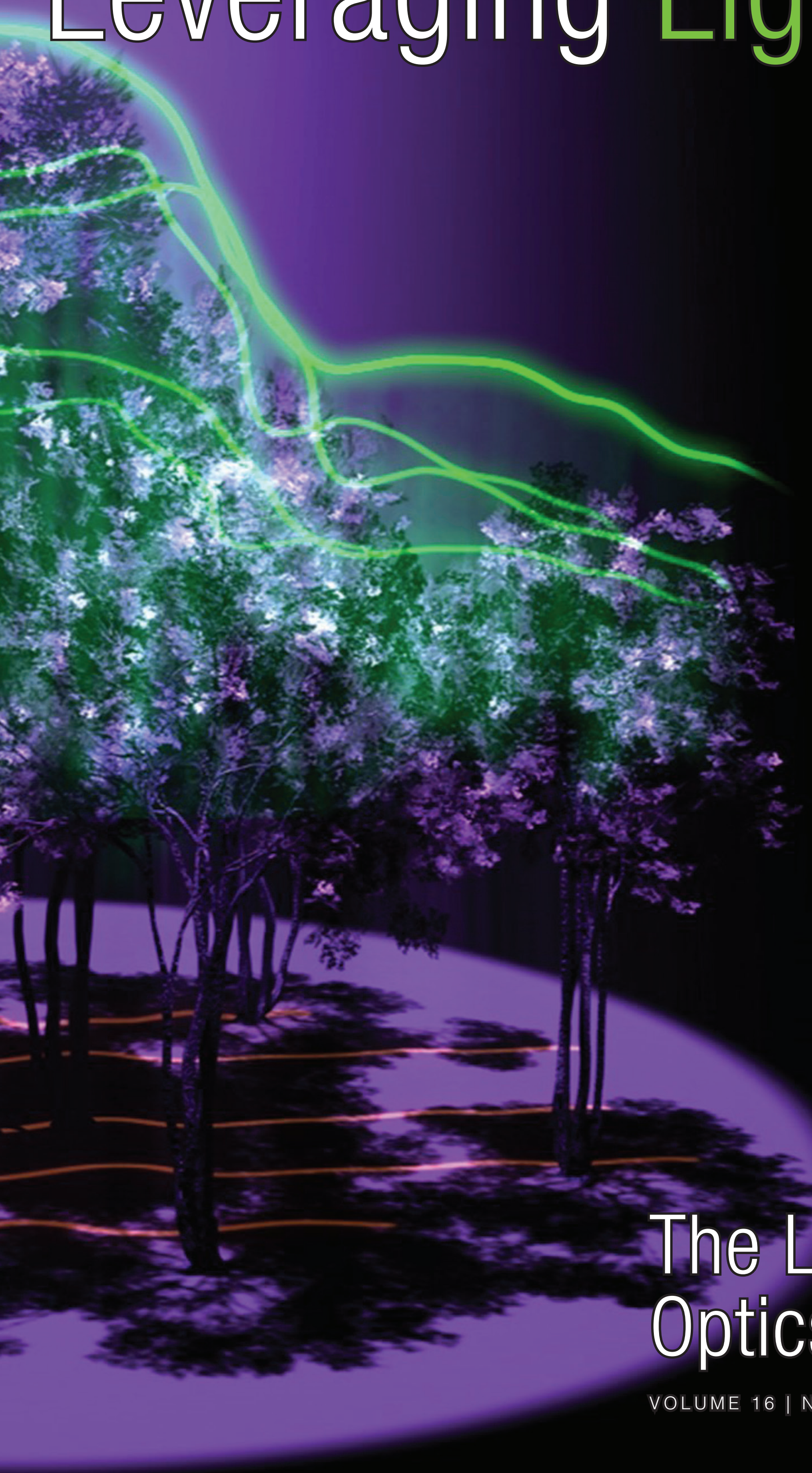
National Aeronautics and Space Administration

tech transfer

Leveraging Light



The Lasers and Optics Edition

VOLUME 16 | NUMBER 4 | FALL 2018

Contents

About the cover: This illustration depicts how lidar from the Global Ecosystems Dynamics Investigation (GEDI) mission will uncover the 3-D architecture of forests. At the time of publication, GEDI is slated to launch in November 2018.

From the Office of the Chief

Nona Cheeks

Chief, Strategic Partnerships Office
NASA Goddard

Lasers are everywhere in our daily lives, from the printers in our offices to the medical instruments that correct our vision and perform life-saving surgeries. In the coming years, lasers might play an even larger role at NASA's Goddard Space Flight Center and the world in the form of optical communication.

Through the Laser Communications Relay Demonstration (LCRD), a mission slated for 2019, NASA will test the ability of lasers to quickly and efficiently transmit information from satellites to ground stations on Earth. Once demonstrated, this promising technology could deliver data rates 10 to 100 times faster than radio frequency systems, opening the door for exciting new capabilities in the communications realm.

Given the enormous potential of this development for the television broadcast industry and other commercial sectors, the Technology Transfer Program, as part of the Strategic Partnerships Office, is encouraging prospective industry partners to step forward and see what possibilities exist for partnership opportunities. Our recent Space Act Agreement with optical communications company BridgeSat, Inc. is just one example of how NASA Goddard can work with industry to advance the private sector and NASA's spaceflight goals.

Let the following stories of new NASA technologies inspire you to dream big about the future of optics.

Darryl Mitchell

Deputy Chief, Strategic Partnerships Office NASA Goddard

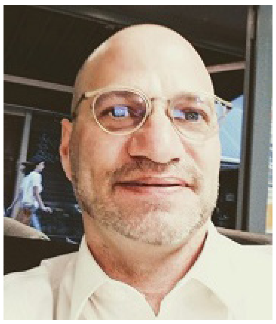
At NASA Goddard, we're harnessing the power of light to accomplish our goals. Many NASA missions depend on lasers to succeed, including OSIRIS-REx, ICESat-2 and GEDI. Through missions such as these, laser technologies developed at NASA Goddard can confer many benefits to society, including innovations in the following areas: spectroscopy; ground-based monitoring of atmospheric gases; radiometer calibration; high-energy laser systems; remote sensing systems; real-time 3-D imaging; optical fiber communications; and many other applications.

Over the past year, innovators at NASA Goddard have made advances in laser technology, some of which we have highlighted in this magazine. We spoke with Dave Israel, principal investigator for LCRD, to get his perspective on the advantages of laser communications. We also caught up with Mike Krainak, Goddard's laser and electro-optics branch head, to hear about his latest work developing technology with applications for artificial guide stars. These technologies have the potential to advance the field of optical communications.

Finally, we're investing in laser technologies through Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards. This year, NASA Goddard funded AdValue Photonics, Inc., of Tucson, Arizona, with a 2017 SBIR Phase II award to develop a fiber laser system that will support the measurement of atmospheric carbon dioxide from space. Eventually, these investments could reap societal benefits in the form of climate science research or fast-scanning biomedical imaging.

Principal Perspectives

Dave Israel
Principal Investigator



Dave Israel is principal investigator for the Laser Communications Relay Demonstration at NASA's Goddard Space Flight Center. He has worked at NASA for 29 years and currently serves as an architect in the Exploration and Space Communications Projects Division at NASA Goddard.

The Bright Future of Laser Communications

In 1979, the historic Voyager 1 mission sent photographs of Jupiter back to Earth via radio waves, providing rich, detailed images of Jupiter's Great Red Spot and its never-before-seen rings. The radio waves traveled more than 300 million miles through space to reach Earth and convey new information about the previously mysterious gas giant.

To this day, radio waves still serve as the primary way to transmit data between spacecraft and ground stations on Earth, even as radio frequency spectrums grow crowded and data transmission needs increase. All that could change with the arrival of optical communications technology. Innovators at NASA's Goddard Space Flight Center say that lasers offer several compelling advantages over radio waves, and if successfully demonstrated, the technology eventually could change space communications as well as the communications industry at large.

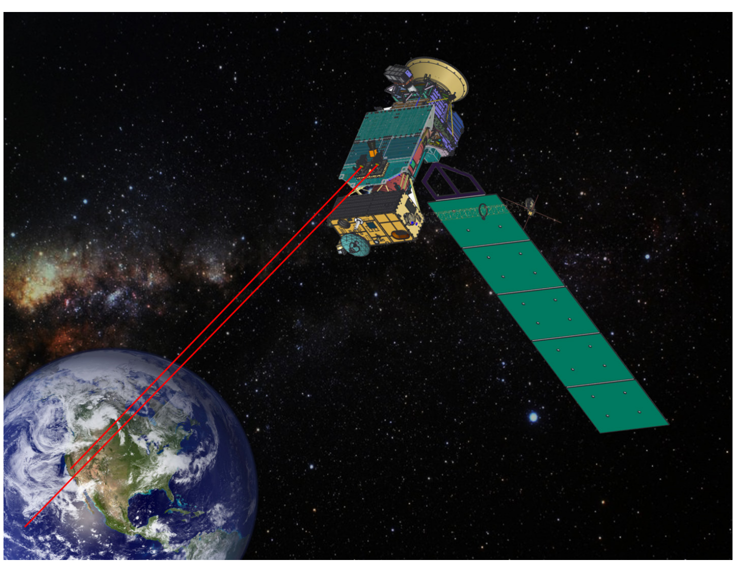
Optical communications systems already have hit the market via providers of fiber optic internet. The average fixed broadband internet speed in the U.S. is 96.9 megabits per second (Mbps), but commercial fiber optic internet providers take download rates to an even faster rate of 1 Gbps (equal to 1,000 Mbps) by using the shorter wavelength of light to rapidly transmit vast amounts of data across thin strands of glass.

The technology drastically boosts internet speeds because light is a high frequency signal, allowing it to transfer more data per second than traditional copper wires carrying electrical current. A minimum two-year, Goddard-led mission will seek to demonstrate a laser-based space communications network, beaming lasers to and from space and paving the way for higher data rate connections for future missions. "We're doing optical communications without the fiber," explains Dave Israel, principal investigator for NASA's Laser Communications Relay Demonstration (LCRD).

Technology demonstrations

With LCRD, Israel and his team will demonstrate how optical communications technology uses lasers to encode data and transmit information more quickly with less mass and power than radio frequency (RF) based communications. In 2013, an earlier mission called the Lunar Laser Communication Demonstration (LLCD) successfully sent and received a high-definition video of then-NASA Administrator Charlie Bolden.

–The Laser Communications Relay Demonstration (LCRD) team is led by NASA's Goddard Space Flight Center.



"The LLCD mission worked very well, but it was a short duration technology demonstration, so LCRD will give us two years in orbit for experiments using laser communications for an operational relay, followed by an extended period of initial operational relay services," Israel says.

With download speeds of 622 Mbps, LLCD displayed the significant potential of this technology. Israel says the advantages include more than just speed. Because light travels with smaller wavelengths than radio waves, optical systems can be smaller in size, taking up less room and weighing less.

Additionally, optical wavelengths are not as regulated or crowded as the RF portion of the electromagnetic spectrum, meaning that no government body currently assigns or allocates the optical spectrum. The narrow beam of a laser serves to decrease the likelihood of interference, giving it another advantage over radio waves, which disperse more broadly.

LCRD will consist of a space relay network including two optical communications terminals carried on a geosynchronous satellite. Using two optical ground stations — one in Table Mountain, California, and one in Hawaii — LCRD will relay optical signals from the satellite to Earth, with data rates expected to reach a whopping 1.244 Gbps.

Commercial opportunities

Because optical systems are relatively new, they cost more than RF systems at this point of development. Ultimately, LCRD will lay the groundwork for industry and commercial interest to continue growing, and the mission seeks to demonstrate the capabilities and desirability of optical communication, leading to greater industry participation, more availability and lower costs. Israel has observed a growing market for technologies used in building laser communication systems.

"We are starting to see more interest in everything from components and system developers on the space side, to businesses interested in providing optical communications and services," Israel says.

For NASA, LCRD presents the opportunity to provide higher data rate connections for missions currently limited by size, weight and power constraints. As plans for manned missions to the Moon and Mars pick up speed, Israel sees optical links playing a role in sending data back to Earth from remote locations.

The farther NASA ventures into the solar system, the more important fast, reliable data transmission becomes.

"For missions beyond Earth, the only way to bring data rates up is to switch to optical," Israel notes.

In the private sector, optical communications could improve television broadcasting, home internet speeds, commercial spacecraft operations and airplane WiFi access, to name a few applications. As the market develops, Goddard can partner with industry to obtain parts for missions.

"There is only so much we can build at NASA within a limited time frame, so it's important for industry to be able to provide components," Israel says. "It's an advantage to have multiple places where we can procure parts."

Optical communications and technology transfer

As this technology shows promising advancements, it could enhance various communication platforms, which can then be transferred to industry, academia and other government agencies.

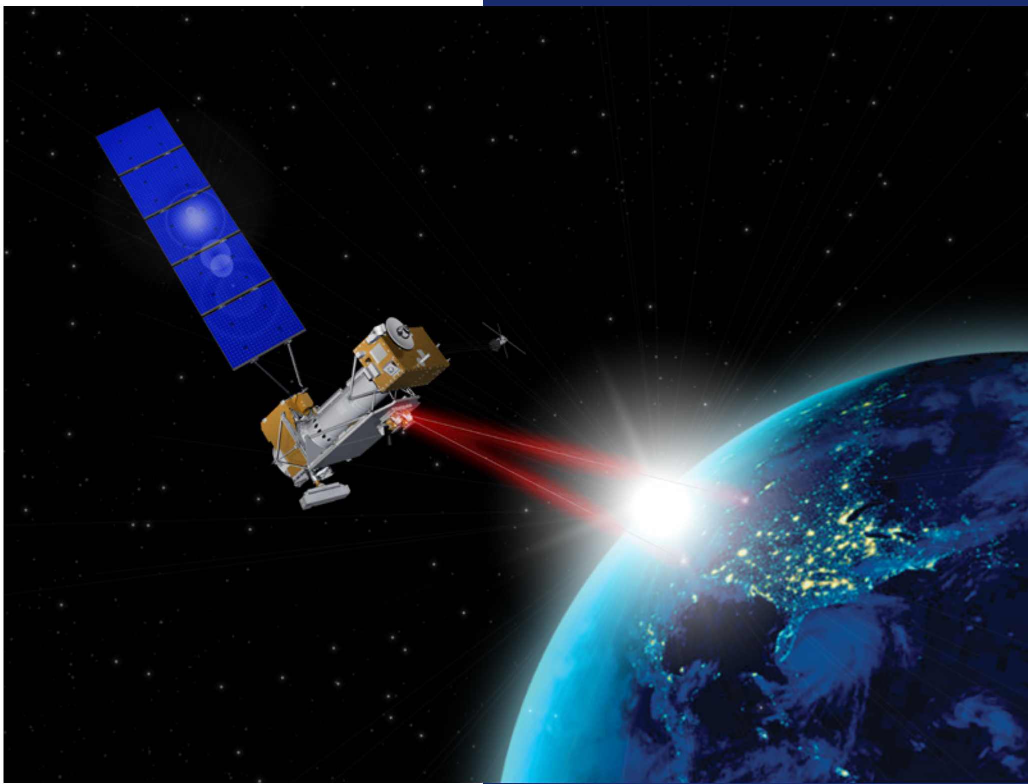
"Having standards helps with commercialization because it lets people know how to invest and build without having to produce all kinds of variations," Israel points out.

As LCRD continues moving toward its launch date in 2019, the mission holds promise of progress for Goddard as well as the private sector.

"One of the main purposes of our mission and ongoing technology development program involves working out issues and doing technology transfer to industry," Israel says.

Partners for LCRD include NASA's Jet Propulsion Laboratory (JPL) and MIT Lincoln Laboratory. The project is funded by the NASA Human Exploration and Operations Mission Directorate's Space Communications and Navigation (SCaN) Program and the Space Technology Mission Directorate's Technology Demonstration Missions Program.

–The Laser Communications Relay Demonstration (pictured in this illustration) builds on the success of the Lunar Laser Communications Demonstration in 2013.



FEATURED PARTNERSHIP

NASA's **Goddard Space Flight Center** signed a **Space Act Agreement** with **BridgeSat, Inc.** of Denver, Colorado in February 2018. BridgeSat seeks to develop an optical communications system offering faster data downloads and lower costs compared to radio frequency communication options. NASA will work with the company to refine its design and ensure system standardization.

Technology Manager Assessment

Hossin Abdeldayem
Senior Technology Manager

Hossin Abdeldayem is a senior technology manager in the Technology Transfer Program at NASA's Goddard Space Flight Center. He has worked at NASA for 27 years, and he works with NASA Goddard innovators in the Instrument Systems and Technology Division and the Exploration and Space Communications Project Division to commercialize new technologies.

Q&A with Hossin Abdeldayem

When Senior Technology Manager Dr. Hossin Abdeldayem thinks about emerging technologies, optical communication strikes him as one of the most exciting. Abdeldayem, who works at NASA Goddard Space Flight Center's Technology Transfer Program, spoke at the Conference on Lasers and Electro-Optics (CLEO) earlier this year to share how partnering with NASA Goddard through technology transfer can lead to benefits across all sectors of the space communications and television industries.

On Oct. 4, 2018, Abdeldayem gave a talk entitled, "Lasers – The Future Means of Space Communication" at the Institute of Electrical and Electronic Engineers (IEEE) Conference in Reston, Virginia.

In addition to these efforts, Abdeldayem is currently organizing an Industry Day Workshop scheduled for 2019. (For more, see the announcement at https://www.fbo.gov/notices/2c15270ad71d47b359e5b807aee0f62b.) The workshop will introduce industry to NASA's laser communication technology in addition to the latest Goddard technologies, aiming to improve partnerships. So far, more than 30 companies have expressed interest in participating in the workshop. Because NASA Goddard is one of the leading NASA centers in optical communication technology, Abdeldayem released an optical solicitation in May of this year, which can be seen here: https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=e272f36cccfa2296e279fe375e5336ec

This solicitation seeks to make the private sector aware of reimbursable partnership agreements with NASA Goddard, and that through these agreements, Goddard is willing to provide the technical support to help private companies acquire their own commercial optical communications systems.

Optical communication uses lasers to transmit data at impressive speeds in comparison to radio frequency (RF) communication, offering data transmission of 10 to 100 times faster than RF technologies. According to Abdeldayem, this development represents a major leap forward in the communications industry, and it's one of several promising technologies ready for partnership opportunities at Goddard.

> "We have a broad range of technologies with great commercial potential, including new types of lasers with unique characteristics that are not available anywhere else but at NASA Goddard."
> — Hossin Abdeldayem, NASA Goddard Technology Transfer Program

Tech Transfer met with Abdeldayem in his office at NASA Goddard to discuss the dynamic field of optics and his thoughts on the state of the industry.

Why is the NASA Goddard Technology Transfer Program encouraging private sector companies to partner with Goddard on optical communications?

Goddard is obligated by federal law to disseminate its technologies to the general public, but beyond that, the NASA Goddard Technology Transfer Program encourages partnership because the results are mutually beneficial. When companies in the space industry build their own commercial optical communications systems, they create a larger market for the technology. This improves system performance by boosting speed, increasing power efficiency and reducing mass. At the same time, having more systems in the market brings the price down for NASA, and Goddard in particular, to acquire these commercial systems for future space missions. This will cost the agency less than building the system from scratch. It also enhances competition, creates high-paid jobs and improves the national economy.

What does NASA Goddard have to offer industry in terms of optics and photonics technologies?

We have a broad range of technologies with great commercial potential, including new types of lasers with unique characteristics that are not available anywhere else but at NASA Goddard. Specific examples include high quality lasers of different frequencies, sizes and power ranges; fast and unique sensors and cameras; laser beam steering mechanisms for star-tracker-based altitude control systems; stable optical pointing instruments; and several others.

How will optical communications change the entire field of communications?

Optical communication offers a much faster data rate than RF communication can do for less cost. The Lunar Laser Communications Demonstration (LLCD) in 2013 produced six times faster data rates than the RF system used in the Lunar Reconnaissance Orbiter (LRO) mission. The Laser Communications Relay Demonstration (LCRD) mission, set to launch in mid-2019, is projected to offer 10 to 100 times faster speeds than RF. More efforts are in progress to increase the speed of optical communications systems to 10 gigabits per second (Gbps) and beyond, extending its use farther into deep space.

To visualize what optical communication can offer: Using radio frequency at 30 centimeter resolution, the mapping of the entire surface of Mars will take nine years, while laser communication can do it in only nine weeks. LLCD demonstrated speeds of 622 Mbps, which can handle more than 30 high definition television channels simultaneously from a distance of 400,000 kilometers. You can imagine the implications of optical communication technology on the television broadcasting industry. This is a faster and less expensive way to communicate.

What can you tell me about Goddard's partnership with BridgeSat, Inc.?

In February 2018, BridgeSat, Inc. signed a Space Act Agreement with NASA Goddard to develop its own commercial free space optical communication system. BridgeSat plans to own and operate 10 ground control stations supporting down-link services with 10 Gbps space terminals on client buses. The company has a unique laser communication system design, but it needs Goddard expertise in a few key areas. First, BridgeSat needs NASA Goddard expertise to improve upon the performance of its uniquely designed laser communication system and demonstrate its functionality from a low Earth orbit (LEO) terminal to round down-link. Second, BridgeSat is interested in making its system consistent with the standards used by NASA to ensure future interoperability in regulatory compliance with Federal Aviation Administration (FAA) rules and regulations. Third, BridgeSat also needs Goddard's expertise to develop the system's modulation, synchronization and coding, and how to best operate the system with respect to weather impacts.

What commercial applications exist for optical technologies outside of optical communications?

Since the invention of the first laser in 1958, lasers as optical systems have found a wide variety of uses in scientific research, material processing and in military, medical and commercial applications. Optical components in general are used in hundreds of thousands of instruments that people interact with on a daily basis, such as cell phones; cameras; telescopes; microscopes; interferometry; lidar; holographs; astronomy; spectrometry and medical equipment, to name just a few.

> "When companies in the space industry build their own commercial optical communications systems, they create a larger market for the technology." — Hossin Abdeldayem, NASA Goddard Technology Transfer Program

What steps can companies take to work with the Technology Transfer Program to acquire Goddard technologies?

Companies can contact NASA Goddard's Technology Transfer Program at techtransfer@gsfc.nasa.gov. Companies will get matched with a technology manager, who will guide interested companies through the process of establishing a partnership for the technology of interest.

Artificial Guide Star

Mike Krainak
Branch Head

Mike Krainak is laser and electro-optics branch head (Code 554) at NASA's Goddard Space Flight Center. He has a Ph.D. in electrical engineering from Johns Hopkins University, and he has worked at NASA for 28 years.

Custom Laser Crystal Supports More Efficient Artificial Guide Star

Telescopes like the Hubble Space Telescope have a huge advantage over ground-based telescopes — they don't have to deal with Earth's atmosphere. The atmosphere's constant state of flux causes trouble for telescopes on the ground, due to its tendency to distort light traveling through it. One solution to this problem involves a technique called adaptive optics. With it, astronomers can correct blurry images and produce better pictures.

Dr. Mike Krainak, laser and electro-optics branch head at NASA's Goddard Space Flight Center, and his team have created a custom laser crystal to assist with adaptive optics. Pending a patent, the crystal has potential applications for ground-based astronomy and laser communications ground stations.

With adaptive optics, telescopes use a tool called a guide star to correct for fluctuations in the Earth's atmosphere. Astronomers use guide stars to deal with atmospheric aberration by measuring light distortions from the guide star and correcting for those distortions.

When natural stars aren't bright enough, telescopes can use artificial guide stars produced with laser beams. A team of scientists and engineers from the W.M. Keck Observatory and the Lawrence Livermore National Laboratory introduced this technique in the 1990s.

When tuned precisely to the right wavelength, a sodium laser can excite sodium atoms in the upper atmosphere, causing the atoms to produce an orange-yellow glow from about 80 to 110 kilometers in altitude.

"Using a telescope to look at it from directly below," Krainak says, "it appears star-like."

Crystals play an important role in the function of lasers — they act as a gain medium to amplify light. Krainak's custom laser crystal is tuned specifically to allow a sodium Raman laser to function more efficiently. Adjusting the composition ratio of two elements — Yttrium and Gadolinium — within the crystal causes the laser to resonate at exactly the right wavelength for sodium atoms.

> "The space program has always been associated with pushing technology forward."
> — Mike Krainak, Laser and Electro-optics Branch Head, Code 554

Specifically, a Raman laser allows for higher beam quality and better electrical efficiency, and the Raman crystal enables the laser to perform these functions, acting as the core of the laser.

Krainak and his team designed the crystal as part of a research and development project to construct a sodium lidar for future science missions, but the technology also has applications in laser communications, where atmospherically distorted signals affect the integrity of data being transmitted via laser beam. Just as artificial guide stars can help correct aberrations in telescope imaging, they also can help with optical communications.

"You can use an adaptive optics system to correct the distortion and focus the beam more tightly," Krainak says.

The laser crystal could lead to more widespread use of artificial guide stars for ground-based astronomy and laser communications ground stations. Krainak and his team have published a paper about their working prototype as they await a patent.

Later this year, a new laser communications ground terminal at the Goddard Geophysical and Astronomical Observatory (GGAO) will seek to demonstrate the value and functionality of optical communications. Krainak and his team have proposed adding a sodium guide star and lidar to GGAO to further bolster the observatory's capabilities.

To move optical technologies forward, Krainak says it will take government, industry and academia working together for the benefit of each sector and the country as a whole.

"The space program has always been associated with pushing technology forward," Krainak adds. "It's good to see NASA Goddard playing an active role in cultivating knowledge and growth for the industrial base and the economy."

NASA Goddard's Technology Transfer Program congratulates Mike Krainak for being selected as FY18 Internal Research and Development (IRAD) Innovator of the Year due to his leadership, skill and vision as NASA Goddard's Laser and Electro-optics Branch Head.

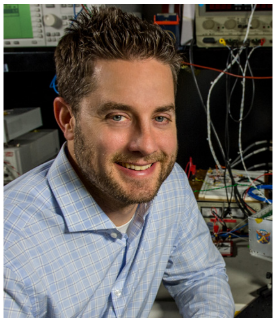
–Part of the European Southern Observatory's Very Large Telescope, this laser guide star helps astronomers correct blurry images caused by atmospheric turbulence. Photo credit: G. Hüdepohl/ESO

FEATURED PARTNERSHIP

NASA works with the **American Institute for Manufacturing (AIM) Integrated Photonics**, a public-private partnership striving to position the U.S. as a leader in the photonic integrated circuit industry. Established in 2015, AIM Photonics seeks to establish a viable framework for integrated photonics manufacturing through partnerships with government, industry and academia. As NASA representative to AIM Photonics, Goddard innovator Mike Krainak advocates for NASA's interests to the group. Ultimately, integrated photonics could supplement or replace the use of electronics in many industries, including data communications, sensing and laser-based radar.

Commercial Capabilities: 3-D Imaging

Nat Gill
Technologist



Nat Gill is a technologist in the Components and Hardware Systems Branch of the Mission Engineering and Systems Analysis Division at NASA's Goddard Space Flight Center. He has a master's degree in electrical and computer engineering from Johns Hopkins University, and he has worked at NASA for 18 years.

Kodiak System Provides 3-D Imaging Capabilities for Satellite Servicing

Not everyone gets to create a 3-D image of their own hand, but for Nat Gill, a technologist at NASA Goddard Space Flight Center, it's all in a day's work. Gill recalls testing the 3-D imaging technology he's working on to scan the contours of his hand and create a picture.

"I could see the structure of each individual finger in the image it generated," Gill describes.

Gill is principal investigator for the Kodiak system, a lidar-based technology which will take part in a satellite servicing mission called Restore-L, allowing an autonomous spacecraft to locate a satellite and attach to it in order to refuel and repair. Previously called the Goddard Reconfigurable Solid-state Scanning Lidar, or GRSSLi, the technology has potential commercial applications in the robotics, manufacturing and automotive industries, as well as the burgeoning satellite servicing industry.

The Kodiak system has "the 3-D imaging capability of GRSSLi, as well as long range laser range finding," Gill says, explaining how the technology has evolved over time from GRSSLi to Kodiak — referencing a close grizzly relative, the Kodiak bear.

GRSSLi started out as a scanning lidar prototype built with commercial parts by the U.S. Army Research Laboratory (ARL) in Adelphi, Maryland. The GRSSLi team adapted the ARL design and built an engineering development unit with a clear path to flight. When tested, GRSSLi performed better than other imaging lidars and was chosen by the Restore-L mission for the purpose of autonomous satellite servicing.

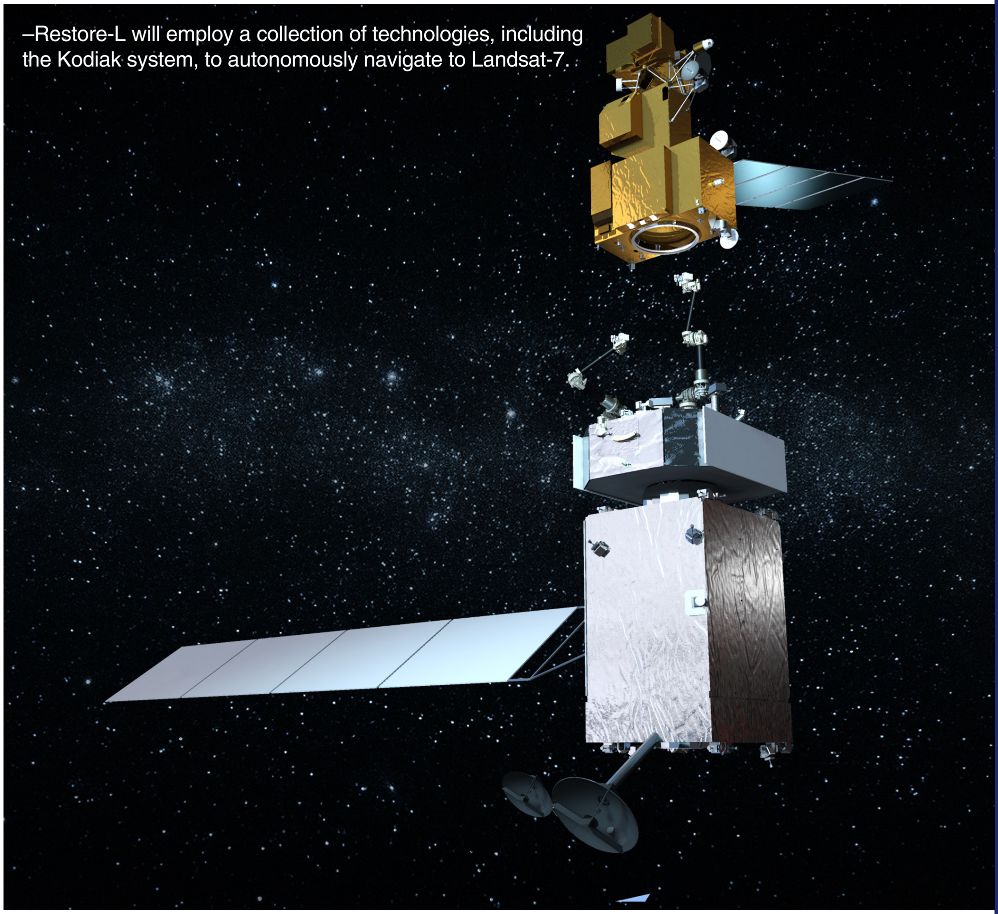
> "New technologies like this can lower the barriers to space and allow more people to access this industry."
> — Nat Gill, PI of the Kodiak System

Similar to a self-driving car, Restore-L employs the Kodiak lidar and machine vision algorithms to estimate the relative attitude and position of a client spacecraft quickly and accurately. By bouncing light against the target, using a photodetector and FPGA (field-programmable gate array) signal processing to receive and interpret that information, the Kodiak system can produce 3-D, high resolution images in real time, allowing the spacecraft to autonomously rendezvous with its client spacecraft.

The Restore-L mission will use a robotic spacecraft equipped with tools to rendezvous with Earth science satellite Landsat-7. Then, the spacecraft will attach to Landsat-7 and essentially provide a tune-up to the satellite, enabling the mission to continue beyond its planned duration.

The successful completion of this mission will demonstrate the readiness and value of servicing technologies to other NASA missions. Goddard also plans to transfer Restore-L's technologies to the commercial sector, building a foundation for a satellite servicing industry to take root.

Gill says it's gratifying to imagine the Kodiak system playing a role in a future satellite servicing industry. "New technologies like this can lower the barriers to space and allow more people to access this industry," Gill adds. "The possibilities are endless."



–Restore-L will employ a collection of technologies, including the Kodiak system, to autonomously navigate to Landsat-7.

NEW INVESTMENTS: INTEGRATED CIRCUITS

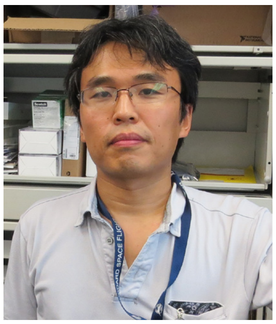
In 2018, NASA's **Goddard Space Flight Center** awarded funding to **Freedom Photonics, LLC** of Santa Barbara, California. The company received a Small Business Technology Transfer (STTR) Phase II award for photonic integrated circuits. Using NASA seed funding, Freedom Photonics will team with the University of California, Santa Barbara to integrate optical components with high performance Silicon Photonics components, resulting in lower cost and lower size, weight and power technologies for space communications. The photonic integrated components could have medical and data center applications, as well.

About the Components and Hardware Systems Branch of the Mission Engineering and Systems Analysis Division:

Engineers and technologists in the Components and Hardware Systems Branch provide expertise in the area of guidance navigation and control components. Some science missions at NASA Goddard require access to newly developed technologies that will allow spacecraft to navigate remotely, and the Components and Hardware Systems Branch plays a role in creating these technologies. For the Restore-L mission, this means developing 3-D imaging capabilities that play a part in enabling the spacecraft to navigate.

Commercial Capabilities: Fast Laser Tuning

Kenji Numata
Laser Electro-Optics Engineer



Kenji Numata is a laser electro-optics engineer at NASA's Goddard Space Flight Center. He has worked at NASA for 15 years and is in the Lasers and Electro-optics Branch of the Instrument Systems and Technology Division.

"This new dual side-band scheme can be applied to commercial applications more easily."
— Kenji Numata, Electro-optics Engineer

Fast Laser Tuning for Gas Monitoring

When Dr. Kenji Numata, an opto-electronics engineer at NASA's Goddard Space Flight Center, began studying optics in graduate school, he became fascinated with technologies that take extremely precise measurements. Now at NASA Goddard, Numata works on a project related to gravitational wave detection, an endeavor requiring extreme precision.

The Laser Interferometer Gravitational-Wave Observatory (LIGO) made history in 2017 when it directly detected gravitational waves emanating from two colliding neutron stars. A mission called the Laser Interferometer Space Antenna (LISA) will follow in LIGO's footsteps to learn more about these ripples from space.

Numata and his colleagues have developed a method for stabilizing and quickly tuning lasers based on their work from the LISA mission and from lidar missions, and the method has potential applications in environmental monitoring. As the primary author on the innovation's patent application, Numata took concepts developed for the LISA mission and tweaked them to create a fast, stable laser system for gas-sensing lidar and other purposes.

"The advantage of this innovation is in its extreme simplicity and its high tuning capability," Numata shares.

LISA, a collaboration between NASA and the European Space Agency (ESA), employs three spacecraft, each flying about 2.5 million miles away from the other. Much like LIGO, LISA will use lasers to measure subtle changes in the wavelengths of the traveling light.

LISA requires highly stable lasers in order to detect distance changes caused by the gravitational waves between two reference test masses in the distant spacecraft pairs, but the mission also requires tunable lasers, meaning that the laser's wavelength can be altered as needed to compensate for the relative spacecraft drift.

To make the system usable for applications beyond the LISA mission, the innovation utilizes fast wavelength tuning in order to measure rapidly changing targets, such as gases in the air or atmosphere.

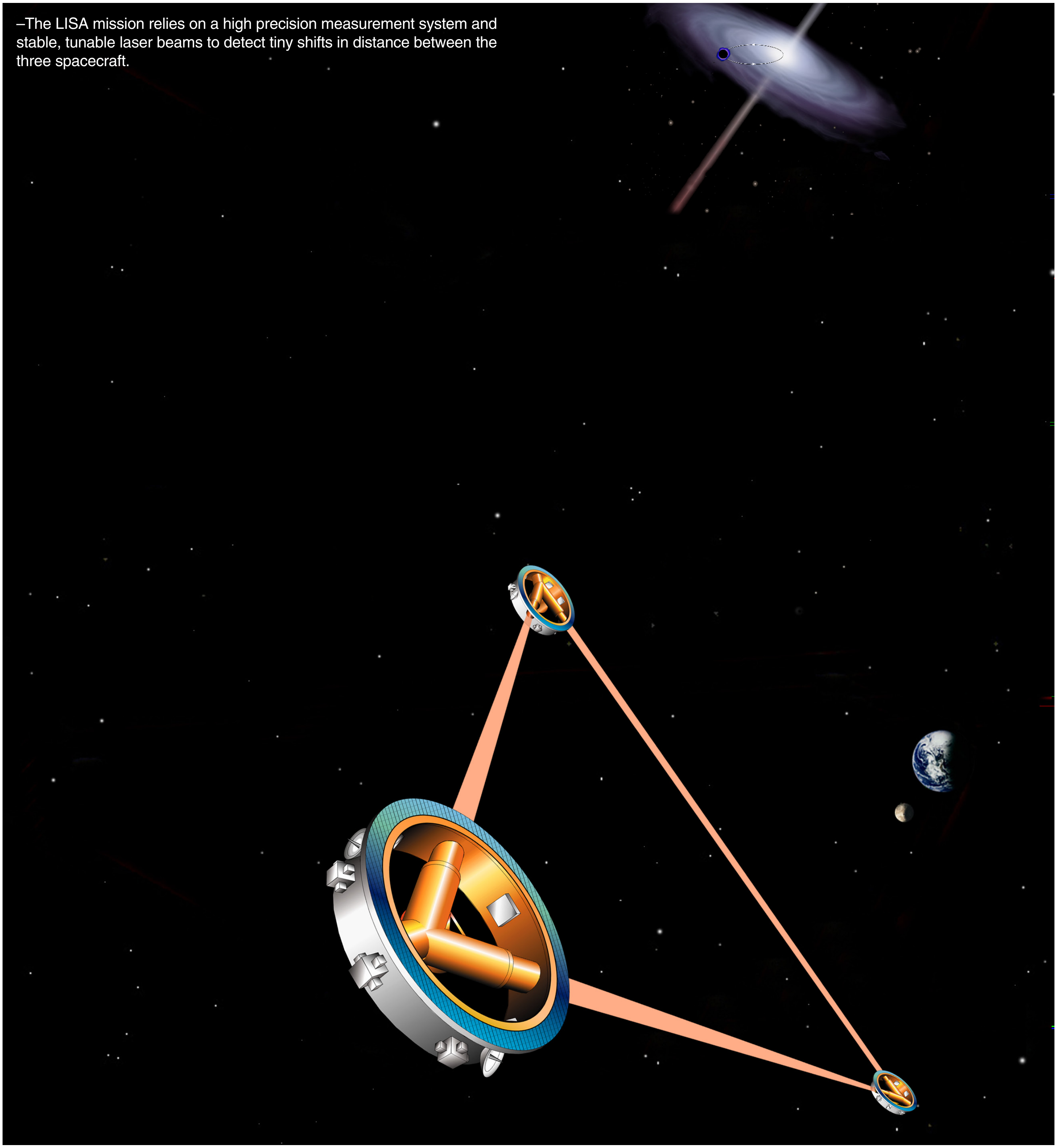
To accomplish this objective, Numata had to devise a way to both lock and tune the lasers.

Numata and his fellow researchers had developed previous systems that succeeded at this, but they involved complicated schemes consisting of multiple lasers and a number of radio frequency electronics. The new innovation, utilizing a dual-sideband locking mechanism, presents a drastically simplified system that decreases the size, weight and power (SWaP) requirements and reduces the number of necessary components.

Since spacecraft need to be compact and efficient, the reduction in size and decrease in power consumption make it ideal for space applications, but its minimalistic design makes it appealing for commercial purposes, as well.

One application involves gas analysis and ambient monitoring — environmental companies could use the system's quick tuning capabilities for spectroscopy, allowing them to measure and study air samples or emissions in dynamically changing situations, such as airborne environmental monitoring and dynamic analysis of chemical interactions.

"This new dual side-band scheme can be applied to commercial applications more easily," Numata notes.



–The LISA mission relies on a high precision measurement system and stable, tunable laser beams to detect tiny shifts in distance between the three spacecraft.

NEW INVESTMENTS: CUBESATS

In 2018, NASA's **Goddard Space Flight Center** awarded funding to **CrossTrac Engineering, Inc.** of Mountain View, California. The company received a Small Business Technology Transfer (STTR) Phase II award for optical inter-satellite communications for CubeSats. With funding from NASA, CrossTrac Engineering, Inc. will partner with faculty at the Massachusetts Institute of Technology (MIT) to develop an optical communications system for CubeSat swarms, enabling them to handle high volumes of data while allowing the CubeSats to stay in formation and monitor the position of each satellite in the constellation.

Success Story

Success Story: NASA Licenses SmallSat Technology to Thermal Management Technologies

A conversation at last year's Small Satellite Conference in Utah led to the Strategic Partnerships Office (SPO) at NASA's Goddard Space Flight Center signing a non-exclusive license agreement with Thermal Management Technologies (TMT) of North Logan, Utah.

"We chatted a bit about a couple of NASA technologies that complemented some small satellite structures TMT is developing, and I became interested in learning more about one technology in particular," says Scott Schick, director of engineering at TMT. "Our company really values the Small Satellite Conference, because you get to share what you know while learning about what others are doing."

The patented technology — Diminutive Assembly for Nanosatellite deploYables (DANY) — provides a reliable mechanism to secure deployable elements of a small satellite, safely stowing them until receiving a signal to burn through a plastic restraining link and release them for use in space. Deployable elements on a small satellite can include solar arrays, sun shades, radiators or antennas. The entire assembly is about the size of a credit card, making it ideal for small satellites that have significant space constraints.

The agreement allows TMT to use the technology, developed at Goddard for the Dellingr mission, as the core of TMT's "Gecko Release Mechanism," named after the device's gecko-like size and ability to grip tightly onto a spacecraft.

"SPO and DANY's inventors — Luis Santos, Scott Hesh and John Hudeck — are excited to see the technology made available to the commercial space community through this license agreement with TMT," says Eric McGill, a technology manager in Goddard's SPO. "We're impressed with the research and development progress made by the company to date."

"Eric McGill was great to work with from day one," Schick adds. "As a small business, this was our first experience licensing a NASA technology, but we're super happy with the result."

TMT specializes in custom thermal and mechanical products, including spacecraft hardware and systems. Schick said that DANY, a thermal-based technology, fits well into the company's niche.

"This really matches our overall objective to provide small spacecraft with high-reliability thermal control components," Schick says.

NASA Goddard has a growing list of patented small satellite technologies available for licensing. To learn more, please contact techtransfer@gsfc.nasa.gov.

–Thermal Management Technologies' Gecko Release Mechanism is based on a NASA technology for SmallSats. Photo credit: TMT

Technology Transfer – Promoting Opportunities

Conference on Lasers and Electro-Optics

May 15-17, 2018

A technology manager from NASA Goddard's Technology Transfer Program (TTP) presented at the annual Conference on Lasers and Electro-Optics (CLEO) at the San Jose Convention Center in San Jose, California. CLEO convenes the world's experts in scientific and technical optics, with 200 exhibiting companies. NASA Goddard's Dr. John Mather gave a plenary talk on exploring the universe at the speed of light, and TTP presented a talk entitled, "Technology Transfer: Benefits to NASA, Mankind, and the U.S. Economy" on May 17. Attendees learned more about the capabilities of free-space optical communication technology to accelerate broadcasting speeds at a fraction of the cost of radio frequency communication. TTP also shared information about the licensing process at NASA Goddard, inviting communications companies in attendance to consider partnering with Goddard to help them acquire this new technology.

Advancing Innovation Training

June 26, 2018

TTP hosted a training called "Advancing Innovation" on the purpose and benefit of technology transfer and the related activities of TTP. The training brought together 19 attendees from various disciplines and backgrounds around NASA Goddard, providing an introduction to technology transfer with an emphasis on the various aspects of reporting, marketing and licensing NASA technology. The training also highlighted internal and external partnerships, as well as NASA's SBIR/STTR program.

Science Jamboree

July 25, 2018

Staff members from TTP participated in NASA Goddard's 10th Annual Science Jamboree on July 25. Hosted by the Goddard Sciences and Exploration Directorate, the Science Jamboree brings together Goddard scientists and potential collaborators from across the center. At the event, TTP representatives had an exhibit and handed out printed materials and notebooks, interacting with around 150 people and participating in numerous conversations to raise awareness of technology transfer and the importance of filing new technology reports.

National Conference of State Legislatures Legislative Summit

July 30 – August 2, 2018

Staff members from TTP helped represent NASA Goddard at an exhibit at the 2018 National Conference of State Legislatures (NCSL) Legislative Summit to raise awareness of Goddard's capabilities and impact across the country through economic development, technology transfer projects and new strategic opportunities. Conference planners estimate that more than 1,000 state legislators, business groups and other decision makers attended the conference.

–TTP staff talk to innovators at the Goddard Science Jamboree.

Technology Transfer – Promoting Opportunities

Small Satellite Conference

August 4-9, 2018

Representatives of TTP traveled to the Small Satellite Conference in Logan, Utah, where they represented NASA Goddard with an exhibit, along with members of Goddard's SmallSat team. TTP staff members handed out printed materials about technology transfer pertaining to small satellites and discussed Goddard's capabilities with attendees.

U.S. PTO Trademark Expo

July 27-28, 2018

TTP representatives participated in the United States Patent and Trademark Office Trademark Expo on July 27-28 at the National Museum of American History in Washington, DC. TTP's exhibit included a model of an AeroPod, a patented Goddard technology. TTP staff interacted with hundreds of members of the public, answer questions about technology transfer and the patent process at NASA. The exhibit also displayed an informational poster about Goddard's trademarked processor technology, SpaceCube.

Technology Transfer Outreach

OPSPARC Winners Workshop and Ceremony

June 13-14, 2018

OPSPARC (OPTIMUS PRIME Spinoff Promotion and Research Challenge) 2018 came to a close as 15 challenge winners and their families explored behind the scenes at NASA's Goddard Space Flight Center. OPSPARC challenges kids in grades 3-12 to improve the world using NASA Spinoff technology. For two days, the winning students toured Goddard from top to bottom, chatting with Hubble Space Telescope scientists and visiting Goddard's Virtual Reality Lab to see star clusters in 3-D. A life-size replica of the OPTIMUS PRIME truck joined the list of tour stops this year. The festivities concluded with an awards ceremony, where TTP and collaborators honored the winners with medals, prizes and congratulations. Actor Peter Cullen, the voice of OPTIMUS PRIME, added his own words of encouragement, telling the winners to "hold on to your dreams, for the future is built on dreams."

Patent Innovation Entrepreneurship Rapid Research Pilot Program

June-August 2018

Goddard TTP staff members attended the awards ceremony in Lanham, Maryland for the Patent Innovation and Entrepreneurship Rapid Research (PIERR) pilot program, where staff members recognized three high school students and their mentor for their participation in the three-week challenge to research a NASA patent and invent commercial applications for it. The students presented their work on a NASA technology that reduces the amount of electricity needed to charge batteries. They proposed using the technology in a variety of modern devices, from electric cars to smartphones.

–Nona Cheeks congratulates OPSPARC winner Sreekar Bheemavarapu.

Upcoming Laser and Optics Events:

SPIE Photonics West
Feb. 5-7, 2019
San Francisco, California

International Conference on Photonics, Optics and Laser Technology (PHOTOPTICS)
Feb. 25-27, 2019
Prague, Czech Republic

Goddard Lasers/Photonics Workshop
2019
Greenbelt, Maryland

Conference on Lasers and Electro-Optics (CLEO)
May 5-10, 2019
San Jose, California

IEEE Photonics Conference
Sept. 30 to Oct. 3, 2019
San Antonio, Texas

Disclosures and Patents

New Technology Disclosures

Report Generator
Joseph Fox-Rabinovitz

High Performance 3D Photonic Integration for Space Applications
Leif Johansson

Fortran Argument Parser
Thomas Clune

Snap together magnetic assembly for freeform optical telescopes
Brian Myer, Dan Brooks, Todd Blalock, Matt Brunelle, Jen Coniglio

Ocean Color Instrument Flight Software Build 1.0.0 Release
Daniel Berry, Dwaine Molock, Jose Martinez-Pedraza, Keegan Moore, Mark Pallone, Michael Blau

Modular Unified Space Technology Avionics for Next Generation Board Bootstrap Flight Software
Michael Blau, Dwaine Molock, Alan Cudmore, Daniel Berry

Ocean Color Instrument Telemetry Output Flight Software
Daniel Berry, Michael Blau

Ocean Color Instrument Platform Support Package Flight Software
Daniel Berry, Dwaine Molock, Jose Martinez-Pedraza, Keegan Moore, Mark Pallone, Michael Blau

Ocean Color Instrument Memory Scrub Flight Software
Mark Pallone, Daniel Berry, Michael Blau

Ocean Color Instrument Spacewire Router Flight Software
Keegan Moore, Daniel Berry, Michael Blau

Ocean Color Instrument Board Support Package Updates to the Gaisler GR712RC BSP for JPL MAIA instrument.
Dwaine Molock, Daniel Berry

Ocean Color Instrument SIDECAR Loader Flight Software
Jose Martinez-Pedraza, Daniel Berry, Michael Blau

Risk Matrix and Table
Susan Semancik

Mixed Reality Engineering Toolkit
Thomas Grubb, Dylan Baker, Matthew Brandt, William Gallagher, Andre Young

Communication Cost Tracker
Susan Semancik, Karon Eichelberger

Design and miniaturization of small-footprint, wide bandwidth printed dipole antenna in S-band
Marta Shelton

Rapidly Extending And Contracting Tubular (REACT) Boom System
Joshua Yacobucci, Scott Hesh

640 GHz Heterodyne Polarimeter
Eric Bryerton

High-speed, high-resolution, laser detection and ranging
Richard Katz, Igor Kleyner, Bryan Blair, Greg Neumann

Method for Blindly Mating Electrical Connectors using a Mechanical Drive
Mark Behnke, Paul Nikulla, Patrick O'Neill

Extension of Athena4.2 fluid dynamics package
Fabian Heitsch

Common Metadata Repository Record Analyzer
Ryan Miller, Erich Reiter

Radio Frequency Interference Detection for Passive Remote Sensing Using Eigenvalue Analysis
Adam Schoenwald, Seung-Jun Kim

Numerical Techniques and Models for Simulation of Radiation and High Temperature Effects in SiC Power Electronics
Robert Arslanbekov, Ashok Raman

Large Displacement, High-Precision, Passive Gravity Offloading System for Deployable Booms
Thomas Rutledge

Stowage Device for Robotic Tools used during On-orbit Satellite Servicing
Patrick O'Neill

Robot Driven Structural, Electrical, and Fluid Blind Mate Mechanism
Elliott Martin, William Davies, Michael Liszka, Christopher Lashley, Charles Bacon, Patrick O'Neill

W-Band Solid State Power Amplifier for Remote Sensing Radars
Mark Koker

GSFC Explosives Safety System
Kimberly Cherrix, Shad Combs, Brandon Wright

libbrace
Damon Earp, Navid Golpayegani

Using Paraffin Phase Change Material for Thermal Management of Planetary CubeSat Missions in Low Lunar Orbit
Michael Choi

NASA Bioburden Assay Tool (BAT)
David Hughes, Dylan Kline

SYSTEM AND METHOD OF OPTICAL AXIS ALIGNMENT MONITOR AND FEEDBACK CONTROL FOR A SPECTROMETER
Irving Linares, Cathy Marx, James Smith, Peter Shu

Direction of Arrival Estimation Techniques for Signal of Opportunity Receiver for 6U CubeSat Platforms
Manohar Deshpande

New Technology Disclosures/Patent Applications Filed

Electrically Controlled Optical Switch for Space Telescope Applications
Manohar Deshpande

Alternative Transparent Coating Lotus Suitable for Optics with Vacuum Deposition Layer
Sharon Straka, Kenneth O'Connor, Mark Hasegawa, Boxi Chen

Alternative Transparent Lotus Coating Suitable for Optics
Sharon Straka, Mark Hasegawa, Kenneth O'Connor, Boxi Chen

Double Plasma Treated Alternative Transparent Lotus Coating Suitable for Optics
Mark Hasegawa, Kenneth O'Connor, Sharon Straka, Boxi Chen

Durable Opaque Lotus Coating
Sharon Straka, Mark Hasegawa, Kenneth O'Connor, Boxi Chen

Durable Opaque Lotus Coating with Vacuum Deposition Layer
Sharon Straka, Mark Hasegawa, Kenneth O'Connor, Boxi Chen

Patterned Vacuum Deposition Layer on Lotus Coating
Sharon Straka, Mark Hasegawa, Kenneth O'Connor, Boxi Chen

Plasma Treated Alternative Transparent Lotus Coating Suitable for Optics with Vacuum Deposition Layer
Mark Hasegawa, Kenneth O'Connor, Sharon Straka, Boxi Chen

Plasma Treated Alternative Transparent Lotus Coating Suitable for Optics
Sharon Straka, Mark Hasegawa, Kenneth O'Connor, Boxi Chen

Transparent Lotus Coating Suitable for Optics with Vacuum Deposition Layer
Kenneth O'Connor, Sharon Straka, Mark Hasegawa, Boxi Chen

Transparent Lotus Coating Suitable for Optics
Sharon Straka, Mark Hasegawa, Kenneth O'Connor, Boxi Chen

Vapor Deposition of Self-assembling Monolayer in Production of Transparent Lotus Coating
Sharon Straka, Mark Hasegawa, Kenneth O'Connor, Boxi Chen

SPE Threat Assessment Tool
Jon Linker, Ronald Caplan, Cooper Downs, Janvier Wijaya, Nathan Schwadrom, Matthew Gorby

Patent Applications Filed

Wafer-scale membrane release process
Ari Brown, Joseph Oxborrow, Vilem Mikula, Kevin Denis, Timothy Miller

Distributed Hash Archive Server (DISHAS)
Navid Golpayegani, Curt Tilmes, Damon Earp, Jihad Ashkar

SmallSat Common Electronics Board (SCEB) Complement Board Design: Memory Card
James Fraction, Andrzej Jackowski

High Efficiency S-Band Amplifier
Steven Bundick, Wei-Chung Huang

Fast and widely tunable monolithic optical parametric oscillator for laser spectrometer
Kenji Numata, Stewart Wu, Haris Riris, Xiaoli Sun

Ozone detection using cavity enhanced absorption spectroscopy.
Steven Bailey, Thomas Hanisco

Coherent optical transistor
Michael Krainak

Next Generation High Data Rate Ka-band Modulator and Transmitter
Wei-chung Huang, Jeffrey Jaso

Planetary Crater Detection and Registration Using Marked Point Processes, Multiple Birth and Death Algorithms, and Region-Based Analysis
David Solarna, Gabriele Moser, Jacqueline Le Moigne-Stewart, Sebastiano Serpico

System and Method for Providing a NASA Goddard Earth Observing System - Version 5 Forward Processing (GEOS-5 FP) Data Analytics Service
John Schnase, Glenn Tamkin, Jian Li, Savannah Strong

System and Method for Providing a Reanalysis Ensemble Service
John Schnase, Daniel Duffy, Glenn Tamkin, Jian Li, Savannah Strong

System and Method for Providing Multi-Source Data Provisioning for a Reanalysis Ensemble Service
John Schnase, Glenn Tamkin, Roger Gill, Jian Li, Savannah Strong

System and Method for Providing Climate Data Intercomparison and Analytics as a Service Application Programming Interface
John Schnase, Glenn Tamkin, Jian Li, Savannah Strong

System and Method for Providing Climate Data Intercomparison and Analytics as a Service
John Schnase, Daniel Duffy, Glenn Tamkin

Methods for Increasing IR Emittance of Thin Film Second Surface Mirrored Thermal Control Coatings
Mark Hasegawa, Grace Miller, Alfred Wong, Kenneth O'Connor

Ion Control System
Behnam Azimi, Steven West, Dakotah Rusley

Design of Improved Flexible Optical Solar Reflector with Enhanced IR Emittance using Thin Oxide Films
Mark Hasegawa, Kenneth O'Connor

Patent Applications Filed/Provisional Patents/Patents Issued

Methods involving oxygen plasma exposure to improve adhesion of silicate thermal coatings
Mark Hasegawa, Kenneth O'Connor

SpaceCube v2.0 Processor with DDR2 Memory Upgrade
David Petrick, Alessandro Geist, Thomas Flatley

Restore First Stage Bootloader for Spacecube 2.0
Jennifer Corekin

Process for fabricating ultra-thin structured polymer membranes for optical applications from the x-ray to the submillimeter.
Kevin Denis, Edward Wollack, Adrian Daw, Douglas Rabin

Improved Dissipative MLI Outer Cover Blanket Materials for Tailored Optical Properties and Specularity
Mark Hasegawa, Grant Smith, Kenneth O'Connor, Alfred Wong, George Harris

OH detection using gas correlation radiometry.
Steven Bailey, Thomas Hanisco

Goddard's Reconfigurable Laser Ranger (GRLR)
Nathaniel Gill, Kenneth McCaughey

Reconfigurable Operational spacecraft for Science and Exploration Connector Interface Mechanism
Richard Michael, Beth Keer, Thomas Hanyok

Ultra-compact Star Scanner
Sean Semper, Andrew Salamon

Modification of Radiator Coating Pigment with Variable Emissive Encapsulation of VO2 Utilizing Atomic Layer Deposition
Vivek Dwivedi

(ITAR) Robot Electronics Unit Motor Controller Board -- SSPD Restore-L Project
Ike Orlowski, Pietro Sparacino, Seshagiri Nadenlda, Roger Chiei, David Petrick

A Miniaturized Astrometric Alignment Sensor for Distributed & Non-Distributed GN&C Systems
Sabrina Thompson, Sean Semper, Philip Calhoun, Neerav Shah

SpaceCube v2.0 Flight Card Mechanical System
Milton Davis, David Petrick

Provisional Patents

Lotus Wet Chemistry Nano-Textured Dust Mitigation Coating with Hydrophobic Properties, Second Generation (Lotus WC2 Coating)
Sharon Straka, Mark Hasegawa, Kenneth O'Connor, Victoria Pederzani Stotzer, Wanda Peters, Danielle Margiotta, Kristin Mckittrick

Patents Issued

FlashPose: Range and intensity image-based terrain- and vehicle-relative pose estimation algorithm
John Van Eepoel, Joseph Galante, Nathaniel Gill

NASA Operational Simulator Engine
Steven Seeger, Daniel Nawrocki, Scott Zemerick, Justin McCarty, Jeffery Joltes, Brandon Bailey, Gary Carvell, Justin Morris, Mark Pitts

System to perform radio frequency interferometry using optical fiber sensing signal processing techniques
Melanie Ott, William Thomes, Eleanya Onuma

A Robust Waveguide Millimeter Wave Noise Source
Jeffrey Piepmeier, Edward Wollack, Negar Ehsan

Reaction Spheres for Multi-axis Attitude Control and Energy Storage on Small Satellites
Matthew Colvin, Alvin Yew, Emory Stagmer, Jeremiah Williams

Advanced Remotely Operated Vehicle for Education and Research
Ted Miles, Geoffrey Bland

A novel microfabrication process for building thin, large area, suspended x-ray absorbers for low energy x-ray spectroscopy
Thomas Stevenson, Manuel Balvin, Kevin Denis, John Sadleir, Peter Nagler

Climate Data Services Application Programing Interface Reference Model, Library, and Command Interpreter
Glenn Tamkin, John Schnase, Daniel Duffy

Video Distribution & Storage Unit SSCO Restore Program
Madhu Kadari, Serge Svovsky, Seshagiri Nadendla

= denotes laser or optics focused

NASA Goddard *Tech Transfer News*

NASA Goddard *Tech Transfer News* is the quarterly magazine of the Technology Transfer Program, which is part of the Strategic Partnerships Office at NASA's Goddard Space Flight Center.

Also available online at: *https://partnerships.gsfc.nasa.gov*

Send suggestions to Amy Klarup, *amy.k.klarup@nasa.gov*

NP-2018-10-290-GSFC