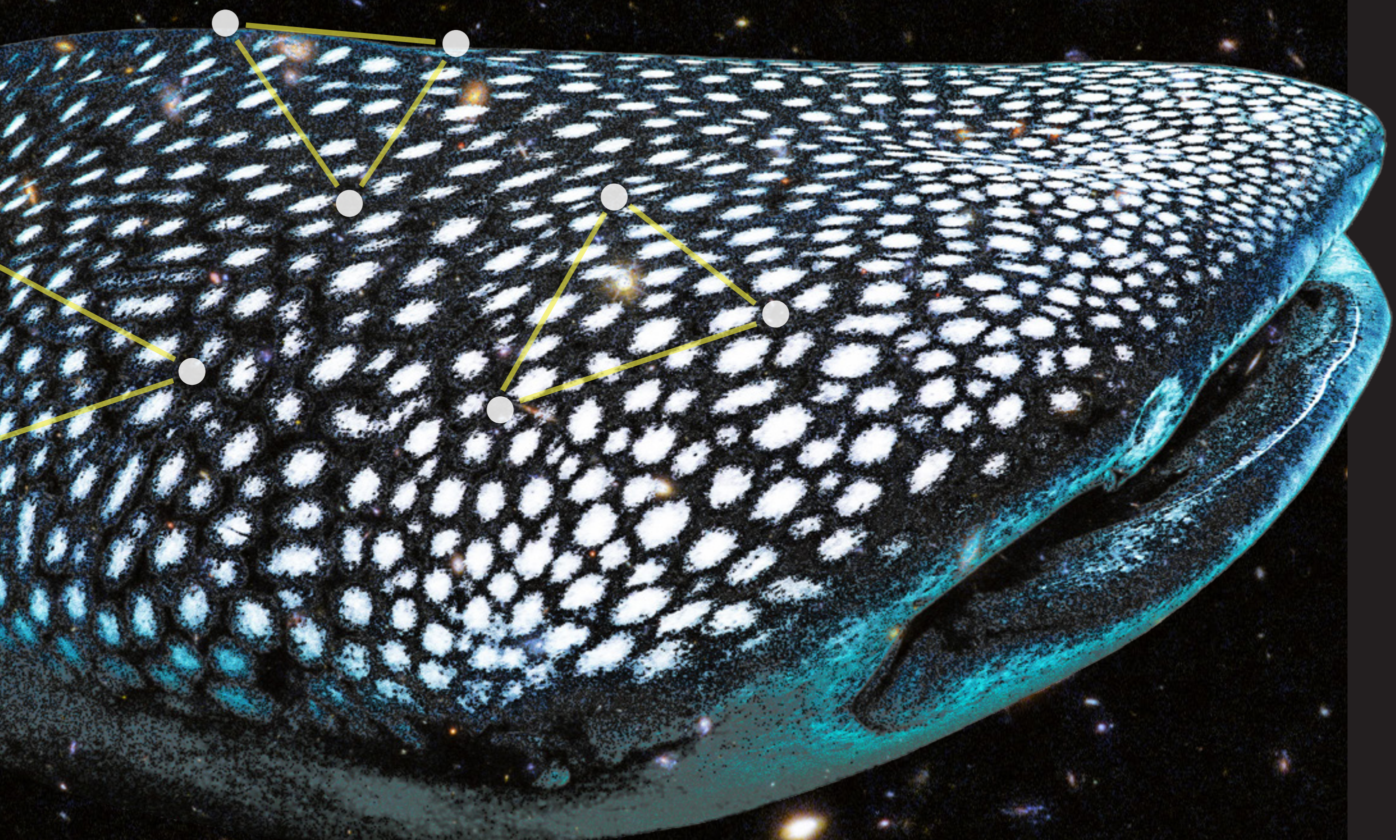
National Aeronautics and Space Administration

NASA

# Celebrating 60 Years of Innovation

## Spinoffs through the Decades



Inside: NASA Perspectives on Emerging Space Business

VOLUME 17 | NUMBERS 1-2 | WINTER/SPRING 2019

tech transfer

# Contents



**About the cover:** In 2005, a collaborative effort between Goddard scientist Zaven Arzoumanian, programmer Jason Holmberg and marine biologist Brad Norman resulted in a new method to track endangered whale sharks using an algorithm originally developed for the Hubble Space Telescope. The Groth algorithm matched patterns in images of stars, but with some modifications, it can identify the unique spot patterns found on individual whale sharks. An online database system called Wildbook provides a place for people to upload their whale shark photos, where pictures can be identified and compared. As executive director for nonprofit Wild Me, Holmberg continues to find creative ways to track wildlife populations. For more on this spinoff, see page 2. For more spinoffs through the decades, see page 12.

**Cover photo:** Simon Pierce (https://oceantripper.com)
**Cover art:** Alex Sharp

# From the Chief

**Darryl Mitchell**
Chief, Strategic Partnerships Office
NASA Goddard

At the start of the 1960s, great waves of change rippled through the nation and the world. The United States entered the Vietnam War; John. F. Kennedy became the youngest president in the history of the country; and the Soviet Union launched Sputnik 5, carrying the first living animals (a pair of dogs named Belka and Strelka) to travel safely to space and back.

Just a year prior to all this activity, NASA established Goddard Space Flight Center on May 1, 1959. Right from the beginning, Goddard jumped headfirst into technology development. The 1960s soared through a flurry of innovations and breakthroughs, and Apollo 11's famous Moon landing in 1969 bookended the decade.

In 2019, we're entering an era of spaceflight advancement with a movement some are calling "NewSpace." A growing collection of aerospace companies have entered the field, pursuing new and different approaches to forming businesses that revolve around space. With small satellites reducing cost and barriers to entry, we expect to see more activity from private space entities in the approaching years, opening the door to more technology transfer and partnership opportunities with Goddard.

In this issue of Tech Transfer magazine, the Strategic Partnerships Office is celebrating Goddard's past with a collection of technology transfer success stories from the last four decades. We're also looking to the future by exploring ways that emerging space businesses can work with Goddard. NASA's partnership with the New York Space Alliance and events like the recent Goddard Workshop on Artificial Intelligence are just two ways Goddard is reaching out to make connections.

Goddard has achieved wonderful things in its 60 years of existence, and I'm excited to ride the next wave of innovation into the coming decade.

# Noteworthy News

## Notable updates from Goddard's Technology Transfer Office

### National Geographic Features Software with Goddard Origins

In a November 2018 story about the use of artificial intelligence to study wild animal populations, *National Geographic* highlighted Wild Me, a conservation nonprofit with early ties to Goddard. The nonprofit took a Hubble Space Telescope algorithm developed to compare star patterns in astronomy images and adapted it to recognize unique arrangements in the spots of endangered whale sharks. By sorting through whale shark images, the algorithm could accurately identify individual whale sharks based on the pattern of their spots. Since then, Wild Me has created Wildbook, an open source platform to track populations of whale sharks and many other species. As a tool, Wildbook saves wildlife researchers time and effort by helping them analyze data and recognize trends.

### Goddard Innovation Ready for Tech Demo in Space

This spring, a technology developed for the Neutron-star Interior Composition Explorer (NICER) mission on board the International Space Station is expected to test the use of X-ray communications in space. The technology is called MXS, short for the **Modulated X-ray Source**. This multifaceted invention can modulate the intensity of X-ray output at predetermined intervals and in a matter of nanoseconds. For NICER, it was used to calibrate an X-ray detector for neutron star observation. Beyond X-ray communication and astrophysics, MXS has other potential applications, including X-ray navigation and medical imaging. Massachusetts General Hospital, in partnership with Goddard, is currently studying the use of MXS in a computed tomography (CT) system. If successful, this work could result in a portable CT system for patients in remote areas, developing countries, and space.

### National Press Foundation Highlights AI Technology at Goddard

The National Press Foundation released a multimedia report on **satellite servicing and artificial intelligence at Goddard** as part of the nonprofit's mission to provide educational experiences for journalists. Entitled "NASA's Emerging Technologies: NASA Is an Obvious Partner for Artificial Intelligence," the October 2018 report describes the work of several Goddard innovators, including robotic technologist Brian Roberts and computer engineer James MacKinnon. The report also includes a presentation on AI by Jacqueline Le Moigne, deputy for New Observing Strategy for the Advanced Information Systems Technology Program in the Earth Science Technology Office, and describes how Goddard plans to develop algorithms, infrastructure, and analytics as they pertain to AI.

NATIONAL PRESS NPF FOUNDATION

### Goddard Technologies Showcased at Satellite Servicing Industry Day

Satellite servicing technologists, industry professionals and technology transfer representatives convened at Goddard on Dec. 6, 2018, to discuss the development of **NASA satellite servicing technologies** and how companies can license these technologies. Satellite servicing, an emerging field, seeks to end the era of "one-and-done" spacecraft through robotic servicing missions in which in-orbit satellites can gain a second life by receiving new fuel and repairs from robotic spacecraft. Featured technologies included the cooperative service valve and the advanced tool drive system. For more information, read the brochure at https://partnerships.gsfc.nasa.gov under the "Publications" tab.

# Q&A: Emerging Space Busines

## Darryl Mitchell
Chief, Strategic Partnerships Office

Investment bank and financial services company Morgan Stanley estimates that revenue from the global space industry could increase dramatically by 2040. The industry currently generates about $350 billion in revenue annually, but Morgan Stanley estimates that number will grow to $1.1 trillion in the next 20 years.

NASA's Goddard Space Flight Center has a role to play in this growth. With 60 years' worth of experience, institutional knowledge and technology development under its belt, Goddard makes an ideal partner for new and emerging businesses looking to dip their toes into the space industry.

When working with Goddard, "Your first stop is the Strategic Partnerships Office (SPO)," says Darryl Mitchell, chief of SPO. "Companies tell us what they need, and we connect them to the right people."

With around 10,000 employees and dozens of active missions, Goddard can seem like a dizzying collection of organization charts, codes, and divisions.

"Goddard's a big place if you're not familiar with its workings, and finding the right person can be challenging," Mitchell points out. "If you talk to SPO first, we can provide insight about working with Goddard from a legal and policy point of view, as well as a capability perspective."

*Tech Transfer* magazine caught up with Mitchell to discuss the benefits businesses can gain from tapping into Goddard's resources.

### What does the term "NewSpace" mean?

The earliest non-government applications for spaceflight involved telecommunications satellites, but now, we're seeing smaller businesses get into the spaceflight and space hardware industries, essentially creating a "new space race." As larger companies generate awareness and buzz surrounding space travel – think Blue Origin or SpaceX – smaller companies are considering how to turn a profit in space.

Of course, the government is taking part in this arena. We're trying to help these emerging new space businesses grow and succeed. There are still many areas of space that lack sufficient commercial pay back, and that's where we fit in.

In addition to technology transfer, which can reduce research and development costs for companies and free up funds for other purposes, the government at large can provide recommendations for regulations and guidelines needed to prevent setbacks for new businesses. With NASA's expertise in mission formulation and quality assurance, the agency is well positioned to offer some guidance.

### What are some examples of emerging space businesses?

The space tourism companies are getting a lot of public attention, but there's been a big surge in companies doing Earth-observing satellites for agriculture and environmental purposes – including crop and carbon emissions monitoring, as well as weather forecasting. Many universities are working with small businesses to collect data as the CubeSat trend continues. As that sector matures and the technology advances, I expect we'll see more miniaturized components, and the private sector will begin to keep pace with NASA.

We're seeing more companies provide launch vehicles to the government by sending supplies to the International Space Station. The telecommunications business is still very important, and there are many space industries still in their very early stages, such as optical communications.

### How is Goddard working with new space businesses?

The primary way is through licensing technologies developed here at Goddard. Certain areas of development — such as sensors, small satellite technologies and satellite servicing innovations — can transfer readily to the space industry, while others might find unexpected fits in industries outside of space.

We're always looking for ways to transfer our technologies to the private sector, but in addition to that, we're exploring how to infuse technology into future Goddard missions. Though we talk a lot about the "spinoff" potential of Goddard technologies, we also consider the infusion potential of technologies from new and emerging companies.

Goddard also has subject matter experts who can share their knowledge with space businesses through Space Act Agreements. For example, Orbital ATK currently has a Space Act Agreement with Goddard to further on-orbit satellite servicing development.

Additionally, we're staying connected with space business organizations, such as the New York Space Alliance.

### What is the New York Space Alliance and how is Goddard involved?

The New York Space Alliance (NYSA) is a public benefit corporation taking advantage of the resources available in New York to generate more commercial space opportunities in the private sector. Through a Space Act Agreement with NASA's Johnson Space Center, NYSA and NASA will work together to promote NASA's technology resources to the space community in New York. By leveraging NASA's technology offerings, space entrepreneurs and startups can take advantage of NASA's expertise and decades' worth of institutional knowledge.

So far, we've participated in some discussions about a pilot program to help businesses in the New York City or upstate New York area. This is a great example of how we can work together in a collaborative fashion.

These collaborations could incorporate both sides of technology transfer — working with small companies to transfer technologies out to them, or bringing together a consortium of several small businesses responding to an opportunity as a team. That could involve bringing technology inside NASA for one of our missions, and then the NYSA entrepreneurial crowd working with the companies to get funding needed to do the work. I also see a role for Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) grants in these sorts of interactions.

### What are some examples of new Goddard technologies that space-related businesses could license?

Just to name a few: vehicle components, software for in-space operations, communications and navigation technology, and radiation hardening processes for spacecraft.

Outside of licensing, companies building spacecraft or vehicle components can test and evaluate their technology using some of Goddard's unique facilities, such as our Space Environment Simulator or our magnetics test site. These facilities simulate the environment of space and have been used by many NASA missions, including the James Webb Space Telescope.

Depending on the situation, companies can sign a reimbursable Space Act Agreement to access these facilities, or in some cases, they can work through an on-site support contractor. Some contractors have language in their contract that allows them to bring in outside companies on a noninterference basis.

### How can emerging space businesses best work with Goddard to achieve their goals?

Businesses can license Goddard technology to jumpstart their ideas. First, get in touch with a Goddard technology manager to define your technology needs and identify a Goddard technology that fits your requirements. Then you can fill out an application through NASA's Automated Technology Licensing Application System (ATLAS). After submitting your application in ATLAS, we'll get in touch to discuss next steps. In addition to that, small businesses can take advantage of Startup NASA, which waives up-front licensing fees for participants and makes it easier for startups to get on their feet.

Goddard also has a wide range of software available for download free of charge through NASA's online software catalog. Beyond licensing, we've partnered with businesses through Space Act Agreements or SBIR/STTR grants.

*Find more information at* https://partnerships.gsfc.nasa.gov *or* https://technology.nasa.gov.

# Artificial Intelligence for Space

## Jacqueline Le Moigne
Goddard technologist

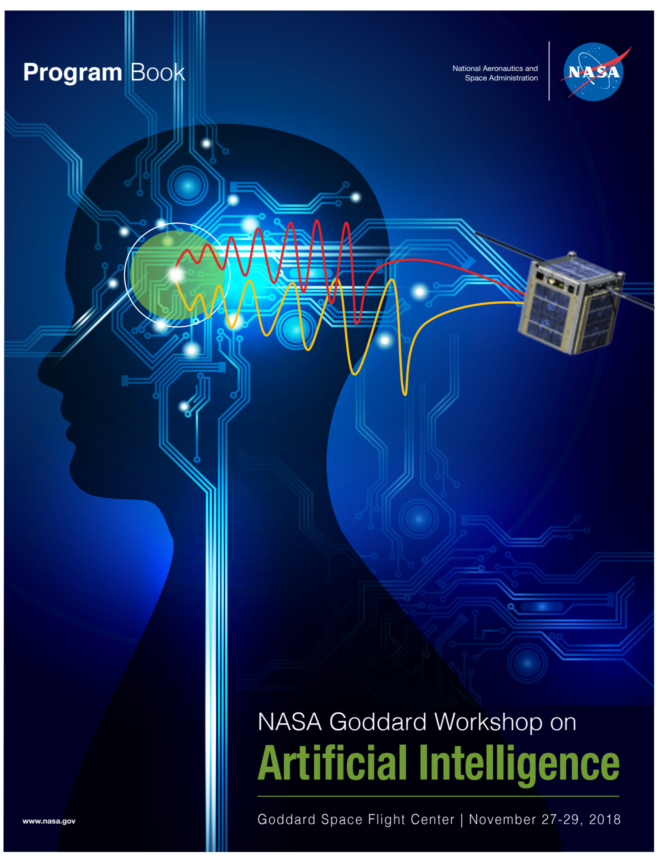
## Building Smarter Systems: Applications for Artificial Intelligence Technology

When Goddard technologist Jacqueline Le Moigne first envisioned hosting a workshop on artificial intelligence at NASA's Goddard Space Flight Center, she imagined a modest gathering of 50 to 75 people.

"But when I started advertising it," Le Moigne says, "I had hundreds of people respond very quickly."

The NASA Goddard Workshop on Artificial Intelligence, held at Goddard for three days in late November 2018, investigated how artificial intelligence (AI) technologies might address some of NASA's and Goddard's challenges. The workshop brought together experts from government, academia and industry to discuss the role AI could play in future space missions.

Artificial intelligence is an umbrella term for an assortment of technologies that can enable the completion of complex tasks through machines endowed with perception and human-like rational reasoning and actions. These technologies have progressed as a result of other recent advancements, such as booming data volumes, improved computing power and new capabilities in data storage.




–The NASA Goddard Workshop on Artificial Intelligence took place in late November of 2018.

A 2018 statement from France Córdova, director of the National Science Foundation, cites artificial intelligence as "transforming every segment of American industry." She goes on to say that "the effects of AI will be profound," and "to stay competitive, all companies will, to some extent, have to become AI companies."

As experts at Goddard investigate ways to use this new technology — including science data applications and satellite servicing — they also continue to explore opportunities to partner with industry in advancing these innovations.

In the not-too-distant future, Le Moigne says, AI could be as ubiquitous and conventional as the smart phones in our pockets.

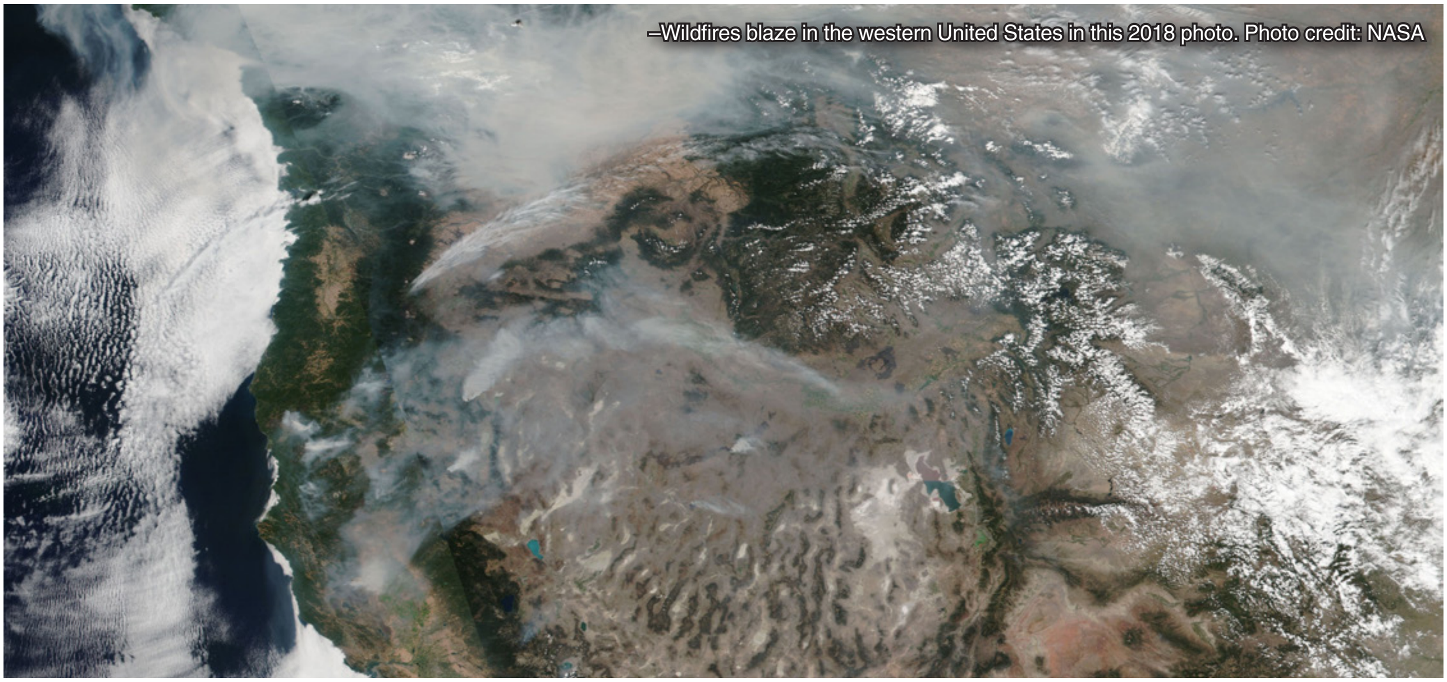
### Branches of AI

It's hard to miss mentions of artificial intelligence in today's headlines, often accompanied by proclamations of the technology's potential impact. "AI Will Add $15 Trillion to the World Economy by 2030," touts a recent Forbes article.

On Feb. 11, 2019, President Trump signed an executive order to maintain American leadership in artificial intelligence, known as the American AI Initiative. "AI promises to drive growth of the United States economy, enhance our economic and national security, and improve our quality of life," the initiative states.

Artificial intelligence is a broad term that sometimes gets confused and misinterpreted in popular culture, Le Moigne explains. The idea of

# Artificial Intelligence for Space



–Wildfires blaze in the western United States in this 2018 photo. Photo credit: NASA

smart machines capable of perceiving, reasoning, planning, acting, and learning dates back to the 1950s with a Dartmouth College professor – John McCarthy – who convened a summer workshop on the topic.

One branch of artificial intelligence that has recently entered a growth spurt is machine learning — a category for a collection of algorithms that improve automatically with experience. They usually find patterns in data to solve complex problems by using training examples to learn how to perform a task. As researchers gain access to big data sets and faster computing power, machine learning algorithms continue to grow larger and more sophisticated, with neural network algorithms taking the spotlight. Data scientists have harnessed this technique to train systems that can understand characteristics of human language, recognize patterns in images, or even play complex games.

For example, Goddard engineer James MacKinnon has demonstrated a neural network based approach to detect wildfires using data from NASA's Terra satellite. These advancements are promising, but Le Moigne says that a strategic approach is needed.

"To take full advantage of AI and make real progress, NASA and other organizations will need to figure out which applications will benefit most from AI and which AI technique is most appropriate for each application," she says.

### Neural networks and wildfires

MacKinnon works in the Science Data Processing Branch at Goddard, where he interacts with terabytes of data from NASA's many science missions. Wildfires drew his attention while he worked as an intern at NASA in 2016.

"I was taking some classes on machine learning and deep learning, and around the same time in Canada, a wildfire had nearly destroyed a town there," MacKinnon explains. "I wondered if there was a better way to predict the fire's path in order to evacuate people more quickly."

The Fort McMurray fire, which blazed from May to August in 2016, forced 80,000 people to evacuate and destroyed 2,500 homes, according to media reports. Troubled by the speed with which the fire struck, MacKinnon wanted to test a new concept: using a satellite to detect wildfires autonomously from space.

While NASA satellites and their instruments collect many images every day, they don't possess the ability to know what they're looking at. By training a neural network to recognize images of wildfires and operating the neural network onboard a fleet of cube satellites (CubeSats), NASA could identify fires from space quickly and provide valuable information to disaster response professionals on the ground.

One challenge to AI in space involves processing power – artificial neural networks typically train with high-performance graphics processing units (GPUs), chips that can grapple with large amounts of data in a relatively short amount of time. Here on Earth, researchers can simply plug their machines into the wall to power these complex computations. In space, however, power is a limited resource.

To address this, MacKinnon trained the neural network on the ground, then ran the inferences on flight-like embedded hardware. This hardware used less power and represented a system that could operate in space onboard a CubeSat.

To train the artificial neural network, MacKinnon pulled data from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument onboard Terra, a NASA Earth science satellite. Specifically, he used a subsection of the data called MODIS Active Fire and Burned Area Products (MODFIRE), ultimately producing a training set with millions of examples, half with images of fires and half without.

With high rates of accuracy, the neural network succeeded at detecting wildfires when analyzing MODIS data as a proxy for real-time satellite observations. In the future, such a network could run onboard a cost-effective constellation of CubeSats, collecting the data and analyzing it in space for quick wildfire identification.

“You need many satellites to achieve lower latency from once a day to once every few hours,” MacKinnon says. “It’s cost prohibitive to launch large numbers of billion dollar satellites, but with SmallSats or CubeSats, it’s feasible.”

Le Moigne says this application of deep learning could be modified for precision agriculture, in which satellites monitor crops via remote sensing and provide valuable information about plant health and environmental stressors.

“On board, you can have a system that recognizes vegetation stress or disease, and the system could decide to take a closer look at a particular area, or task another sensor on another satellite to take better pictures from different angles,” Le Moigne describes.

## Robotic servicing and machine vision

Goddard technologists and engineers are considering other ways to use AI in space, both on other planets and closer to Earth. Future generations of Mars rovers could adapt probabilistic programming techniques to look for signs of life or decide what Martian terrain to explore. Le Moigne points out that AI could be applied to NASA-led lunar-orbiting Deep Space Gateway, serving as a sort of intelligent, autonomous housekeeper to maintain the habitat when astronauts are away.

In the nearer term, the Satellite Servicing Projects Division (SSPD) at Goddard will employ a type of AI on the Restore-L mission, scheduled to launch in 2022. The mission will send a robotic spacecraft to refuel a satellite not designed to be serviced — Earth science satellite Landsat-7 — for the first time ever. The mission will utilize a number of new technologies to autonomously navigate to, rendezvous with, grasp, refuel, and release the satellite.

SSPD is dedicated to ending the era of “one-and-done” spacecraft through robotic servicing missions. In-orbit satellites can gain a second life by receiving new fuel and repairs from robotic spacecraft, which are currently in development at Goddard.

During the Restore-L mission, the spacecraft will employ an autonomous relative navigation system that will enable it to visually locate a client satellite and guide itself to the target destination. Similar to a self-driving car, this system is important to the success of the mission. The spacecraft must execute a series of quick maneuvers in order to grasp the client satellite, and the time delay in commands sent from Earth into space means the spacecraft needs to perform the sequence of events autonomously.

SSPD has a number of patented technologies available for transfer to industry in the interest of jumpstarting a competitive satellite servicing market. It’s just one of many technology areas for which Goddard is seeking technology transfer and partnership opportunities.

For Le Moigne, the AI workshop served to connect people and determine shared interests. “The goal was to get collaboration going with universities and industry because there are a lot of large and small businesses in the area that are interested in AI,” she says, noting that several small businesses have connected with Goddard’s Software Engineering Division to explore the potential for Small Business Innovation Research funding.

“NASA, like other organizations, will have to customize AI tools to our own needs,” Le Moigne concludes. “Industry is making a lot of progress, and in some cases I think NASA should leverage what industry and university are developing. In other cases, we should develop our own technologies. That’s what the AI workshop was aiming to assess.”

–This picture taken from the International Space Station shows the 2018 Carr and Ferguson fires in California.
Photo credit: NASA

# A Closer Look at Deep Learning for

**James MacKinnon**
Computer Engineer

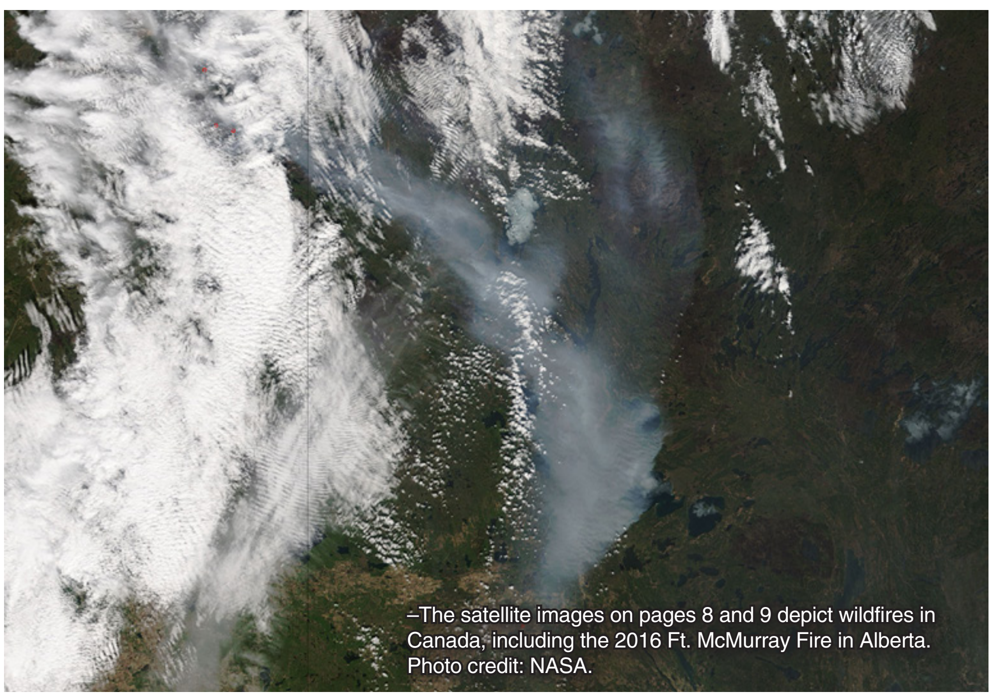
## Goddard computer engineer James MacKinnon explains how deep learning could lead to faster wildfire detection

**Why did you choose to look at wildfire data? What is the origin of this project?**

I grew interested in wildfires as a graduate student, when I was taking some classes on machine learning and deep learning. Around the same time in Canada, a wildfire had nearly destroyed a town there. The fire started spreading out of nowhere and approached the town unexpectedly fast.

As an intern, I connected with Luke Ellington and Charles Ichoku, two fire scientists at Goddard. Currently, we have the Moderate Resolution Imaging Spectroradiometer (MODIS) fire product, but an entire day could pass before you know there's a fire. Charles Ichoku had an idea to launch a constellation of CubeSats with a ready-made instrument to detect wildfires, along with an algorithm to generate the fire product on board. Right now, fire products are generated on the ground with a traditional physics model, but you could use a neural net to learn the model for predicting wildfires and have it run in a less computationally intensive way than the physics model.

I wondered if this would be a better, faster way to predict the fire's path in order to evacuate people more quickly, so I submitted the idea as an Internal Research and Development (IRAD) project, and then started working on it after I graduated.



–The satellite images on pages 8 and 9 depict wildfires in Canada, including the 2016 Ft. McMurray Fire in Alberta. Photo credit: NASA.

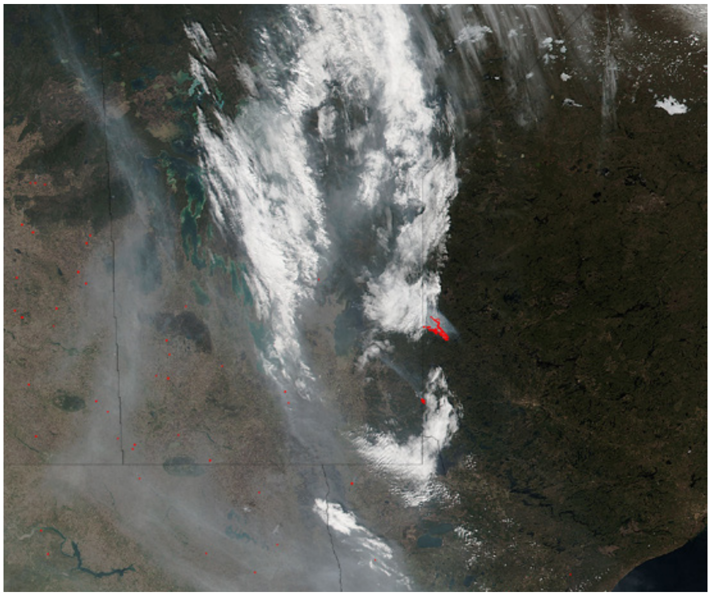
### Why would a constellation of CubeSats be ideal for this approach?

You need many satellites to achieve lower latency from once a day to once every few hours. It's cost prohibitive to launch large numbers of billion dollar satellites, but with SmallSats or CubeSats, it's feasible. By using CubeSats, you could have direct-to-user data products where your CubeSats could constantly transmit locations of fires to first responders.

Something like that already exists, but they only transmit data products if you know how to receive and process them yourself. The CubeSats could take an enormous amount of data in spectral images, but with an algorithm that condenses the data down to information about fire location, that could make it possible to transmit and possibly integrate the information into a larger fire detection system that aggregates data from this constellation.

CubeSats have a lot less computational density than a larger satellite, so you don't have a lot of processing power. The normal fire products run on servers with regular processors that can use hundreds of watts. With a CubeSat you might only have 5 watts. Neural nets, which are the type of deep learning I use, are great at finding patterns in data, especially data that has high dimensionality. I wanted to see if I could train a neural network that matches the model programmed into the physics model. The physics model looks at some thermal aspects, so basically it makes all these decisions to come up with the final result: Is there a fire?

A neural net, on the other hand, takes a bunch of examples – millions of them – and is trained to find the pattern. You give it input and it determines the output. We trained with millions of examples and it learned the model. It's about 99.5 effective, and it takes much less computing power and opens up the option to run on board a CubeSat.



### Who besides NASA would find a capability like this useful?

Anyone doing any sort of disaster management could benefit from this. For future work, we've looked into other possibilities. One big one involves flooding. If you have a lot of satellites and you're looking at a spot on the ground over time, you can observe changes such as water covering normally dry land. You could also use this to look at volcano lava flows. Another big application could be algae blooms. Red tide shows up as a color change, so you could see that spectral data and get an early warning. Ultimately, it depends on what you're trying to do. With wildfires and flooding, it makes sense to process on board because they travel quickly. Algae blooms are a little slower.

***Internal Research and Development Program (IRAD):*** Goddard's program to fund internal, innovative research and development proposals in support of the center's lines of business

***CubeSat:*** Short for cube satellite — a class of nanosatellite with masses of 1-10 kilograms and measured in 10x10x10 centimeter units known as 1U

***Fire product:*** A data set containing information pertaining to wildfire

***Latency:*** The time delay between when data is sent and when it is received

***Red tide:*** Toxic, widespread algae blooms that discolor ocean water

### Are there any other deep learning projects you're working on?

We set out to create a neural network that can detect wildfires on board, and now that exists as a piece of technology, which we can apply to new areas. Part of the technology that was required to make this happen was this high efficiency kind of library called a framework that enabled us to execute neural nets on board. We're taking that technology and applying it to a new IRAD for surface vegetation and tree canopies. In this way, the low level code I made is being used and repurposed for other projects.

### Can you think of any partnership opportunities involving this work?

Any agencies or organizations dealing with remote sensing could find it useful. We try to work with universities that enable extremely new and innovative types of deep learning, such as the University of Florida's High Performance Computing Center as well as the University of Arizona. With how fast the field of deep learning moves, you need collaborators to keep on top of the newest developments.

# 24th Annual NTR Program

## Goddard Innovators Recognized at 24th Annual NTR Program

In the early days of NASA's Goddard Space Flight Center, James Kerley paved the way for future innovators by inventing some of Goddard's most well-known spinoffs and becoming a prolific champion of technology transfer. His work in the 1980s on cable-compliant mechanisms led to the development of a therapeutic walker for physical therapy, just one example of a Goddard invention that went on to make a positive impact outside of NASA.

That's why the Goddard Technology Transfer Office (TTO) named its annual innovator award in his honor. The Kerley Award recognizes individuals who go above and beyond to connect with industry and facilitate the process of technology transfer. At the 24th Annual New Technology Reporting Program on Dec. 12, 2018, Goddard TTO presented the award to Nithin Abraham, a thermal coatings engineer in the Contamination and Coatings Engineering Branch. James Kerley's family attended the program, carrying on the tradition of celebrating technology transfer leaders at Goddard.

On Dec. 12, Goddard TTO also debuted the Master Innovator Program, a new way to acknowledge inventors who actively participate in new technology reporting and licensing. The program borrows a concept from the belt system used in martial arts training. Different colored lapel pins are awarded to innovators depending on their level of expertise with technology transfer. As innovators progress through their career, they earn opportunities to advance through the program, culminating in the master black belt pin level. At the NTR Program, Goddard TTO recognized innovators Geoff Bland, Tom Flatley, and James Tilton as the first-ever recipients of the Goddard Master Innovator black belt title.

–Innovator Negar Ehsan receives her patent certificate.

Finally, Goddard TTO and the Office of Patent Counsel thanked all innovators whose technologies had received patents over the past few fiscal years. They included:

**Advanced Remotely Operated Vehicle for Education and Research**
U.S. Patent Number: 10,059,418
Ted K. Miles and Geoffrey L. Bland

**Apparatus for Controlling Low Power Voltages in Space Based Processing Systems**
U.S. Patent Number: 9,705,320
David J. Petrick

–Goddard innovators display their Master Innovator pins, awarded to them for their proficiency in technology transfer.

**Auto-Zero Differential Amplifier**
U.S. Patent Number: 9,685,913
Gerard T. Quilligan and Shahid Aslam

**CubeSat Form Factor Thermal Control Louvers**
U.S. Patent Number: 9,862,507
Allison L. Evans

**Gated Chopper Integrator (GCI)**
U.S. Patent Number: 9,985,594
Gerard T. Quilligan and Shahid Aslam

**Low Friction Reaction Wheel System and Containment Structure with Integrated Electromagnets**
U.S. Patent Number: 10,053,242
Alvin G. Yew and Matthew C. Colvin

**Method and Apparatus of Implementing a Magnetic Shield Flux Sweeper**
U.S. Patent Number: 9,913,414
John E. Sadleir

**Method of Fabricating X-ray Absorbers for Low Energy X-ray Spectroscopy**
U.S. Patent Number: 10,074,764
Thomas R. Stevenson, Manuel A. Balvin, Kevin L. Denis, John E. Sadleir, Peter C. Nagler

**Miniature Release Mechanism or Diminutive Assembly for Nanosatellite Deployables (DANY)**
U.S. Patent Number: 9,546,008
Scott V. Hesh, John D. Hudeck, Luis Santos Soto

–James Kerley Award winner Nithin Abraham displays her award with members of the Kerley family.

**Normally Closed Zero-Leak Valve with Magnetostrictive Actuator**
U.S. Patent Number: 9,657,858
Daniel J. Ramspacher

**Optimized Wavelength-Tuned Nonlinear Frequency Conversion Using a Liquid Crystal Clad Waveguide**
U.S. Patent Number: 9,933,687
Mark A. Stephen

**A Printed Circuit Board Assembly for Use in Space Missions**
U.S. Patent Number: 9,549,467
David J. Petrick and Dennis Albaijes

**Process for Fabrication of Superconducting Vias for Electrical Connection to Groundplane in Cryogenic Detectors**
U.S. Patent Number: 9,865,795
Kevin L. Denis

**Radiation Hardened 10BASE-T Ethernet Physical Layer (PHY)**
U.S. Patent Number: 9,680,527
Michael R. Lin, Kevin M. Ballou, Daniel C. Espinosa, David J. Petrick

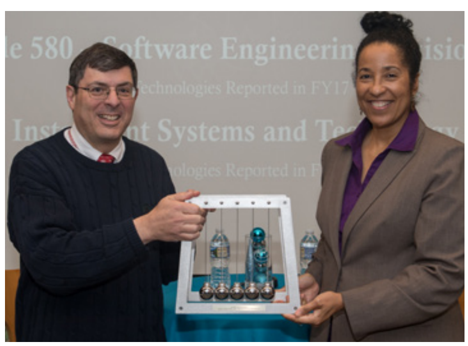
**Range and Intensity Image-Based Terrain and Vehicle Relative Pose Estimation System**
U.S. Patent Number: 10,024,664
Nathaniel Gill, John M. Van Eepoel, Joseph M. Galante

**A Robust Waveguide Millimeter Wave Noise Source**
U.S. Patent Number: 10,044,320
Negar Ehsan, Jeffrey R. Piepmeier, Edward J. Wollack

**Shape Memory Actuated Normally Open Permanent Isolation Valve**
U.S. Patent Number: 9,677,681
Daniel J. Ramspacher and Caitlin E. Bacha

**SpaceCube 2.0 Micro Single Board Computer**
U.S. Patent Number: 9,851,763
David J. Petrick, Alessandro Geist, Michael R. Lin, Gary R. Crum

**Spectral and Radiometric Calibration Using Tunable Lasers**
U.S. Patent Number: 9,680,286
Joel McCorkel and Brendan McAndrew



–Goddard Center Director Chris Scolese presents the Newton's Cradle for most NTRs submitted.

**Spherical Occulter Coronagraph CubeSat**
U.S. Patent Number: 9,921,099
Joseph M. Davila, Douglas M. Rabin, Qian Gong, Neerav Shah, Phillip C. Chamberlin

**System and Method for Fabricating Super Conducting Circuitry on Both Sides of an Ultra-Thin Layer**
U.S. Patent Number: 9,577,177
Ari D. Brown

**System and Method for an Integrated Satellite Platform**
U.S. Patent Number: 9,938,023
Charles E. Clagett, Scott R. Starin, Salman I. Sheikh, Michael Hesse, Nikolaos Paschalidis, Michael A. Johnson, Aprille J. Ericsson, Luis Santos Soto, Scott V. Hesh

**System and Method for Providing a Climate Data Analytic Services Application Programming Interface**
U.S. Patent Number: 10,075,678
John L. Schnase and Daniel Q. Duffy

**System and Method for Providing a Climate Data Persistence Service**
U.S. Patent Number: 9,940,329
John L. Schnase, Daniel Q. Duffy, Mark McInerney

**System and Method for Using Hollow Core Photonic Crystal Fibers**
U.S. Patent Number: 9,964,699
Jeffrey R. Chen and Stewart T. Wu

**System to Perform Radio Frequency Interferometry Using Optical Fiber Sensing Signal Processing Techniques**
U.S. Patent Number: 10,036,632
Melanie N. Ott, William J. Thomes, Eleanya E. Onuma

**Universal and Automated Monte Carlo Method Code for Uncertainty Propagation in Metrology Databases**
U.S. Patent Number: 9,990,335
Manal A. Khreishi, Theodore J. Hadjimichael, Raymond G. Ohl

# 60 Years of Goddard Spinoffs

More than 40 years ago, medical staff at the Veterans Administration Hospital tested a revolutionary new way to screen for unhealthy arteries using Goddard technology. Arteriosclerosis, an arterial disease that can lead to heart attacks and strokes, posed a challenging problem to doctors due to the painful and invasive methods available at the time to test for it. Using Goddard transducers developed for spacecraft, medical professionals could determine the flexibility of an artery externally instead of inserting a hollow needle directly into the artery.

This example of technology transfer was included in the very first edition of NASA's *Spinoff* publication in 1976. "Technology developed at NASA has been applied to thousands of products and processes throughout the nation," reads the introduction, and though 43 years old, the statement still holds true today.

As Goddard celebrates its 60th anniversary on May 1, 2019, we're revisiting some of the center's technology transfer success stories of years past. From briefcase communicators to ingestible thermometers, Goddard has spinoff tales from every decade, starting in the 1970s. See the full archive of NASA spinoff stories at https://spinoff.nasa.gov.

Thank you to students from the University of Maryland's technical writing class for helping to adapt these stories from previous editions of NASA's *Spinoff* publication. Goddard worked with University of Maryland technical writing instructor Alexandra Calloway to produce these stories as part of the students' service learning project.

# 1970s Spinoffs

## Satellite Beacon Improves Safety

The first successful Atlantic crossing in a free-flying balloon after many attempts over a span of a century was aided by satellite beacon from Goddard. Comprised of a battery, a signal transmitter, and an antenna, the satellite beacon – also known as the Random Access Measurement System (RAMS) – saved the lives of Ben Abruzzo, Maxie Anderson, and Larry Newman on their previous attempt a year before in 1978 to cross the Atlantic in their predecessor balloon, the *Double Eagle*.

The trio, all from Albuquerque, New Mexico, ran into trouble several days after liftoff when they encountered a massive storm. *Double Eagle* was force-landed off Iceland and heavy rain made voice communication impossible. The 7-pound beacon aboard the *Double Eagle* had continuously transmitted signals to NASA's Nimbus-6 satellite, which was then relayed to monitors at Goddard Space Flight Center, where Goddard was able to calculate the position of the balloon. The position of the balloon was reported regularly to *Double Eagle*'s control center at Bedford, Massachusetts. As a result, a Navy rescue plane was able to quickly save the aeronauts.

For their successful crossing on the *Double Eagle II*, the trio of aeronauts carried aboard two beacons. Abruzzo and Anderson visited Goddard later to thank NASA for intervening. According to Abruzzo, the beacons were "the most important pieces of equipment aboard."

The beacon also made headlines when it was carried by Japanese explorer Naomi Uemura on two 1978 Artic expeditions: a solo dog-sled trek from Ellesmere Island in Canada's Northwest Territories across 600 miles to the North Pole and another dog-sled trek across the length of Greenland of about 2,170 miles. NASA was able to track the location of Uemura on both expeditions through the Nimbus-relayed signals from the beacon. Both expeditions were successful and no rescue was necessary, but the beacon had upgraded safety features. The beacon had a special switch to indicate an emergency as a backup for voice communication. Along with ensuring safety, the beacon also helped the Smithsonian Institution, which requested that Uemura take snow, ice, and air samples. The beacon transmitted accurate positions for each of the samples.

Other applications of the beacon in 1978 included extensive use on buoys to track currents for oceanographic and environmental studies and deployment on icebergs by the U.S. Coast Guard to predict drift routes in the waters off Greenland and Labrador to aid the International Ice Patrol. Additionally, a miniature version of the beacon was used to track Arctic polar bears in ecology studies conducted by the U.S. Department of the Interior.

Initially, the beacon was designed to gather data from around 450 balloons in tropical locations for a meteorological experiment. Newer developments by the manufacturer Handar, Inc., included a hand-held Emergency Location Transmitter powered by battery. This technology could be used aboard private aircraft that flew over unpopulated areas. Although it is obsolete now, it was an important technology of its time.
— *Adapted by Lucia Kim*

## Briefcase Facilitates Emergency Communications

In 1979, Goddard technology entered the market with the release of the briefcase communicator. This technology could function within confines as small as a briefcase. For the 1970s, this compact represented a remarkable innovation.

The briefcase communicator featured powerful transmitting and receiving technology embedded within the container. It used the same transmission and receiving technology as NASA satellites, such as the Applications Technology Satellite-6 and the joint United States and Canadian Communications Technology Satellite. Normally, the satellite signals would have to be received by larger and more intricate ground devices, but the briefcase communicator was able to access satellite relayed signals through the small, onboard antenna.

Goddard developed the briefcase communicator in order to help in disaster relief situations. In particular, it could be used in natural weather events, such as tornados, hurricanes or floods that disrupt traditional power grids. When traditional means of communications are down, or even in extremely hard to reach or remote areas, the briefcase communicator can be used to contact people there and give them the help they need. The communicator could establish connections to areas where access was difficult or where communications were down.

Tests were even done at the Baltimore/Washington International Airport in the summer of 1978 by the Maryland Institute for Emergency Medical Services. The drill simulated a major accident with a large number of burn patients who needed immediate attention. The briefcase communicator was used to contact doctors as far away as Boston and Chicago, demonstrating the communicator's efficacy in delivering critical information in a timely manner. The emergency technicians on location were able to use the briefcase communicators to administer treatment to patients on the scene while still being directed by specialists hundreds of miles away.

With the prevalence of modern cellular technologies, this technology is obsolete, but the spirit of the idea is now being used in other situations. NASA is creating briefcase-sized satellites known as CubeSats that have made space accessible to a new generation. Originally created to teach university students about satellites, they now are used commercially to collect and communicate data.
— *Adapted by Astha Singhal*

# 60 Years of Goddard Spinoffs

## 1980s Spinoffs

### Goddard and Lady Liberty

The Statue of Liberty was given to the United States in 1886, but thanks in part to technology created at NASA's Goddard Space Flight Center, it will be preserved for future generations. As the statue aged, the salt spray, air pollution, and fog of the New Jersey/New York area slowly corroded the copper that makes up the Statue of Liberty's structure. It was deemed necessary to restore the statue after an inspection from the National Park Service in 1980, which sparked an effort to protect the statue. If not reinforced with stainless steel alloys, cleaned from head to toe and protected from the elements, the Statue of Liberty would not have continued to corrode. The corrosion protectant called IC 531, a NASA spinoff, was the answer to protecting the inside of this icon from further damage.

IC 531 is an aerospace spinoff product created by Inorganic Coatings Inc., in Malvern, Pennsylvania, and was used for corrosion protection for the interior structure of the world-famous sculpture. The coating was initially created at Goddard to protect structures at NASA launch sites and specifically NASA's Kennedy Space Center. Goddard's original formulation resulted from research starting in the 1940s by other sources, eventually culminating with a high ratio 5:3:1 potassium silicate that enabled its use for production. It resulted in long-term protection in marine environments, helping to protect Kennedy Space Center against wear and tear.

NASA licensed the coating to Shane Associates in Wynnewood, Pennsylvania in 1981, but Inorganic Coatings in Malvern, Pennsylvania became the sole manufacturer the next year under the same license. IC 531 is nontoxic, nonflammable, and has no organic emissions, allowing it to bind to steel and create a hard ceramic finish within 30 minutes of the initial application.

Moreover, it is easily deployed to production, because it can be mixed and applied with standard equipment, meaning that no specialized equipment is needed in a typical use case. This enables the compound to be applied more quickly. The coating has long-lasting effects, producing effective corrosion resistance. It has been used on test panels at the Kennedy Space Center, the Golden Gate Bridge, the Astoria River Bridge, and on antenna installations in California, Hawaii, and the Canton Islands.
— *Adapted by Astha Singhal*

## SARSAT Saves Lives

The NASA-based Search and Rescue Satellite Aided Tracking (SARSAT) was introduced in 1982, and since then, it has pioneered an international effort that has saved tens of thousands of lives.

The development of the SARSAT program began from a collective realization of discrepancies in the U.S. emergency communications rooted in a 1972 plane crash, in which two United States congressmen died and were never found.

The emergency communications system at the time was underdeveloped, simplistic and sorely lacking in necessary fail-safes that were revealed in the 1972 plane crash. The emergency signal was limited to beacons that transmitted a single signal, which would be broadcast to any pilots flying over the immediate distress or emergency area. This single signal would only transmit a tone signifying an emergency but no key data such as location or identification.

A solution was found by using satellites at low Earth orbit (LEO) that were capable of detecting signals at the same frequency used by airplanes and subsequently processed information from spacecraft to ground stations. The need for developed, advanced technology to detect distress calls quickly drove the creation of the international entity COSPAS-SARSAT (COsmicheskaya SIsteyama Poiska Avariynich Sudov: the Russian acronym for Space System for Search of Distress Vessels), which became a joint effort championed by the United States, Canada, France and the Soviet Union.

Over time, geostationary satellites, satellites with orbits that match Earth's rotation, were incorporated, creating a second dimension of communication and signal processing by receiving emergency signals at different frequencies which ultimately led to globalized coverage. This effort was championed by both NASA and Techno-Sciences Inc. (TSi) to establish the components comprising the beacon and ground station. NASA's Goddard Space Flight Center granted TSi several contracts to establish the first set of operational ground stations.

A second augmentation over later years included a NASA-developed technology called Distress Alerting Satellite System (DASS), which added another layer of enhancement by installing search and rescue instrumentation and programs into global positioning system (GPS) satellites, which greatly increased the data refinement and volume relayed to rescue operators. This enhancement enabled rescuers to further hone incoming information, which subsequently improved the precision and accuracy of the measurements and calculations done to locate the distress beacon.

Successive generations of COSPAS-SARSAT have improved the reliability of the system, the precision of total data analysis and SARSAT's efficiency.
*— Adapted by Mauricio Defngin*

## The Library of Congress and NASA Partnered to Save Thousands of Books from Deterioration

In the 1980s, NASA's Goddard Space Flight Center and the Library of Congress worked together to preserve thousands of historic books in Goddard's vacuum chamber.

Vacuum chambers are rigid enclosures from which air and other gases are removed by a vacuum pump, which operates similarly to vacuum cleaners used in households around the country. They can replicate the lack of atmosphere, the lighting conditions and the extreme temperature of space. Vacuum chambers are extremely useful for pre-flight testing of instruments and satellites because they help analyze how hardware might react in a space environment. Goddard's vacuum chamber was built in 1960, and though it has undergone modifications and updates, it is still in use today.

In 1982, Goddard found a new use for the vacuum chamber. The Library of Congress possesses millions of books in its collection, with quite a few suffering from age-related deterioration. By de-acidifying the books, the Library of Congress hoped to preserve them for years to come. Goddard's vacuum chamber provided an airless environment for the vapor phased de-acidification process, a method patented by The Library of Congress to extend the life of books.

The process consists of neutralizing the acid found on paper and by depositing on the book pages "an alkaline reserve to combat their return to acid condition." The process involves the use of a highly volatile chemical vapor known as diethyl zinc (DEZ). In addition to providing an oxygen-free environment, the vacuum chamber also removes moisture from books.

The Goddard facility contributed to the development of the procedure for scaling the de-acidification procedure. The process went from treating 400 books in one treatment to 5,000 books, and it was concluded that 15,000 to 20,000 books could be treated in a single run. Approximately 72,000 books were preserved through this process.
*— Adapted by Elsa Paulette Tchasso Madzo*

# 60 Years of Goddard Spinoffs

## 1990s Spinoffs

### Biopsy System for Breast Cancer

According to the American Cancer Society, one in eight women in the United States will develop breast cancer. If a doctor suspects that a patient has breast cancer, they may require a breast biopsy. This procedure can cause discomfort and pain to women. A Goddard technology called a Charged Couple Device (CCD) played a role in helping to solve this problem by providing less intrusive and more accurate breast biopsy scans.

The LORAD Stereo Guide™ Breast Biopsy System was manufactured by LORAD Corporation in 1994. Prior to this, scientists at Goddard were working on the Space Telescope Imaging Spectrograph for the Hubble Telescope. The CCD technology was found inadequate to fulfill the mission, but the team realized there could be commercial uses for their technology.

NASA worked with Scientific Imaging Technologies, Inc. (SITEe) of Beaverton, Oregon to manufacture CCDs that were very thin and supersensitive. These CCDs could be manufactured cheaply, and they quickly found their niche in the digital mammography market due to the shared needs between astronomy and mammography.

With the LORAD Stereo Guide™, patients could leave the office immediately after the procedure and go back to normal activities that same day. In the past, a breast biopsy was done using a scalpel, which required time to heal and left a scar. The new system left only a small puncture wound from a needle, leading to a quick recovery. Specifically, this technology can reduce the procedure time from one third to one half of the original time. Additionally, the CCD reduced patient's exposure to radiation by one half compared to the X-ray film method. From the practitioner's point of view, the LORAD Stereo Guide™ produces digital images that can be enhanced to sharpen details and make diagnosis easier and less uncertain.
*— Adapted by Melissa Maurer*

### Communication Technology and Portable Routers

It is often easy to take for granted how easily we can connect to the internet in our homes. However, such technology went through many phases of research, design and improvement. The simple routers we see today started out as technology used to communicate with satellites thousands of miles away.

In 1992, NASA and the U.S. Department of Defense worked together to commission the development and research of a new wireless technology that would improve the way people on Earth are able to communicate with satellites in space. In the end, the group of researchers and experts created a new suite of protocols that are designed for space-based communication. This protocol is called Space Communication Protocol Standards (SCPS).

Global Science & Technology (GST), the company responsible for the development of this new technology, commercialized SCPS by selling it to the public. This was made possible by the support of NASA's Goddard Space Flight Center, which funded the maintenance SCPS reference implementation. The funding was essential in defining the need for this technology.

The efforts from GST eventually lead to protocol commercial product: SkipWare®. GST created a child company — Global Protocols, Inc. — for the purpose of commercializing SkipWare®. Global Protocols distributed SkipWare® as a software license on the hardware platforms of its partner, and the company also produced the corresponding piece of hardware: turboIP. This hardware, used in conjunction with SkipWare®, worked to allow wireless communication within a certain vicinity.

Like the wireless routers we use at home, turboIP has a relatively easy-to-use interface. This new technology offered unprecedented ease-of-installation and a great reduction in maintenance costs. Previously, one of the biggest issues with wireless communication involved loss of power. SkipWare® and turboIP addressed the single point of failure issue by using fail-to-wire technology to ensure that network connectively remains alive in the event of a power outage. This was a massive leap in practicality because power loss was a very real and limiting factor to previous methods of wireless communication.

The development and commercialization of SkipWare® and turboIP made it clear that there is a vast potential market for wireless communication.
*— Adapted by Joseph Wobus*

## Space Guidance System Enables Efficient Highway Traffic Network

With an increasing number of cars on the highway, traffic congestion becomes an increasing problem. In 1995, a NASA contractor called AlliedSignal revolutionized the way major highways are constructed. Using technology developed in part through contracts at NASA's Goddard Space Flight Center, highway designers were able to develop a more efficient way of detecting road accidents. This was accomplished by placing road sensors and cameras at key highway locations on the highway. The first installment of this effort focused on Texas, where the initial 26-mile operation would eventually boom into a 191-mile freeway network.

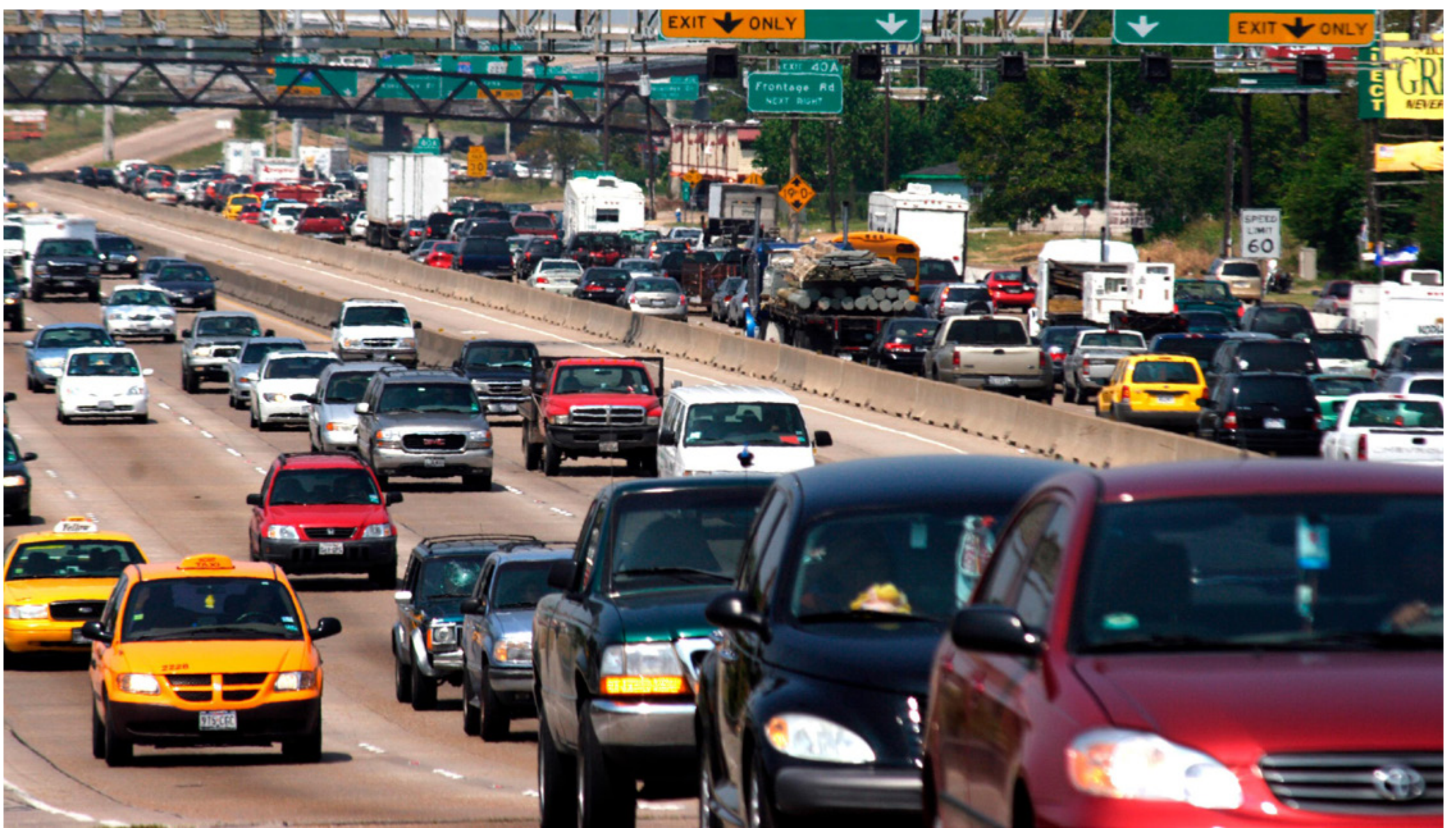
This highway system accomplishes many operations at once.  First, it enables smoother traffic flow by allowing traffic accidents to be dealt with at a quicker rate. This in turn leads to cleaner traffic, less fuel consumption and less costly road trips because of decreased fuel consumption.  Secondly, the system has inductive loop detectors at half-mile intervals and full color video cameras at one mile intervals. Using these detectors and cameras, network specialists can detect accidents on the road within seconds and deploy proper responses. The highway system has 50 fiber optic message signs, 358 overhead lane control signals and computerized control of traffic signals. These signs help guide the flow of traffic and reduce confusion on the highway.

Previously, sensor technology was unreliable and buggy. Many times, highway traffic monitors had a hard time knowing the status of the highway because of unreliable sensor technology or a complete lack of sensors. With the introduction of highway monitor sensors produced by AlliedSignal, highway monitoring allowed for quicker response time to accidents.

Finally, the highway system is supported by a remarkable upgrade in highway monitoring command and control system. Inspired by the layout of one of NASA's major control centers, the 48,000-square-foot control center is filled with hundreds of displays of many video and computer images, which are all shown on a huge 60-foot wall. In addition, each operator has four video monitors that display the roadside images.

The camera sensors placed throughout the road are located in strategic positions that are most likely to see a traffic accident. When the system detects an accident, an operator takes over and assesses the situation. Depending on the circumstances, the operator will determine the best course of action. AlliedSignal made roadside monitoring much more efficient through its development of smart monitoring technology.

— *Adapted by Joseph Wobus*



# 60 Years of Goddard Spinoffs

## 2000s Spinoffs

### Crycooler Technology

Cryogenics is the study of the production and behavior of matter in extremely cold temperatures. Usually, getting materials to very low temperatures involves the use of liquid nitrogen, liquid helium or mechanical cryocoolers. One such cryocooler, produced by Sunpower Inc. in Athens, Ohio, was used to fuel space exploration.

NASA sought a cryocooler that would operate smoothly at a steady temperature of 75 degrees Kelvin (-324 Fahrenheit) without malfunctioning for long stretches of time. This cryocooler was needed for the 2002 launch of the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), which contained numerous sensitive detectors that needed to be kept at low temperatures. Through NASA's work with Sunpower Inc., they were able to achieve this feat.

Typically, mechanical cryocoolers use liquid lubricants to keep pistons operating properly, but in space, the liquid would freeze. Sunpower's cryocooler circumvents this problem by using helium gas to keep pistons operational. The cryocooler must be perfectly sealed in order to prevent helium from leaking out of the system.

The RHESSI mission was a success, and with Sunpower's cryocooler on board, RHESSI continued its mission for 16 years, observing more than 40,000 X-ray flares. As of 2016, at least a dozen cryocoolers have been used for science experiments aboard the International Space Station. With Small Business Innovation Research grants through Goddard and NASA's Glenn Research Center, Sunpower has continued to develop a variety of coolers for space applications.
*— Adapted by John Blanco*

### Ingestible Thermometer Helps Detect Heat Exhaustion

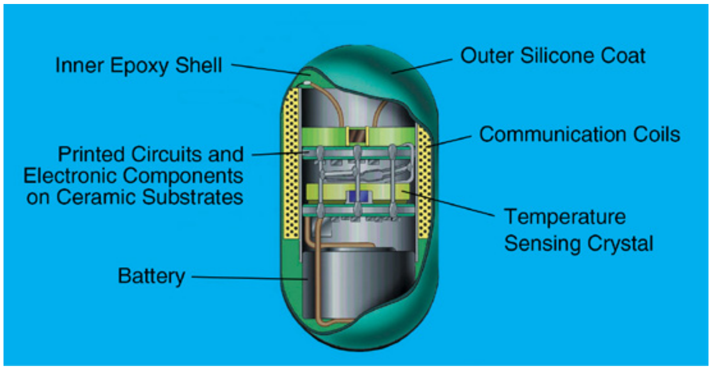
Hundreds of people die of heatstroke each year in the U.S., and even astronauts are susceptible to heatstroke when performing tasks in their space suits. Though the suits are insulated, exertion causes astronauts to release body heat, which can humidify the interior of the suits. In the late 1980s, NASA worked with the Johns Hopkins University Applied Physics Laboratory (APL) to develop a method for detecting and preventing heatstroke in astronauts.

With a $75,000 grant from NASA, APL and Goddard Space Flight Center created the first Ingestible Thermal Monitoring System. The system consisted of a thermometer embedded in a capsule that can be swallowed like a pill. The tiny capsule included a telemetry system, a microbattery and a quartz crystal temperature sensor.

The temperature-reading pill was first used by a Johns Hopkins University veterinarian to monitor an animal's temperature during surgery. In 1988, a company called HQ, Inc. licensed the temperature pill, and in 1991, astronauts first digested the capsules in space.

Ten years later, when football players Eraste Autin and Korey Stringer died a week apart from heatstroke, the thermometer pill was considered for use in athletes. As football players often start training in the hottest days of the summer, and many athletes weigh over 300 pounds, football players are more susceptible to heatstroke. HQ Inc. turned NASA's pill into the CorTemp Ingestible Core Body Thermometer Pill.

Athletes can swallow the pill, and it allows for noninvasive monitoring of the athlete's temperatures by team physicians and certified athletic trainers. The capsule has been used to limit the amount of time players can practice on hot days, and several teams in the National Football League have used this technology to monitor players. CorTemp has been used by Olympians in track and field and in a wide range of sports, from hockey to cycling and auto racing. Outside of athletics, CorTemp has helped firefighters and deep-sea divers, and it also can monitor important temperatures for non-medical applications such as paper manufacturing.
*— Adapted by Melissa Maurer*



## Telescope Innovations for Eye Surgery

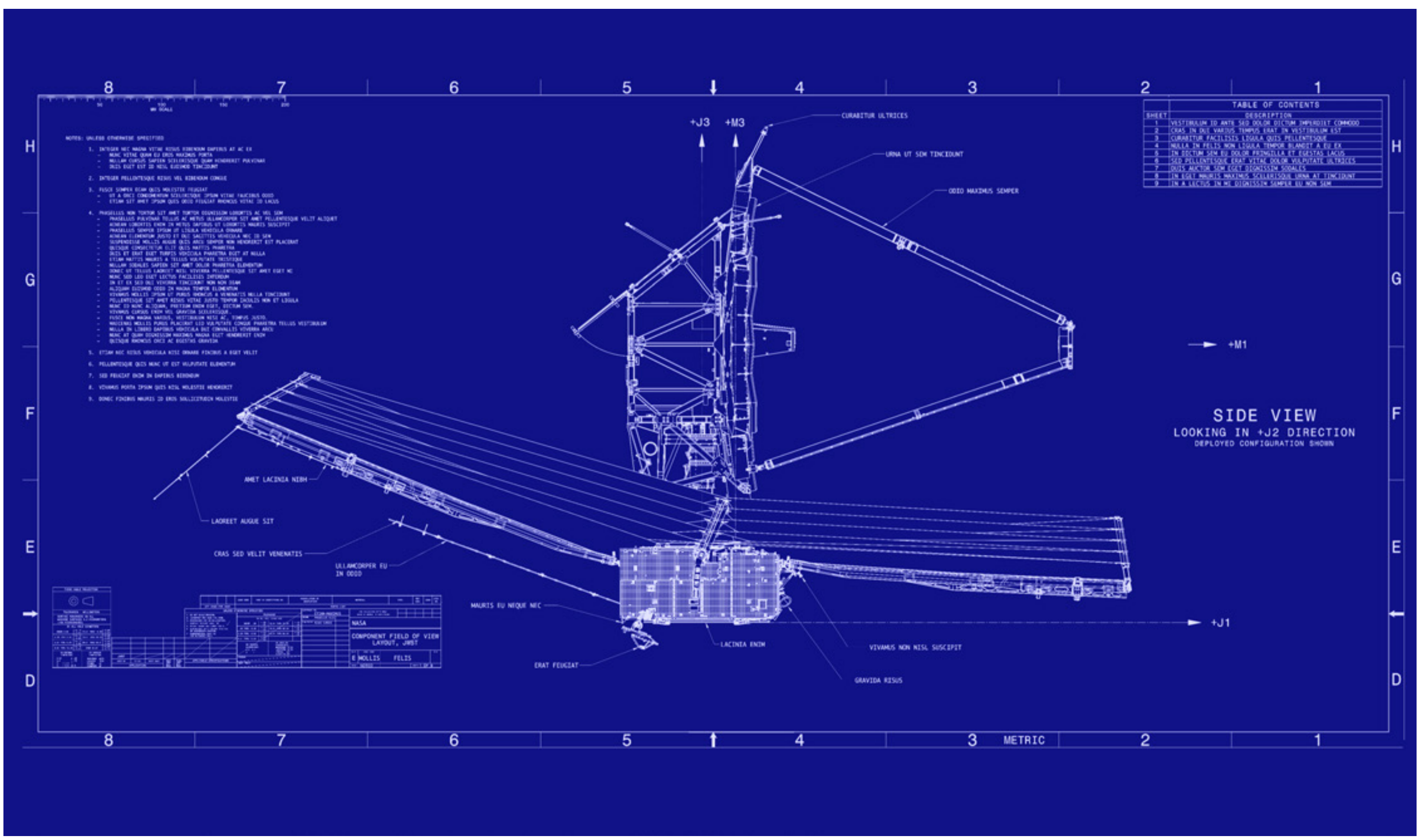
The James Webb Space Telescope (JWST), scheduled for launch in 2022, is expected to observe extrasolar planets as well as enable advanced astrophysics. Peering out through such vast distances will require JWST to have incredibly large mirrors, wider than two stories in diameter and consisting of 18 separate segments. To deliver a view that is 13 billion light years away, each of the 18 segments needed to be constructed using multiple rounds of measuring, grinding, polishing and testing. The grinding phase is the most time-consuming phase of mirror development and took multiple years.

NASA's Goddard Space Flight Center contracted with Northrop Grumman Aerospace Systems and Ball Aerospace, as well as their contractors and subcontractors, to build and grind the mirrors for JWST. One subcontractor, Wavefront Sciences, created a new method called the infrared Scanning Shack Hartmann System, which allowed the team to test the mirror's surface immediately after grinding and shortened the amount of time it took to carry out the testing. By measuring a small part of the mirror, the system could create an image of the entire surface. For NASA, this not only reduced the time it took to build these high-quality mirror segments, but also reduced the cost significantly.

This innovation extends to doctors who measure a different kind of lens — the lens of the human eye. The techniques initially developed for the JWST mirrors have resulted in improvements to the machines testing for LASIK surgery in human eyes. WaveFront Sciences created the Complete Ophthalmic Analysis System (COAS) based on its JWST work. COAS was able to diagnose certain eye conditions as well as support research in cataracts, reduced vision (keratoconus) and eye movement.

After a series of acquisitions resulted in the COAS technology changing hands, a company called Abbott Medical Optics released a product based partially on COAS. Called the iDesign Advanced WaveScan Studio, the product can be used by a doctor to measure a patient's eye, and it creates a map of the LASIK treatment, which then is transferred to a computer that guides the laser used for the treatment. Within seconds, it presents four different measurements and can accurately measure distorted surfaces in cases of nearsightedness, farsightedness and astigmatism.

While NASA initially was trying to solve the problem for the mirrors in JWST, their innovation opened new doors in the medical field as well.
— *Adapted by Urvi Parikh*



# Technology Transfer Outreach

## New York Space Alliance

**September 28, 2018**

Members of the Goddard Technology Transfer Office (TTO) traveled to New York to attend the signing of a Space Act Agreement (SAA) between the New York Space Alliance (NYSA) and NASA. NYSA President Sidney Nakahodo signed the SAA in advance of its signing at NASA's Johnson Space Center in Houston. Goddard TTO representatives attended to support the event that was spearheaded by Steven Gonzalez of Johnson. Goddard also participated in AstroCafe, a collaborative effort to highlight entrepreneurs, visionaries, and innovators.

## ILI T.I.M.E. Challenge Winners Tour

**October 26-27, 2018**

Goddard TTO welcomed participants of the Institute for Local Innovations (ILI) Technology Implementation Market Engine (T.I.M.E.) Challenge to the Goddard campus on Oct. 26 for tours and presentations. The ILI T.I.M.E. Challenge champions entrepreneurship by asking students from Historically Black Colleges and Universities to select patented NASA technologies and develop marketing strategies for commercialization. The student finalists presented their ideas to a panel of judges on Oct. 27 in Washington, DC. Daryl Cunningham, Jr. won the contest for his “Invisible Wall,” a child safety mechanism to keep balls from reaching the street while children play in the driveway. It uses a non-contact position sensor and a levitated interaction element to create a magnetic field. Winners were honored with an awards ceremony, with Goddard TTO representatives in attendance.

## Astropreneurship Day

**November 1, 2018**

Goddard TTO’s deputy chief participated in Astropreneurship Day, a joint event by the New York Space Alliance and Space & Satellite Professionals International (SSPI). The event brought together entrepreneurs who create businesses around space and satellite technologies. Participants attended presentations on space commercialization and entrepreneurship in New York, followed by networking with fellow attendees.

## SpaceCom

**November 27-28, 2018**

Staff members from Goddard TTO participated in the Space Commerce Conference and Exposition (SpaceCom) in Houston, Texas. Technology Manager Kerry Leonard gave a presentation on Nov. 27 about technology transfer and partnerships at Goddard, explaining the goals and responsibilities of Goddard TTO while giving technology examples in each of Goddard’s four science focus areas. On Nov. 28, Leonard participated in a panel discussion on NASA innovations, sharing some Goddard technologies with potential agribusiness industry applications. Goddard TTO staff also had a booth at the exhibition, where they shared educational materials on technology transfer and displayed models of licensable Goddard technologies, including the Miniaturized High-Speed Modulated X-Ray Source (MXS).

# Technology Transfer Opportunities

## Goddard Technology Transfer Training

**September 26, 2018**

The Goddard Technology Transfer Office (TTO) hosted an "Advancing Innovation" training session on Sept. 26. The training explains the benefit and purpose of Goddard technology transfer, bringing together 19 attendees from various organization codes around Goddard. Participants of the training received an introduction to technology transfer with an emphasis on the various aspects of reporting, marketing, and licensing NASA technology. Additionally, the training material highlighted internal and external partnership opportunities, explaining to attendees how to connect with Goddard TTO's technology managers.

## IRAD Poster Session

**October 25, 2018**

Staff members from Goddard TTO participated in the Goddard Internal Research and Development (IRAD) Poster Session on Oct. 25. Goddard TTO displayed an exhibit with an informational poster on technology transfer and handed out reading materials and notebooks. Staff members answered questions about NTRs and software release from innovators who stopped by the exhibit. Additionally, representatives from Maryland Aerospace attended the poster session as guests of Goddard TTO.

## Detector Development Talk

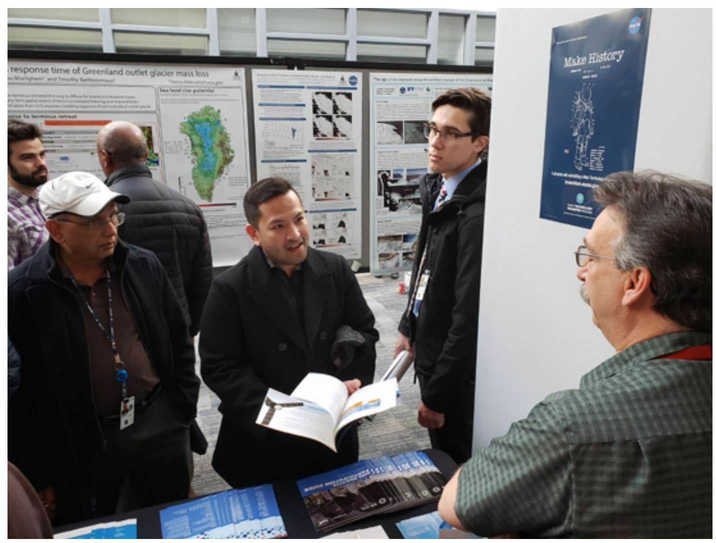
**November 19, 2018**

Goddard TTO helped facilitate a presentation by Goddard innovator Murzy Jhabvala on the history of detector development at Goddard and the role of technology transfer in this area. The chief of Goddard TTO introduced Jhabvala, and during the talk,  Jhabvala encouraged members of the audience to seek out technology transfer collaborations in their work. More than 90 people attended the standing-room only presentation, and based on the high level of interest, Goddard TTO is working with Jhabvala to repeat the presentation at a later date.

## Sciences and Exploration Directorate Poster Party

**February 26, 2019**

Representatives with Goddard TTO participated in the 12th Annual Sciences & Exploration Directorate Poster Party, bringing an exhibit on technology transfer and speaking to innovators about submitting new technology reports. The event gave innovators an opportunity to showcase their scientific work from the past year through displaying scientific posters. Goddard TTO handed out in-reach materials, including fact sheets, Tech Transfer magazines, brochures, and innovator notebooks. Additionally, Goddard technology managers connected directly with innovators by talking to them about their posters and explored the potential for submitting new technology reports related to their work.



# New Technology Disclosures

### NAFTU SDL Editor
Nathan Riolo

### Near Earth Network (NEN) Now
Ryan Turner, Jonathan Little, Aliyah Shah, Emily Ragan, Ezra Brooks, Anjali Mittu, Kierra Harrison, Micajuine Ho, Nicole Luddy, William Varner, Carl Kendall, Todd Googins, Reese Patillo, Vuong Ly, Naje Fields, Alan Schonbrunner, Harvey Elliott

### Land Information System (LIS) Framework
Christa Peters-Lidard, Sujay Kumar, James Geiger, David Mocko, Kristi Arsenault, Shugong Wang, Augusto Getirana, Abheera Hazra, Amy McNally, Bailing Li, Eric Kemp, Hiroko Kato Beaudoing, Jossy Jacob, Mahdi Navari, Jessica Erlingis Lamers, Robert Rosenberg, Yeosang Yoon, Scott Rheingrover, Jerry Wegiel, Soni Yatheendradas, Chandana Gangodagamage, Rhae Sung Kim, Kris Verdin, Daniel Sarmiento

### Aerogel Scattering Filters
Thomas Essinger-Hileman

### PointClouds VR
Thomas Grubb, Matthew Brandt, William Garry, Marc Kuchner, Horace Mitchell, Douglas Morton, Troy Ames, Nargess Memarsadeghi, Stephanie Schollaert Uz

### Development of the Multi-Angle Stratospheric Aerosol Radiometer (MASTAR)
Mathew Kowalewsi, Luis Ramos-Izquierdo, Matthew Deland

### Kamodo Analysis Suite
Asher Pembroke, Lutz Rastaetter

### The Application of Electron Enhanced Atomic Layer Deposition (EE-ALD) for the Room Temperature Coatings of Boron Nitride (BN) of Micro Particles
Vivek Dwivedi

### Conjunction Assessment for University Space Programs
Alinda Mashiku, Lauri Newman, Matthew Hejduk, Jeffrey Kelley

### Doorstop Requirements Template
Ewan Douglas

### ALD Modified Carbon Nanotubes for Highly Conductive Wire
Vivek Dwivedi, Henry Degroh

### Reflectometer Instrument for Bi-static Synthetic Aperture Radar (GRIBSAR) Measurements of Earth Science Parameters
Aditi Bansal, Minerva Morana, Satya Ponnaluri, Arvind Bhat

### Optical Transceiver Small Optics Design Allowing Wavelength Switching without Moving Parts
Russell Roder

### NAFTU Telemetry Report Generator
Nathan Riolo

### Tailoring Absorptance and Emittance of Silicon Oxide Coated Aluminized Kapton as Radiator Coating for CubeSat Thermal Management
Michael Choi

### Solar Soft Enhancements for Heliophysics Program
Neal Hurlburt

### Pyramid Image Quality Indicator (IQI) for X-ray Computed Tomography
Justin Jones, Antonio Moreno, Olivia Landgrover

### Impact Ice Shear Adhesions Strength Quantification Apparatus
Jose Palacios

### BRO-Based Intertial Reference Unit (BCIRU)
Darren Laughlin

### General Mission Analysis Tool (GMAT) Version BETA R2019a v0.2
Steven Hughes, Joshua Raymond, John McGreevy, Michael Stark, Tuan Nguyen, D. Cooley, Tetyana Royzman, Steven Slojkowski, Mark Nicholson, John Downing, Donald Ginn, Ravishankar Mathur, Wendy Shoan, Darrel Conway, Claire Conway

### Li Intercalated Boron Nitride, Nano Tube and Nano Mesh for Tailored Conductivity TCMS Space Applications
Mukund Deshpande, Vivek Kamat, Narayan Hosmane

### Li4Ti5O12 based Conductive TCMS for Space Applications
Mukund Deshpande, Vivek Kamat, Hetal Patel

### Li Intercalated Boron Nitride Nano Mesh for Conductive TCMS for Space Applications
Mukund Deshpande, Hetal Patel

### Passivated BaTiO3 - PBT50 based Conductive TCMS for Space Applications
Mukund Deshpande, Vivek Kamat, Hetal Patel

### Doped and Miscible Solid Solutions of -Li(Al/Ga)O2 for Conductive TCMS Space Applications
Mukund Deshpande, Vivek Kamat, Hetal Patel

### S2 UAS
Maciej Stachura, Geoffrey Bland, Jack Elston

### A method for measuring and trending the focus alignment of telescopes and finite conjugate systems using laser radar
Raymond Ohl, Phillip Coulter, Manal Khreishi, Martyn Wells

### Productization of a Fiber-Optic Gyroscopes (FOG) Product for High Accuracy Space Applications based on Hollow-Core Photonic Crystal Fiber
Behzad Moslehi, Ram Yahalom, Levy Oblea, Richard Black

### Puppet Module Master
Alakom-Zed Pobre, Lynne Valencic, John Jasen, Bennett Samowich, Adina Tarshish

### Decision Support Platform for Cropland Management and Forecasting
Jeffrey Orey, Bernie Johnston, Andrew Catellier, Matthew Kotalik, Nicholas Dana

### SEDAC HazPop Android Version
Frank Pascuzzi, Alfonso Pinto, Sritharan Vinayagamoorthy, Kathleen Baynes

### Satellite Laser Communication Network Wavelength Plan Implemented with Multi-Chroic Filters
Scott Merritt

### DAPHNE - Data Acquisition Processing and Handling Network Environment
Salem El-Nimri, Deepak Kaul, Thomas Bialas, Philip Baldwin

### Worldview Snapshots
Mike McGann, Benjamin King, Edward Plato, Kathleen Baynes, Matthew Cechini, Minnie Wong, Natalie Pressley, Ryan Boller, Zachary Rice, Diane Davies, Jeffrey Schmaltz

### File Commander Extended (FCX) cFS Application
Susanne Strege, Walt Moleski, Michael Deschu, Scott Walling

### Induction Brazing With Portable Purge Enclosure
Justin McCarthy, Jonathan Prouty, Matthew Pate

### 5.5K Coarse Azimuth Pointing System for Balloon Gondolas
Caitlin Gibbons

### 14-Decades Calibration in Airborne Detectors for Environmental Science (14DeCADES)
Charles Booth, Randy Lind, John Morrow, Stanford Hooker

### Phase data acquisition on Low Coherence Virtual Spherical Probe
Artur Olszak, Chase Salsbury

### Global Modeling Initiative ICARTT Processing Software
Megan Damon

### Robust FARADAYIC CNT Based Coating for Scattered Light Suppression
Dan Wang, Timothy Hall

### Radiometer Rev C
Michael Hurowitz, Jack Elston, Albin Gasiewski

### S2 Pneumatic Launcher
Jack Elston, Stachura Maciej, Josh Fromm

### Optically Interrogated Thin Film Strain Gauge for Balloon Applications
Marc Ramsey, Richard Kaszeta, Michael Swanwick

# New Technology Disclosures

### Low temperature isothermal turboalternator
Mark Zagarola, John McCormick, Kenneth Cragin, Christian Passow

### Compact, Long-lifetime Atom Source for Space
Matthew Cashen, Arman Cingoz, Martin Boyd, Jamil Abo-Shaeer

### Particle and X-Ray collimator with improved optical blocking
Vladimir Kochergin, Elena Kochergina

### HSI Acquisition with Random Filtering and Random Spectral Summing
Christopher Buurma, Andrew Stevens, Nigel Browning

### Sensing Element for Ice and Total Water Content Measurements in Clouds
John Bognar

### Silicon Carbide Integrated On-Chip Power for Harsh Environments
Akin Akturk, Neil Goldsman, Zeynep Dilli, Mitchell Gross, Aysanew Abate

### Sustained Low-Altitude Lunar Orbital Mission (SLALOM) Engineering Model
Charles Cain

### Simulated Lunar Observations of Peaks and Elevations (SLOPEs)
Alec Forsman

### GLobal Lunar Auto-maneuver Demonstration Engine (GLADE)
Ethan Kayser

### Successful Use of Microporous Polytetrafluoroethylene Thin Sheets in NASA's OSIRIS-REx Mission
Michael Choi

### Goddard Mission Services Evolution Center (GMSEC) Application Programming Interface (API) 4.5
David Whitney, Matthew Vargo, Ellen Leu, John Bugenhagen

### Infrastructure for computation of the atmospheric angular momentum using numerical weather model
Leonid Petrov

### XTCE Database Enhancement Tool (XTCE DET)
Vadim Korotkikh, Wayne Jackson

### Mechanically robust and large format polyimide aerogel scattering filters
Thomas Essinger-Hileman

### Optical Window for Far-IR Instruments Using Thin TOPAS Film for Ground Based and Airborne Applications
Berhanu Bulcha, Edward Wollack, Alexander Kutyrev

### Namz plugin
Nathan Riolo

### The use of the quaternions for describing the Earth's rotation
Christian Bizouard, Leonid Petrov

### Virtual SCRAMNet device for VirtualBox
Timothy Riley, Justin Morris

### Design of 1U Optical Tranceiver and Evaluation of Carpal-Wrist Gimbal to Enable Laser Communications for Distributed Spacecraft Missions
Mark Storm, Keith Petrillo, Jacob Hwang, Nigel Martin

### Updating scripts in (pre-existing) MultiKing software package
Paul Goudfrooij

### Dram software
Nathan Riolo, Pamela Pittman

### Coating-less non-planar ring oscillator laser
Kenji Numata, Anthony Yu

### Personnel Tracker
Nathan Riolo

### Ace application
Nathan Riolo

### Cryogenic bolometric detectors with microfabricated superconducting thermal isolation structures
Ari Brown, Karwan Rostem, Edward Wollack, Kevin Denis

### Automated Radiation Measurements for Aerospace Safety – Dual Monitor
Kent Tobiska

### Category III funded design effort on the COSIE ISS-based instrument
Leon Golub, Amy Winebarger, Chad Madsen, Alex Bruccoleri

### Silicon carbide structures and methods of fabrication
Bruce Lairson

### Intelligent Collaborative Constellation
Jacqueline Le Moigne-Stewart, Eric Pollack, Caroline Kuzio

### Perl 6 Docker API
Curt Tilmes

### Second Harmonic Mixer Operating above Loop Resonance
Jeffrey Hesler, Thomas Crowe, Theodore Reck

### Compact, monolithic gas cell made of mirror substrates
Kenji Numata, Stewart Wu, Haris Riris

### Passive Cryogen Storage System (PCSS)
Shuvo Mustafi, Matthew Francom, Xiaoyi Li, Daniel McGuinness, Ryan Simmons, Lloyd Purves

### “Hopper” Ultra-Low Read Noise Charge Coupled Device
Bernard Rauscher

### Broad Spectrum X-Ray Attenuator Based on Micro Lithography
Kyle Gregory, Steven Christe, Albert Shih, Daniel Ryan, Eliad Peretz

### Global Ecosystem Dynamics Investigation Lidar (GEDI) Instrument Flight Software (FSW)
Ronald Miller, Shiraz Bhalwani, Michael Yang, Bruce Trout, Larry Shackelford

### Deep Learning Enhanced Fidelity InSAR Toolkit (DEFIT)
Jason Hill

### Perl 6 Interface to libarchive multi-format archive and compression library
Curt Tilmes

### Improved Forecasting of Solar Particle Events and their Effects on Space Electronics
Ashok Raman, Dan Howe

## Goddard *Tech Transfer* Magazine

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