APRIL 2024

THE INNOVATION CATALYST NEWSLETTER

Can We Find Life On Europa?

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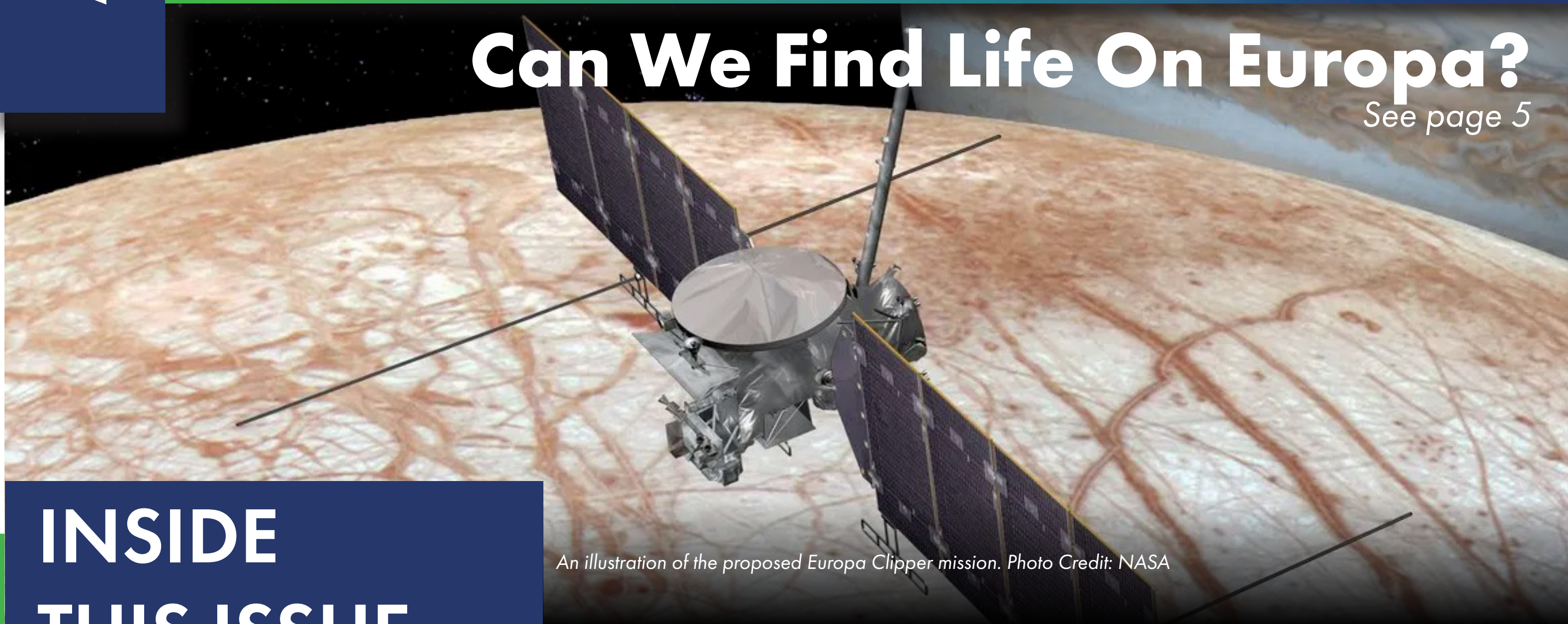

An illustration of the proposed Europa Clipper mission. Photo Credit: NASA

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EVENTS

Byte Sized Talks
Wednesday April 24, 2024
12:00 PM - 1:00 PM
Join us in the building 33 cafeteria for a refreshing twist on the traditional lunch-and-learn format!

This month's Tech Transfer Tip with Senior Technical Writer

Doug Scott

At NASA Goddard, the new technologies that you have developed have not only advanced human knowledge of our universe but through commercialization have directly led to improvements in everyone's life on Earth. That is not a side effect of the work that you do but a key part of NASA's mission. Each month in The Innovation Catalyst, we've identified technologies that the Strategic Partnership Office (SPO) believes one day soon could be ready for licensure and commercialization. File your NTR (New Technology Report) and the next success story can be yours.

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Technology Transfer Innovations of the Month

Mapping New Worlds

This is the third of a continuing monthly series highlighting Goddard technologies, which the Strategic Partnership Office (SPO) believes may have commercial potential. These are also innovations, whose patent application was recently sent to the United States Patent and Trademark Office for consideration.

Senior Data Scientist, Douglas Trent (left) and acting laboratory chief, Conor Nixon. Photo Credit: NASA

When Christopher Columbus discovered the "new world" in 1492, he helped prove the Earth was spherical and not flat. That paved the way for Portuguese explorer Ferdinand Magellan to be the first to circumnavigate the globe in 1522. Like Earth, planets, moons, and stars in the galaxy are spherical, and when contemplating their topography, it creates certain challenges.

When scientists at NASA Goddard's Planetary Systems Laboratory (PSL) are tasked with studying objects in the solar system, their analysis is often based on imagery from orbiting spacecraft or space-based telescopes. Attempting to measure an accurate area of various objects such as craters or icebergs on the curved surface of a planet or a moon from flat two-dimensional imagery can become problematic. When scientists use a camera on a spacecraft or telescope to take a 2-D photograph from a distant vantage point in space, it is not always easy to later translate this data into the spherical shape of the planet or moon. Large-scale features that appear close to the horizon of a spherical image will appear "distorted" compared to a view from directly overhead.

NASA scientists have created a novel method that will generate precise and automated estimations of the surface area for objects on a sphere by superimposing an imagined grid of equal-sized cells onto the two-dimensional image captured of a planet or moon. Conor Nixon, acting laboratory chief with PSL and Douglas Trent, senior data scientist in the Office of the Chief Information Officer at Langley Research Center, have developed the Grid-Oriented Normalization for Analysis of Spherical Areas (GONASA).

This technique is neither a piece of hardware or a software, but an algorithm or mathematical formula. GONASA is designed to be used in tandem with artificial intelligence and machine learning recognition to map objects onto a planetary grid. Using GONASA, an engineer or scientist can easily superimpose a grid onto any satellite imagery of a planet or

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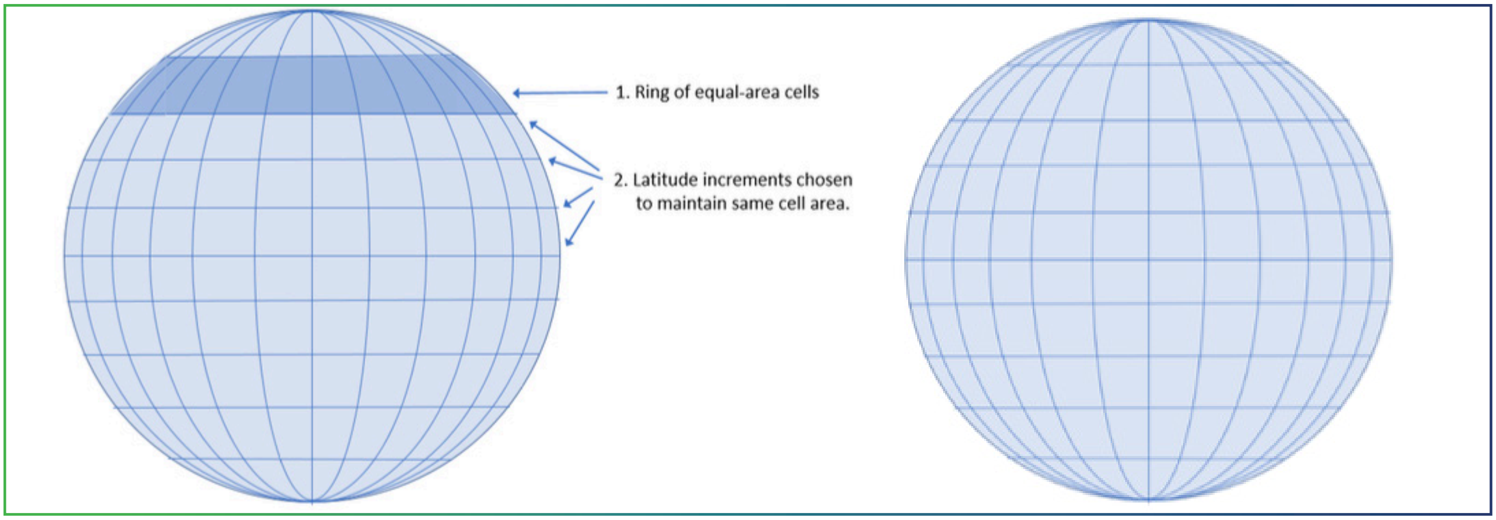


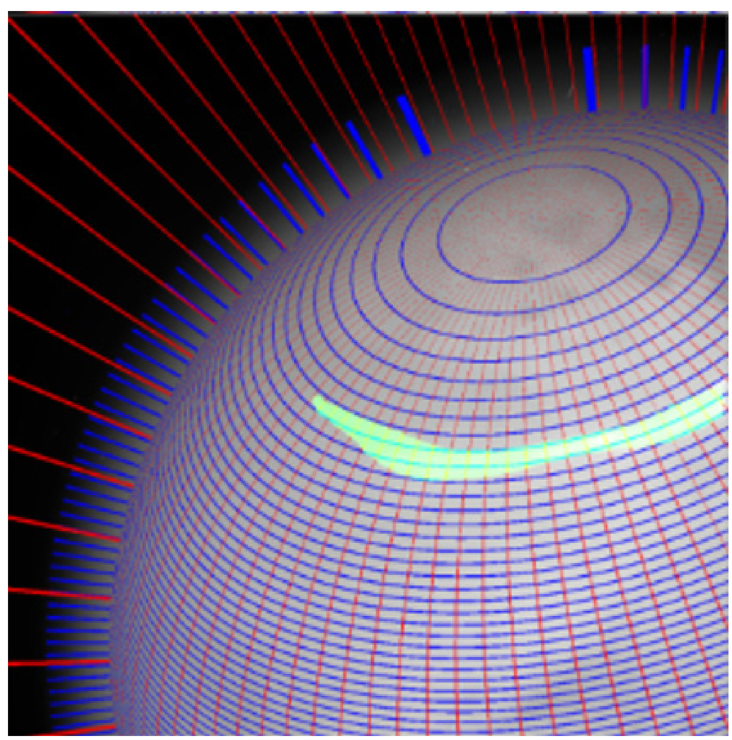
Latitude divisions chosen by GONASA to create a grid of equal-area cells. Image Credit: NASA

a moon in space, to discover an object's exact size and shape. GONASA is accompanied by an Excel spreadsheet for examples of implementation and ease of adoption.

"Measuring features on a spherical surface is tricky business," said Trent, who was lead inventor of GONASA. "GONASA simplifies this by generating fixed longitude and variable latitude lines that create a rectangular grid of equal area cells, or alternatively, rings of fixed latitude cells whose area varies by the cosine of their latitude. Once you've overlaid the grid on a feature and measured the percentage of overlap for each cell, you have an analysis-ready table of data to feed GONASA's various measurement algorithms."

When superimposed over the surface imagery of a planet, Trent said the advantage of using a grid of equal-area cells is that it produces exact measurements of features such as clouds, icebergs, or craters in an automated way. GONASA includes several other important algorithms for creating a grid on a spherical object as opposed to a flat surface. It is also compatible with computational matrices and data frames, which are used to represent rectangular tables of numbers and symbols that are arranged in rows or columns on grids.

"I would describe GONASA as a mapping technique and the reason why it was invented was to allow a way to accurately measure the size of features on planetary surfaces," added Nixon. "It is a different kind of technology from what we typically think of where we have a camera or circuit board or other hardware item. Our invention is a broad-based, wide-ranging technique that could be used for many different purposes. For example, you could implement it on a Landsat mission to acquire satellite imagery of Earth or on a Mars orbiting mission. The goal is to simplify cartographic measurement from satellite images, so that you can quickly map the size of a feature like an ice floe on the Earth or a crater on Mars for example."



GONASA grids map the clouds on Titan. Image Credit: GSFC

GONASA has already been successfully used to study images taken from NASA's Cassini mission to probe Saturn and Titan, the planet's largest moon. Cassini's 13-year mission ended on September 15, 2017. However, scientists today are still studying imagery taken from the satellite.

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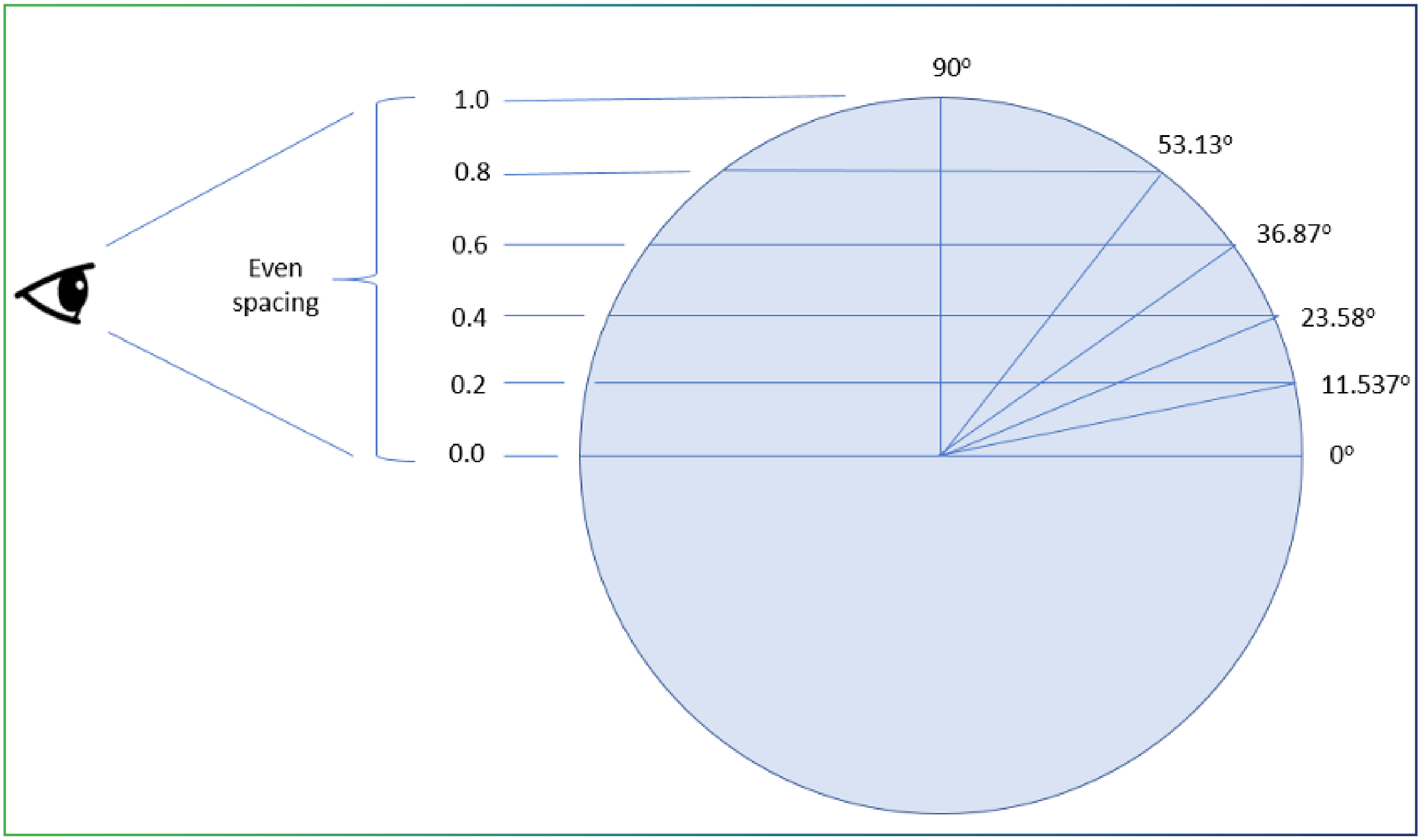

How GONASA creates equal-area rings to appear evenly spaced from a distance. Image Credit: NASA

"We originally designed this technique because we were mapping the clouds on Titan and then realized we could turn this into a widely used technique for other purposes. That's why we filed the NTR (New Technology Report)," explained Nixon. "It seems to have received a good reception from the science community and we were excited to hear that Goddard's Strategic Partnership Office (SPO) wanted to take it forward for a patent application and potential commercialization."

Both Trent and Nixon believe that GONASA has commercial potential within both private industry and government. SPO is working with the inventors to license the invention for other commercial applications after it receives a patent.

"I believe GONASA will have commercial application for remote sensing of planetary bodies in general, including our own planet," Trent said. "Especially for features or areas that may change their shape over time, we need to accelerate and simplify the measurement process for 'big data' tasks. Here on Earth, you could imagine measuring crop coverage, fire damage, dust storms, coral reefs, polar ice, and anything else that might be driven by climate change."

Using mathematics as opposed to a traditional hardware or software implementation may seem like an abstract way to solve a complex astrophysics problem. But, today, mathematical algorithms are used in many areas including in GPS (Global Positioning System) devices and solutions and for encryption in cybersecurity devices and systems, like our government PIV (Personal Identity Verification) cards.

"Sometimes creating a new circuit board is easier for people to understand versus a mathematical technique," said Nixon. "Something starts as a mathematical curiosity and then, over time, the more applications are found. For example, with Einstein's General Theory of Relativity it seemed like an abstract concept for many years without practical relevance. It is neat to know how the universe works. However now we are using it for a practical purpose as well in GPS. Our positional accuracy would be off by meters if we did not include the General Theory of Relativity on our measurements from GPS satellites. Number Theory, which can be used to factor large numbers, is another example. It is now being used in the RSA [Rivest-Shamir-Adleman] algorithm for secure data transmission. We believe GONASA has a similar potential."

Finding Life on Watery Worlds

This is the fourth of a continuing monthly series highlighting Goddard technologies, which the Strategic Partnership Office (SPO) believes have commercial potential. These are also innovations, whose patent application was recently sent to the United States Patent and Trademark Office for consideration.

When searching for an environment suitable for some form of life beyond Earth, Europa, one of the 90 moons around Jupiter, may be one of the most promising places in our solar system to find it. What makes Europa so tantalizing is that NASA scientists are almost certain that—hidden beneath the icy surface—is a saltwater ocean with about twice as much water as Earth's global oceans. Liquid water is critical for life as we know it.


Dr. Shahid Aslam. Phot Credit: GSFC/ Dr. Shahid Aslam

While the icy shell is believed to be hard and cold, the interior of Europa is thought to be much warmer, heated by its iron-based core. Images from the Hubble Space Telescope also appear to show huge plumes of water vapor erupting from Europa's south pole, although they are not clear enough to be definitive. If a liquid ocean is indeed beneath the surface, it may very well be the first place outside of Earth to find life – be it mostly likely microscopic. But many mysteries remain about Europa, from the thickness of the ice shell to what lies beneath it. The question remains: if microscopic life exists on Europa, how can we find it?

Dr. Shahid Aslam, a planetary scientist in Goddard's Planetary Systems Lab (Code 693), along with a group of scientists and students from the Catholic University of America, developed the Machine Learning Fourier Ptychography Microscope (MLFPM). The team took a Fourier Ptychography Microscope (FPM), a high-resolution microscopic technology that is used mainly in medicine for developing biomedical imaging. They combined it with a camera, an LED (light-emitting diode or semi-conductor) and a NVIDIA® Jetson Nano™ computer board – the kind of machine learning device used on many video games. What they came up with is an MLFPM instrument that can use high-resolution optical microscope imagery on a wide Field-of-View (FoV) to detect biosignature motility or cellular life in liquid samples from water on planets or moons like Europa.

"The problem is, you are trying to detect particles or cells that are around 0.2 to 5 micrometers [equal in size to one millionth of a meter]," explained Aslam, who worked with Professor George Nehmetallah and students Thuc Phan and Thanh Nguyen at Catholic University to develop the MLFPM. "With a normal microscope, it takes a very long time to scan over a specimen when the FoV is a very small area the size of a micrometer. With our technology, which uses an FPM, instead of getting one straight intensity image with a limited field of view, we are recording a series of diffracted images from different angles in a high-speed fashion. Then using analytical inverse techniques or machine learning techniques, we can reconstruct a hi-res wide FoV quantitative phase image. By doing that, we not only creating a wider FoV than a conventional microscope, but we are getting higher spatial resolution

Europa Fast Facts

- First Observed: On a homemade telescope by Italian astronomer Galileo Galilei in 1610
- Average surface temperature: -160 degrees Celsius (-260 degrees Fahrenheit)
- Diameter: 1,940 miles (3,100 kilometers), slightly smaller than Earth's moon
- Solar day: 3.5 Earth days
- Solar year: About 12 Earth years
- Atmosphere: Mostly oxygen

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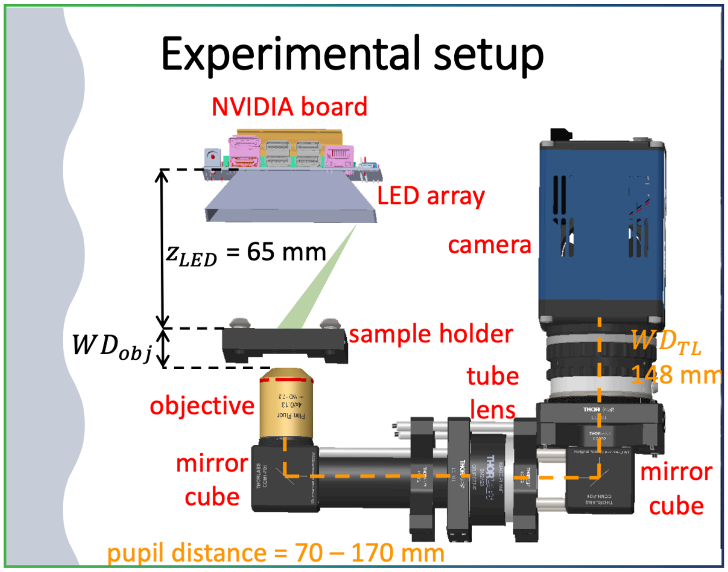

Rendering of the MLFPM setup. Image Credit: NASA

images."

The device that scientists presently propose to detect the molecules of life in oceans on other planets or moons is a mass spectrometer. This is an analytical tool used for measuring the mass-to-charge ratio of molecules. These measurements are used to calculate the exact weight and to determine structure and chemical properties of molecules found.

"Typically, when you look at the structure of cells in a specimen using a microscope, what you see is cell motility (i.e., cells jiggling around)," said Aslam. "A mass spectrometer can detect molecules but won't show the movement of these cellular materials, like you would see in a microscope. Although, a mass spectrometer is highly desired, the MLFPM would be a great complimentary instrument in the quest to seek out biomarkers of life."

In October this year, NASA will be sending its Europa Clipper spacecraft to Jupiter to investigate whether Europa can support life. It is scheduled to enter orbit and begin its search for life in 2030. The Europa Clipper is designed as a flyby mission and will not land on either the moon or planet. If in the future a NASA Europa Lander is proposed as a follow-on mission, then conceivably MLFPM could be part of its payload.

Already, the inventors have shown a proof-of-concept and developed a fully working model of the MLFPM at Catholic University. MLFPM is at Technology Readiness Level (TRL) 3 and the inventors are hoping to acquire funding to further mature the technology, strategically ensuring that they can propose payload opportunities on future Ocean World Lander missions.

Aslam with his colleagues at Catholic University are writing a proposal to NASA's Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) Program. PICASSO supports the development of spacecraft-based instrument systems that show promise for use in future planetary missions. The goal of the proposal is to mature the MLFPM to TRL 4 or greater.

Aslam believes that MLFPM has commercial potential beyond space and Ocean World missions. Goddard's Strategic Partnership Office is working with Aslam to license the technique for other possible commercial applications after it receives a patent. Other potential applications are in the fields of medicine, including digital pathology, hematology, and automated diagnosis.

"One potential commercial application for MLFPM here on Earth is, for instance, for use in medicine when a doctor takes a biopsy and are looking for cancerous cells," said Aslam. "The problem with a conventional microscope is you are narrowing yourself down to a very small FoV. It usually takes many microscope images to scan these very small tissues and cells. With MLFPM, doctors can quickly obtain a comprehensive view of tissues cells. There lies the [commerical] opportunity for us."

Europa in Popular Culture

- Europa was best known in the Arthur C. Clarke novel, 2010: Odyssey Two, which was also adapted into a film in 1984.
- In The Expanse television series (2015–2022), people live and grow food on Europa.
- At least two Star Trek federation starships were named for Europa, and in Star Trek: Picard, a mission to Europa helped save Earth.
- Europa was the setting for the 2013 film, Europa Report, and was featured in an episode of the animated television show Futurama.
- Europa also been the setting or subject of several video games, including Call of Duty: Infinite Warfare and Galaga: Destination Earth.

SBIR · STTR
America's Seed Fund

NASA's SBIR/STTR Programs Are Here to Help

Does your mission or program have a science or technology gap that needs to be filled? Each year, NASA's Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program challenges small businesses nationwide to either develop or improve upon technologies that both fulfill NASA's mission and science needs and have substantial potential for successful commercialization.

NASA's SBIR/STTR programs can yield a substantial impact on Goddard's missions. For example, on June 5, 2023, NASA's Space Technology Mission Directorate (STMD) awarded a total of $45 million in SBIR/STTR grants to 300 small business teams. Forty-two of those small businesses received SBIR/STTR grants totaling $6.3 million that will directly support Goddard missions, flight projects, and research.

"NASA has a key role to play in growing the aerospace ecosystem in our country," said Jenn Gustetic, director of Early-Stage Innovation and Partnerships for NASA's STMD. "Through these early-stage small business awards, we are inviting more innovators into this growing arena and helping them mature their technologies for not only NASA's use, but for commercial impact."

Mission

So, what is SBIR/STTR? These are both highly competitive awards programs that encourage small businesses to engage in federally funded research and development efforts that have the potential for commercialization. The mission of the SBIR/STTR programs is to support scientific excellence and technological innovation through the investment of federal research funds. The program's goals are to:

- Stimulate technological innovation
- Meet Federal research and development needs
- Foster and encourage participation in innovation and entrepreneurship by women and socially or economically disadvantaged persons
- Increase private-sector commercialization of innovations derived from Federal research and development funding
- Foster technology transfer through cooperative research and development between small businesses and research institutions

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The Three Phases of SBIR/STTR

The research, development, and demonstration of these innovative technologies take place through several funding phases. The SBIR/STTR programs are structured in three phases:

Phase I. The objective of Phase I is to establish the technical merit, feasibility, and commercial potential of the proposed research and development efforts. It is also to determine the quality of performance of the small business awardee organization prior to providing further federal support in Phase II. SBIR/STTR Phase I awards are generally $50,000 to $150,000 for 6 months (SBIR) or one year (STTR).

Phase II. The objective of Phase II is to continue the research and development efforts initiated in Phase I. Funding is based on the results achieved in Phase I and the scientific and technical merit and commercial potential of the project proposed in Phase II. Typically, only Phase I awardees are eligible for a Phase II award. SBIR/STTR Phase II awards are generally $850,000 for two years.

Phase III. The objective of Phase III, when appropriate, is for the small business to pursue commercialization objectives resulting from the Phase I/II research and development activities. The SBIR/STTR programs do not fund Phase III. At some federal agencies including NASA, Phase III may involve follow-up, non-SBIR/STTR funded research and development or production contracts for products, processes or services intended for use by the U.S. Government.

Role of the SBA, Funding Amounts and Eligibility

The U.S. Small Business Administration (SBA) serves as the coordinating agency for the SBIR program. The SBA directs the implementation of SBIR, reviews its progress, and reports annually to Congress on its operation. As of October 2023, NASA may issue a Phase I award up to $150,000 and a Phase II award up to $850,000 without seeking SBA approval. Any award above those levels will require a waiver from the SBA.

Only U.S.-based small businesses are eligible to participate in the SBIR/STTR programs. They also must meet the following criteria:

- Organized for profit
- More than 50 percent owned and controlled by one or more individuals who are citizens or permanent resident aliens of the United States
- No more than 500 employees, including affiliates

For STTR, the partnering non-profit research institution must also meet certain eligibility criteria:

- Located in the United States
- Meet one of three definitions:
  - Be a non-profit college or university.
  - Domestic non-profit research organization
  - Federally funded research and development center (FFRDC).

For more information about SBIR/STTR, please contact **Quenton Bonds** at quenton.bonds@nasa.gov or 301-286-7083.

Image Credit: SBIR/STTR/NASA

How You Can Get Involved with SBIR/STTR

For any Phase I or Phase II solicitation, hundreds of small businesses submit proposals on various topics justifying why they should receive funding and why their technology will help meet NASA's needs. There are numerous ways that Goddard innovators can work with and benefit from the program. Needed are technical reviewers, subtopic managers, technical monitors, and contracting officer's representatives (CORs).

A minimum of two subject matter experts or technical reviewers are assigned to each proposal, wherein they perform an independent evaluation based on several criteria. Technical reviewers are not only a foundational piece of the entire SBIR/STTR process, but in evaluating these proposals, they stay abreast of relevant new and developing technologies. Also, by reviewing proposals and identifying their strengths and weaknesses, reviewers become stronger proposal writers as they pursue funding for their own work.

Subtopic managers play a critical role in helping Goddard to remain on the cutting edge of science and technology. They also nominate subtopics and define the scopes that address agency needs. Subtopic managers also participate in mission directorate proposal prioritization and oversee their respective subtopics to ensure all proposals are reviewed, ranked, and evaluated. Lead and participating subtopic managers have a direct influence on Goddard and NASA's research and development future.

Technical monitors and CORs work directly with firms that have been awarded SBIR/STTR contracts. Doing so enables Goddard to manage technology development efforts and mentor small businesses to develop technologies that can benefit NASA missions and research. Technical monitors help ensure that promising technologies are ready for infusion into NASA science and engineering missions. Time spent on technical evaluations can be used as continuing learning credits for the COR certification.

If you are interested in being a technical reviewer, subtopic manager, or technical monitor, please contact Quenton Bonds at quenton.bonds@nasa.gov or 301-286-7083.