3	$373,987
9.0.0 Entry, Descent and Landing Systems		1	**$124,703**
	9.1.0 Aeroassist & Entry	1	$124,703
11.0.0 Modeling, Simulation, Information Technology and Processing		3	**$377,782**
	11.2.0 Modeling	3	$377,782
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		8	**$996,095**
	12.1.0 Materials	3	$379,246
	12.2.0 Structures	2	$248,636
	12.4.0 Manufacturing	3	$368,213
	Total	**47**	**$11,754,566**

ARMD Investments by Topic and Subtopic Area

FY 2011- 2015 Phase I & II Awards

Topic Area	Subtopic Area	Number of Awards	Award Amount
Aeronautics Research Mission Directorate Select Subtopics		4	**$2,493,770**
	Air Traffic Management Research and Development	4	$2,493,770
Aeronautics Test Technologies		21	**$6,774,006**
	Flight Test Techniques and Measurement Technology	10	$3,451,983
	Ground Test Techniques and Measurement Technology	11	$3,322,023
Air Traffic Management Research and Development		19	**$6,326,709**
	Air Traffic Management Research and Development	10	$3,994,394
	Unmanned Aircraft Systems Integration into the National Airspace System Research	9	$2,332,315
Air Vehicle Technologies		94	**$24,729,076**
	Aerodynamic Efficiency	5	$1,246,967
	Aerodynamic Efficiency Drag Reduction Technology	7	$1,996,551
	Controls/Dynamics - Propulsion Systems	5	$1,874,747
	Efficient Propulsion & Power	2	$254,967
	Ground and Flight Test Techniques and Measurement Technologies	3	$994,330
	Ground Testing and Measurement Technologies	4	$509,487
	Low Emissions Propulsion and Power	4	$494,784
	Low Emissions/Clean Power	4	$1,748,795
	Physics-Based Conceptual Aeronautics Design Tools	3	$370,855
	Physics-Based Conceptual Design Tools	6	$1,368,138
	Propulsion Efficiency - Turbomachinery Technology	5	$1,874,737
	Propulsion Efficiency-Propulsion Materials and Structures	6	$1,988,014
	Quiet Performance	14	$3,006,598
	Rotorcraft	10	$3,126,088
	Structural Efficiency - Airframe	3	$999,921
	Structural Efficiency-Aeroservoelasticity	9	$2,374,365
	Structural Efficiency-Hybrid Nanocomposites	2	$249,906
	Vertical Lift	2	$249,826
Airspace Operations and Safety		22	**$2,741,183**
	Advanced Air Traffic Management Systems Concepts	6	$747,580
	Autonomy of the National Airspace System (NAS)	14	$1,743,856
	Future Aviation Systems Safety	2	$249,747

Topic Area	Subtopic Area	Number of Awards	Award Amount
Airspace Systems		38	**$12,069,588**
	Concepts and Technology Development (CTD)	22	$4,521,780
	NextGen Airportal	3	$1,799,970
	NextGen Airspace	5	$2,999,724
	Systems Analysis Integration Evaluation (SAIE)	8	$2,748,114
Aviation Safety		91	**$28,578,195**
	Adaptive Aeroservoelastic Suppression	5	$1,680,283
	Advanced Upset Protection System	1	$124,866
	Assurance of Flight-Critical Systems	6	$1,999,400
	Aviation External Hazard Sensor Technologies	15	$4,244,238
	Crew Systems Technologies for Improved Aviation Safety	5	$1,024,021
	Data Mining and Knowledge Discovery	3	$974,929
	Detection of Aircraft Anomalies	2	$699,338
	Diagnosis of Aircraft Anomalies	1	$99,996
	Engine Lifing and Prognosis for In-Flight Emergencies	1	$599,932
	Flight Deck Interface Technologies for NextGen	6	$2,623,107
	Healing Material System Concepts for IVHM	1	$99,918
	Identification of Sequences of Atypical Occurrences in Massive Heterogeneous Datasets Representing the Operation of a System of Systems	1	$123,144
	Inflight Icing Hazard Mitigation Technology	7	$2,074,668
	Mitigation of Aircraft Aging and Durability-Related Hazards	2	$199,938
	Pilot Interactions with Adaptive Control Systems under Off-Nominal Conditions	2	$799,888
	Prediction of Aging Effects	2	$699,965
	Prognosis of Aircraft Anomalies	3	$1,449,554
	Prognostics and Decision Making	6	$1,990,369
	Real-Time Safety Assurance under Unanticipated and Hazardous Conditions	5	$1,872,996
	Robust Propulsion Control	2	$199,957
	Sensing and Diagnostic Capabilities for Degradation in Aircraft Materials and Structures	1	$123,866
	Sensing and Diagnostic Capability for Aircraft Aging and Damage	4	$1,549,616

ARMD Investments by Topic and Subtopic Area

FY 2011- 2015 Phase I & II Awards

Topic Area	Subtopic Area	Number of Awards	Award Amount
	Technologies for Improved Design and Analysis of Flight Deck Systems	1	$599,996
	Unmanned Vehicle Design for Loss-of-Control Flight Research	2	$824,915
	Vehicle Level Diagnostics	2	$249,836
	Verification and Validation of Flight-Critical Systems	5	$1,649,459
Fundamental Aeronautics		107	**$30,072,845**
	Aero-Acoustics	9	$2,816,754
	Aerodynamics	7	$1,749,303
	Aeroelasticity	9	$2,546,657
	Aerothermodynamics	9	$2,038,665
	Aircraft Systems Analysis, Design and Optimization	9	$3,157,566
	Combustion for Aerospace Vehicles	15	$3,723,220
	Flight and Propulsion Control and Dynamics	7	$1,874,276
	Materials and Structures for Future Aircraft Propulsion Systems	18	$5,288,443
	Rotorcraft	8	$1,994,517
		16	$4,883,444
Ground and Flight Test Techniques and Measurement		15	**$5,000,771**
	Ground Test Techniques and Measurement Technologies	15	$5,000,771
Integrated Flight Systems		19	**$2,356,233**
	Flight Test and Measurements Technologies	8	$988,133
	Unmanned Aircraft Systems Technology	11	$1,368,100
Integrated System Research Project (ISRP)		6	**$2,049,446**
	UAS Integration in the NAS	6	$2,049,446
Unmanned Aircraft Systems		18	**$5,980,928**
	Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Research	18	$5,980,928
	Total	**454**	**$129,172,750**

SBIR Combined Investments by Technology Area

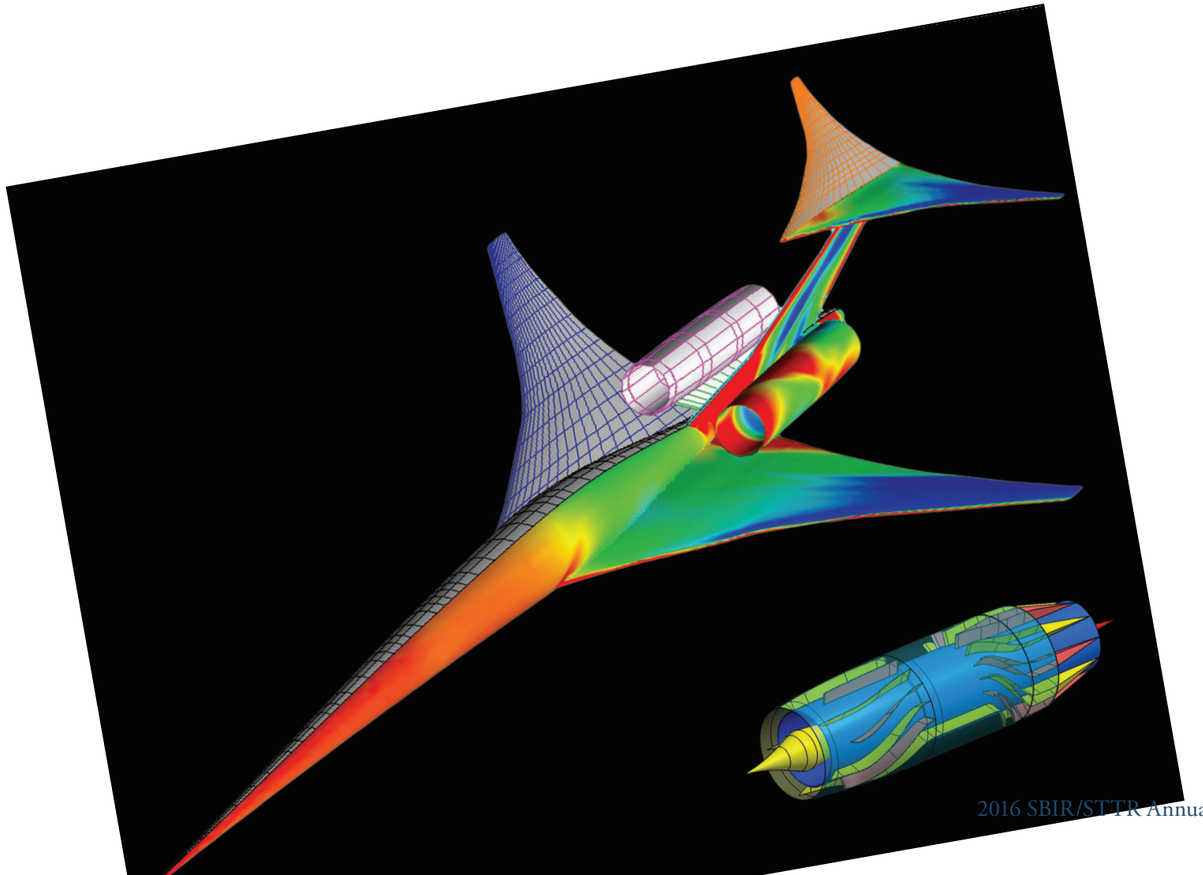
FY 2011- 2015 Phase I & II Awards (HEOMD, SMD, & STMD)

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
1.0.0 Launch Propulsion Systems		35	**$11,087,777**
	1.1.0 Solid Rocket Propulsion Systems	6	$1,774,559
	1.2.0 Liquid Rocket Propulsion Systems	18	$6,582,563
	1.4.0 Ancillary Propulsion Systems	6	$1,631,607
	1.5.0 Unconventional/Other Propulsion Systems	5	$1,099,048
2.0.0 In-Space Propulsion Technologies		166	**$55,133,335**
	2.1.0 Chemical Propulsion	68	$18,063,459
	2.2.0 Non-Chemical Propulsion	62	$25,434,109
	2.3.0 Advanced (TRL <3) Propulsion Technologies	4	$1,049,898
	2.4.0 Supporting Technologies	32	$10,585,869
3.0.0 Space Power and Energy Storage		150	**$44,217,198**
	3.1.0 Power Generation	83	$27,579,028
	3.2.0 Energy Storage	46	$9,871,323
	3.3.0 Power Management and Distribution	20	$6,016,891
	3.4.0 Cross Cutting Technology	1	$749,956
4.0.0 Robotics, Telerobotics and Autonomous Systems		112	**$37,513,112**
	4.1.0 Sensing & Perception	10	$1,238,197
	4.2.0 Mobility	16	$3,615,008
	4.3.0 Manipulation	21	$8,558,632
	4.4.0 Human-Systems Integration	15	$5,441,661
	4.5.0 Autonomy	28	$10,257,368
	4.6.0 Autonomous Rendezvous and Docking	6	$4,354,375
	4.7.0 RTA Systems Engineering	16	$4,047,871
5.0.0 Communication and Navigation		127	**$39,478,003**
	5.1.0 Optical Comm. And Navigation	32	$11,371,122
	5.2.0 Radio Frequency Communications	26	$6,838,260
	5.3.0 Internetworking	3	$972,743
	5.4.0 Position, Navigation, and Timing	43	$13,624,475
	5.5.0 Integrated Technologies	18	$5,487,049
	5.6.0 Revolutionary Concepts	5	$1,184,354
6.0.0 Human Health, Life Support and Habitation Systems		205	**$57,458,792**
	6.1.0 Environmental Control Life Support & Habitation Systems	63	$16,032,640

SBIR Combined Investments by Technology Area

FY 2011- 2015 Phase I & II Awards (HEOMD, SMD, & STMD)

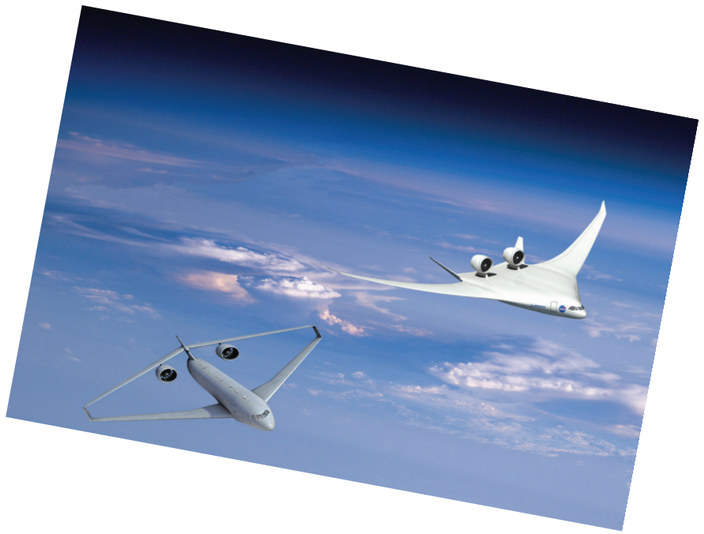
Level 1 TA	Level 2 TA	Number of Awards	Award Amount
6.0.0 Human Health, Life Support and Habitation Systems		205	**$57,458,792**
	6.1.0 Environmental Control Life Support & Habitation Systems	63	$16,032,640
	6.2.0 Extravehicular Activity Systems	36	$7,844,986
	6.3.0 Human Health and Performance	62	$21,229,892
	6.4.0 Environmental Monitoring and Safety	27	$7,952,343
	6.5.0 Radiation	17	$4,398,931
7.0.0 Human Exploration Destination Systems		70	**$19,257,681**
	7.1.0 In-Situ Resource Utilization	47	$11,879,055
	7.2.0 Sustainability & Supportability	10	$3,656,051
	7.3.0 Advanced Human Mobility Systems	2	$1,498,698
	7.4.0 Advanced Habitat Systems	2	$249,863
	7.5.0 Mission Operations & Safety	6	$687,213
	7.6.0 Cross-Cutting Systems	3	$1,286,801
8.0.0 Science Instruments, Observatories & Sensor Systems		317	**$116,179,089**
	8.1.0 Science Instruments	202	$75,974,724
	8.2.0 Observations	42	$16,333,284
	8.3.0 Sensor Systems	72	$23,746,081
	Not Mapped	1	$125,000
9.0.0 Entry, Descent and Landing Systems		51	**$15,030,951**
	9.1.0 Aeroassist & Entry	33	$8,854,265
	9.2.0 Descent	3	$973,430
	9.3.0 Landing	3	$939,359
	9.4.0 Vehicle Systems Technology	12	$4,263,897
10.0.0 Nanotechnology		11	**$4,201,673**
	10.1.0 Engineered Materials and Structures	2	$699,934
	10.4.0 Electronics, Sensors and Devices	9	$3,501,739
11.0.0 Modeling, Simulation, Information Technology and Processing		69	**$24,456,104**
	11.1.0 Computing	13	$4,718,281
	11.2.0 Modeling	28	$8,540,230
	11.3.0 Simulation	6	$1,848,803
	11.4.0 Information Processing	22	$9,348,790
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		125	**$32,080,174**
	12.1.0 Materials	38	$7,129,605
	12.2.0 Structures	31	$7,700,273
	12.3.0 Mechanical Systems	10	$4,053,778
	12.4.0 Manufacturing	32	$8,583,350
	12.5.0 Cross-Cutting	14	$4,613,168
13.0.0 Ground and Launch Systems Processing		23	**$6,357,201**
	13.1.0 Technologies to Optimize the Operational Life-Cycle	2	$874,966
	13.2.0 Environmental and Green Technologies	2	$824,996
	13.3.0 Technologies to Increase Reliability and Mission Availability	12	$3,721,105
	13.4.0 Technologies to Improve Mission Safety/Mission Risk	7	$936,134
14.0.0 Thermal Management Systems		63	**$18,331,762**
	14.1.0 Cryogenic Systems	24	$7,397,200
	14.2.0 Thermal Control Systems	38	$10,834,648
	14.3.0 Thermal Protection Systems	1	$99,914
	Total	**1524**	**$480,782,851**



HEOMD Investments by Technology Area

FY 2015 Phase I & II Awards

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
2.0.0 In-Space Propulsion Technologies		25	**$7,494,773**
	2.1.0 Chemical Propulsion	13	$3,493,853
	2.2.0 Non-Chemical Propulsion	9	$2,997,971
	2.4.0 Supporting Technologies	3	$1,002,949
3.0.0 Space Power and Energy Storage		9	**$3,009,207**
	3.1.0 Power Generation	8	$2,884,207
	3.2.0 Energy Storage	1	$125,000
4.0.0 Robotics, Telerobotics and Autonomous Systems		10	**$5,243,376**
	4.1.0 Sensing & Perception	3	$374,443
	4.2.0 Mobility	1	$124,998
	4.3.0 Manipulation	2	$1,619,860
	4.4.0 Human-Systems Integration	2	$2,249,088
	4.6.0 Autonomous Rendezvous and Docking	1	$749,991
	4.7.0 RTA Systems Engineering	1	$124,996
5.0.0 Communication and Navigation		12	**$3,381,559**
	5.1.0 Optical Comm. And Navigation	9	$2,381,666
	5.2.0 Radio Frequency Communications	1	$749,989
	5.4.0 Position, Navigation, and Timing	1	$124,904
	5.5.0 Integrated Technologies	1	$125,000
6.0.0 Human Health, Life Support and Habitation Systems		49	**$13,002,189**
	6.1.0 Environmental Control Life Support & Habitatio	15	$4,377,268
	6.2.0 Extravehicular Activity Systems	10	$2,500,334
	6.3.0 Human Health and Performance	8	$3,494,111
	6.4.0 Environmental Monitoring and Safety	7	$881,116
	6.5.0 Radiation	9	$1,749,360
7.0.0 Human Exploration Destination Systems		13	**$3,501,367**
	7.1.0 In-Situ Resource Utilization	8	$2,253,720
	7.2.0 Sustainability & Supportability	5	$1,247,647
8.0.0 Science Instruments, Observatories & Sensor Systems		5	**$624,705**
	8.1.0 Science Instruments	2	$249,743
	8.3.0 Sensor Systems	3	$374,962
9.0.0 Entry, Descent and Landing Systems		10	**$3,744,744**
	9.1.0 Aeroassist & Entry	8	$2,871,059
	9.2.0 Descent	1	$748,689
	9.4.0 Vehicle Systems Technology	1	$124,996
11.0.0 Modeling, Simulation, Information Technology and Processing		2	**$874,812**
	11.2.0 Modeling	1	$749,989
	11.3.0 Simulation	1	$124,823
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		26	**$10,109,711**
	12.1.0 Materials	4	$1,123,770
	12.2.0 Structures	10	$2,481,344
	12.3.0 Mechanical Systems	1	$754,999
	12.4.0 Manufacturing	6	$2,626,497
	12.5.0 Cross-Cutting	5	$3,123,101
13.0.0 Ground and Launch Systems Processing		5	**$624,717**
	13.4.0 Technologies to Improve Mission Safety/Missi	5	$624,717
14.0.0 Thermal Management Systems		6	**$2,757,532**
	14.1.0 Cryogenic Systems	3	$382,812
	14.2.0 Thermal Control Systems	3	$2,374,720
	Total	**172**	**$54,368,692**



SMD Investments by Technology Area

FY 2015 Phase I & II Awards

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
1.0.0 Launch Propulsion Systems		1	**$125,000**
	1.1.0 Solid Rocket Propulsion Systems	1	$125,000
2.0.0 In-Space Propulsion Technologies		14	**$3,622,495**
	2.1.0 Chemical Propulsion	10	$2,497,573
	2.2.0 Non-Chemical Propulsion	3	$999,932
	2.4.0 Supporting Technologies	1	$124,990
3.0.0 Space Power and Energy Storage		15	**$4,328,612**
	3.1.0 Power Generation	8	$2,855,434
	3.2.0 Energy Storage	2	$226,588
	3.3.0 Power Management and Distribution	5	$1,246,590
4.0.0 Robotics, Telerobotics and Autonomous Systems		12	**$3,340,584**
	4.1.0 Sensing & Perception	3	$374,556
	4.2.0 Mobility	3	$373,211
	4.3.0 Manipulation	1	$730,911
	4.5.0 Autonomy	2	$874,879
	4.6.0 Autonomous Rendezvous and Docking	1	$738,629
	4.7.0 RTA Systems Engineering	2	$248,398
5.0.0 Communication and Navigation		9	**$2,377,155**
	5.2.0 Radio Frequency Communications	1	$124,945
	5.4.0 Position, Navigation, and Timing	8	$2,252,210
8.0.0 Science Instruments, Observatories & Sensor Systems		95	**$29,580,388**
	8.1.0 Science Instruments	61	$21,445,902
	8.2.0 Observations	13	$2,246,212
	8.3.0 Sensor Systems	20	$5,763,274
	Not Mapped	1	$125,000
9.0.0 Entry, Descent and Landing Systems		3	**$372,710**
	9.1.0 Aeroassist & Entry	1	$124,997
	9.3.0 Landing	2	$247,713
11.0.0 Modeling, Simulation, Information Technology and Processing		12	**$5,362,833**
	11.1.0 Computing	4	$2,500,158
	11.2.0 Modeling	1	$749,961
	11.3.0 Simulation	2	$249,320
	11.4.0 Information Processing	5	$1,863,394
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		1	**$754,876**
	12.3.0 Mechanical Systems	1	$754,876
13.0.0 Ground and Launch Systems Processing		1	**$124,037**
	13.3.0 Technologies to Increase Reliability and Missi	1	$124,037
14.0.0 Thermal Management Systems		13	**$3,498,255**
	14.1.0 Cryogenic Systems	3	$373,813
	14.2.0 Thermal Control Systems	10	$3,124,442
	Total	**176**	**$53,486,945**

STMD Investments by Technology Area

FY 2015 Phase I & II Awards

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
2.0.0 In-Space Propulsion Technologies		2	**$1,624,881**
	2.2.0 Non-Chemical Propulsion	1	$1,499,954
	2.4.0 Supporting Technologies	1	$124,927
3.0.0 Space Power and Energy Storage		7	**$4,008,456**
	3.1.0 Power Generation	4	$1,753,698
	3.2.0 Energy Storage	2	$1,504,802
	3.4.0 Cross Cutting Technology	1	$749,956
4.0.0 Robotics, Telerobotics and Autonomous Systems		3	**$374,571**
	4.3.0 Manipulation	3	$374,571
5.0.0 Communication and Navigation		2	**$1,623,939**
	5.1.0 Optical Comm. And Navigation	1	$1,499,306
	5.4.0 Position, Navigation, and Timing	1	$124,633
11.0.0 Modeling, Simulation, Information Technology and Processing		2	**$252,800**
	11.2.0 Modeling	2	$252,800
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		7	**$871,132**
	12.1.0 Materials	3	$379,246
	12.2.0 Structures	2	$248,636
	12.4.0 Manufacturing	2	$243,250
	Total	**23**	**$8,755,779**

ARMDMD Investments by Topic and Subtopic Area

FY 2015 Phase I & II Awards

Topic Area	Subtopic Area	Number of Awards	Award Amount
Air Traffic Management Research and Development		2	**$2,994,690**
	Air Traffic Management Research and Development	2	$2,994,690
Air Vehicle Technologies		34	**$10,588,554**
	Aerodynamic Efficiency	1	$749,795
	Aerodynamic Efficiency Drag Reduction Technology	3	$371,988
	Efficient Propulsion & Power	2	$254,967
	Ground Testing and Measurement Technologies	4	$509,487
	Low Emissions Propulsion and Power	4	$494,784
	Low Emissions/Clean Power	1	$748,958
	Physics-Based Conceptual Design Tools	4	$1,120,796
	Propulsion Efficiency-Propulsion Materials and Structures	2	$1,495,825
	Quiet Performance	5	$1,337,475
	Rotorcraft	2	$1,504,796
	Structural Efficiency-Aeroservoelasticity	2	$1,499,951
	Structural Efficiency-Hybrid Nanocomposites	2	$249,906
	Vertical Lift	2	$249,826
Airspace Operations and Safety		22	**$2,741,183**
	Advanced Air Traffic Management Systems Concepts	6	$747,580
	Autonomy of the National Airspace System (NAS)	14	$1,743,856
	Future Aviation Systems Safety	2	$249,747
Aviation Safety		4	**$2,999,870**
	Prognostics and Decision Making	2	$1,499,990
	Real-Time Safety Assurance under Unanticipated and Hazardous Conditions	2	$1,499,880
Ground and Flight Test Techniques and Measurement		5	**$3,759,799**
	Ground Test Techniques and Measurement Technologies	5	$3,759,799
Integrated Flight Systems		19	**$2,356,233**
	Flight Test and Measurements Technologies	8	$988,133
	Unmanned Aircraft Systems Technology	11	$1,368,100
Unmanned Aircraft Systems		6	**$4,487,834**
	Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Research	6	$4,487,834
	Total	**92**	**$29,928,163**

SBIR Combined Investments by Technology Area

FY 2015 Phase I & II Awards (HEOMD, SMD, & STMD)

Level 1 TA	Level 2 TA	Number of Awards	Award Amount
1.0.0 Launch Propulsion Systems		1	**$125,000**
	1.1.0 Solid Rocket Propulsion Systems	1	$125,000
2.0.0 In-Space Propulsion Technologies		41	**$12,742,149**
	2.1.0 Chemical Propulsion	23	$5,991,426
	2.2.0 Non-Chemical Propulsion	13	$5,497,857
	2.4.0 Supporting Technologies	5	$1,252,866
3.0.0 Space Power and Energy Storage		31	**$11,346,275**
	3.1.0 Power Generation	20	$7,493,339
	3.2.0 Energy Storage	5	$1,856,390
	3.3.0 Power Management and Distribution	5	$1,246,590
	3.4.0 Cross Cutting Technology	1	$749,956
4.0.0 Robotics, Telerobotics and Autonomous Systems		25	**$8,958,531**
	4.1.0 Sensing & Perception	6	$748,999
	4.2.0 Mobility	4	$498,209
	4.3.0 Manipulation	6	$2,725,342
	4.4.0 Human-Systems Integration	2	$2,249,088
	4.5.0 Autonomy	2	$874,879
	4.6.0 Autonomous Rendezvous and Docking	2	$1,488,620
	4.7.0 RTA Systems Engineering	3	$373,394
5.0.0 Communication and Navigation		23	**$7,382,653**
	5.1.0 Optical Comm. And Navigation	10	$3,880,972
	5.2.0 Radio Frequency Communications	2	$874,934
	5.4.0 Position, Navigation, and Timing	10	$2,501,747
	5.5.0 Integrated Technologies	1	$125,000
6.0.0 Human Health, Life Support and Habitation Systems		49	**$13,002,189**
	6.1.0 Environmental Control Life Support & Habitation Systems	15	$4,377,268
	6.2.0 Extravehicular Activity Systems	10	$2,500,334
	6.3.0 Human Health and Performance	8	$3,494,111
	6.4.0 Environmental Monitoring and Safety	7	$881,116
	6.5.0 Radiation	9	$1,749,360
7.0.0 Human Exploration Destination Systems		13	**$3,501,367**
	7.1.0 In-Situ Resource Utilization	8	$2,253,720
	7.2.0 Sustainability & Supportability	5	$1,247,647
8.0.0 Science Instruments, Observatories & Sensor Systems		100	**$30,205,093**
	8.1.0 Science Instruments	63	$21,695,645
	8.2.0 Observations	13	$2,246,212
	8.3.0 Sensor Systems	23	$6,138,236
	Not Mapped	1	$125,000
9.0.0 Entry, Descent and Landing Systems		13	**$4,117,454**
	9.1.0 Aeroassist & Entry	9	$2,996,056
	9.2.0 Descent	1	$748,689
	9.3.0 Landing	2	$247,713
	9.4.0 Vehicle Systems Technology	1	$124,996
11.0.0 Modeling, Simulation, Information Technology and Processing		16	**$6,490,445**
	11.1.0 Computing	4	$2,500,158
	11.2.0 Modeling	4	$1,752,750
	11.3.0 Simulation	3	$374,143
	11.4.0 Information Processing	5	$1,863,394
12.0.0 Materials, Structures, Mechanical Systems and Manufacturing		34	**$11,735,719**
	12.1.0 Materials	7	$1,503,016
	12.2.0 Structures	12	$2,729,980
	12.3.0 Mechanical Systems	2	$1,509,875
	12.4.0 Manufacturing	8	$2,869,747
	12.5.0 Cross-Cutting	5	$3,123,101
13.0.0 Ground and Launch Systems Processing		6	**$748,754**
	13.3.0 Technologies to Increase Reliability and Mission Availability	1	$124,037
	13.4.0 Technologies to Improve Mission Safety/Mission Risk	5	$624,717
14.0.0 Thermal Management Systems		19	**$6,255,787**
	14.1.0 Cryogenic Systems	6	$756,625
	14.2.0 Thermal Control Systems	13	$5,499,162
	Total	**371**	**$116,611,416**

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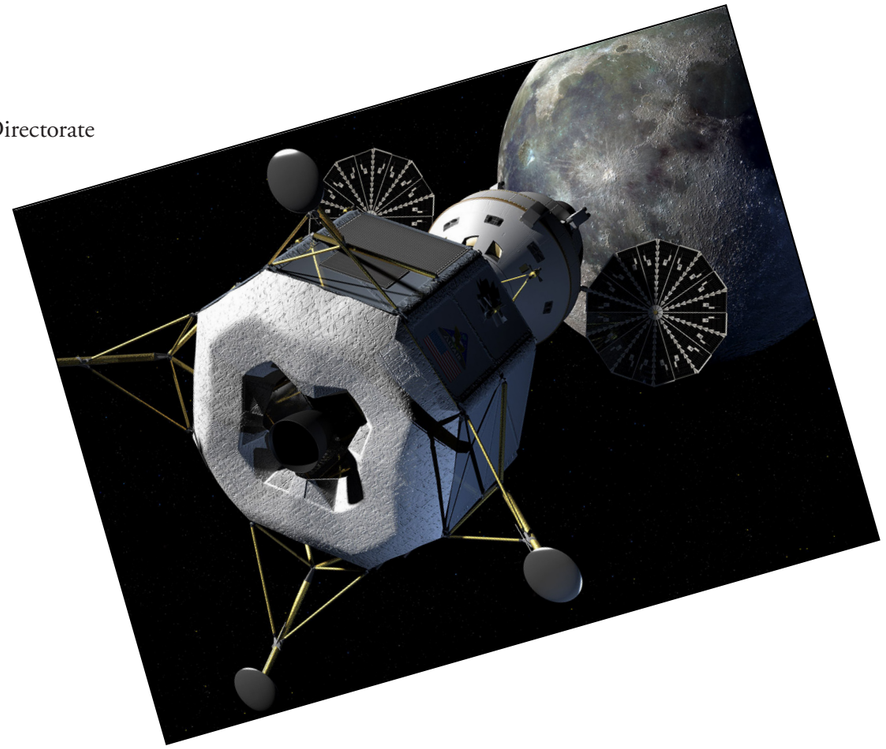

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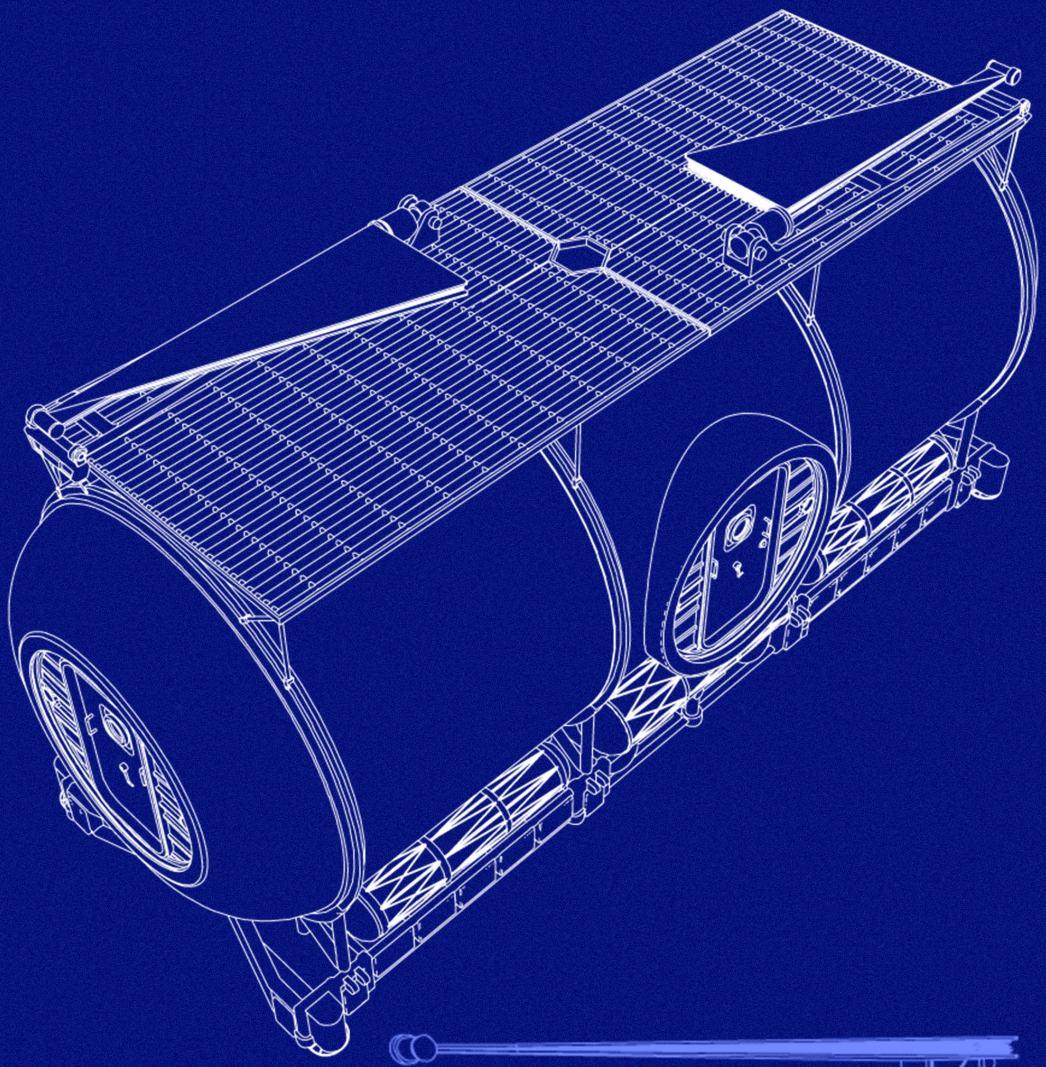

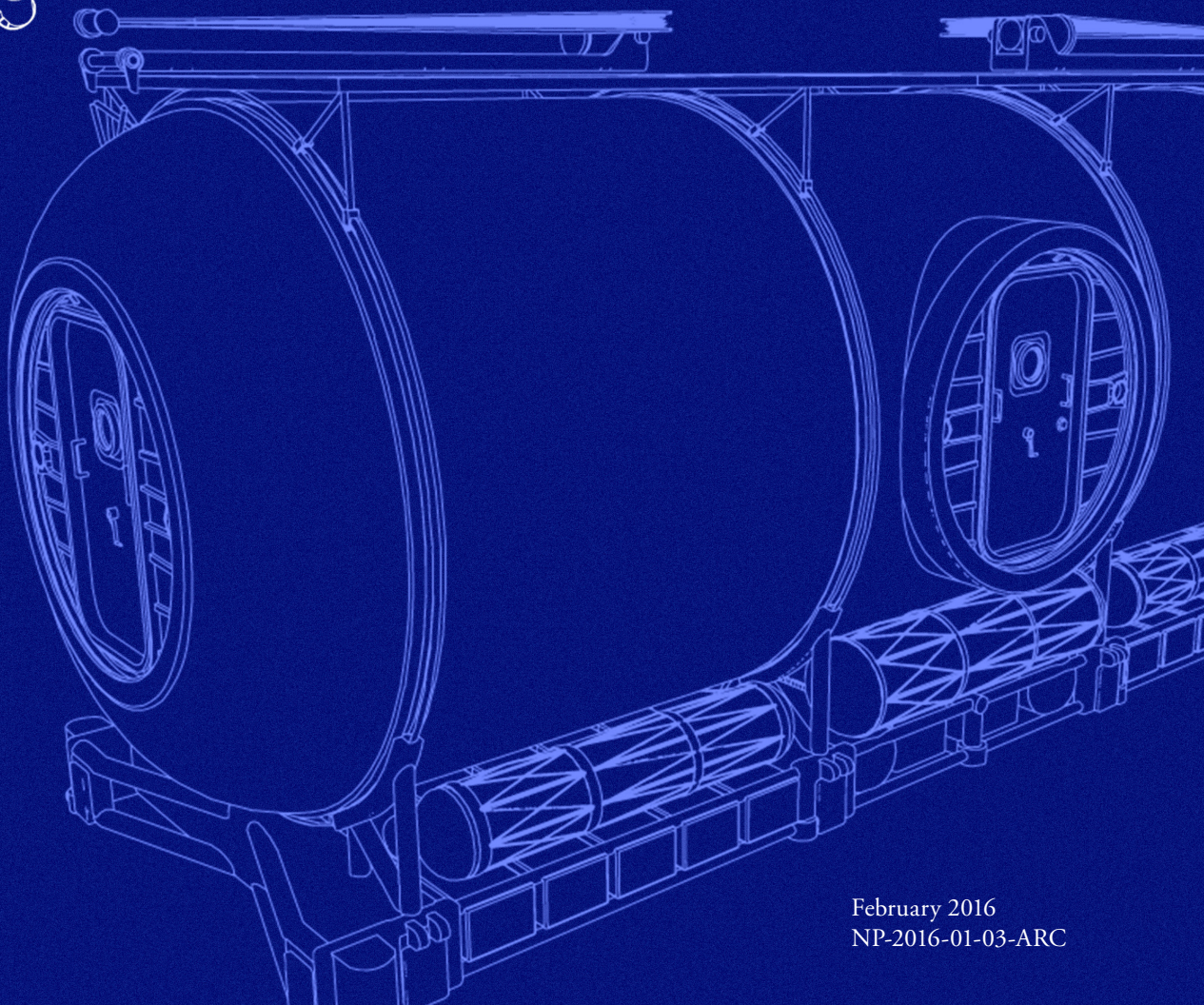

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