National Aeronautics and Space Administration

Cutting edge

Goddard's Emerging Technologies

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EarthShine:
What Our World Can Teach About Finding Life on Exoplanets

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Our World as an Exoplanet

Goddard Scientists Seek Unprecedented Earth Dataset to Help Confirm Life Elsewhere

Goddard astrophysicist Patricia "Padi" Boyd wants to study Earth not so much from the perspective of an Earthling, but rather from the standpoint of an alien scientist dozens of light-years away, searching for life on our tiny blue orb.

Boyd's goal, using a lunar-surface experiment suite called EarthShine, is to look at Earth as an exoplanet proxy, a representative of a habitable and inhabited planet we might find orbiting another star.

"Will we recognize a habitable exoplanet if we see it?" Boyd said. "How can we disentangle unambiguous biosignatures from non-biological changes? While Earth is the best-studied habitable planet, efforts to collect a true Rosetta Stone dataset from the entire Earth as an exoplanet proxy, and compare those data to sophisticated exo-Earth models, have so far been sparse."

By studying Earth from the Moon, she and her team believe NASA could gather data critical to confirming whether life might exist on planets orbiting other stars. Studying exoplanets and searching for biosignatures is a primary mission goal for three of the four Astro2020 Decadal Survey large strategic mission concepts presented to the National Research Council. They will recommend to NASA the next priority large missions the agency should build. These mission concepts would specifically characterize Earth-sized planets to assess their habitability and search for spectral signatures of methane and water vapor, among other compounds.

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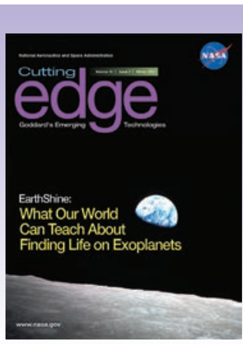

About the Cover

Taken aboard Apollo 8 by Bill Anders, this iconic picture shows Earth peeking out from beyond the lunar surface as the first crewed spacecraft circumnavigated the Moon, with astronauts Anders, Frank Borman, and Jim Lovell aboard.

(Photo Credit: NASA)

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On August 23, 1966, NASA's Lunar Orbiter 1 snapped the first photo of Earth as seen from lunar orbit. A Goddard scientist wants to use the lunar surface to study Earth as an exoplanet proxy.

"The astonishing pace of exoplanet discovery powers our quest to identify unambiguous signs of life elsewhere in the universe," Boyd said. Over the past 25 years astrophysicists have discovered more than 4,000 exoplanets beyond our solar system.

Moon Offers Perfect Location

EarthShine, which Boyd plans to propose under NASA's Payloads and Research Investigations on the Surface of the Moon (PRISM) program, would help fill these gaps, she said. The PRISM opportunity specifically seeks proposals for future payloads to be delivered to the lunar surface through the agency's Commercial Lander Payload Services initiative.

EarthShine aims to determine whether variations in solar illumination, seasons, cloud cover, oceans, and continents — as well as how they interact with one another — can be separated from changes attributable to life on Earth. The goal would be to collect the largest database of its kind, Boyd said: information scientists can feed into computer models to discern the habitability of Earth-sized planets orbiting other stars. The EarthShine database could also help inform next-generation planet-finding missions.

From the Moon's surface, Boyd wants to co-locate a wide-field optical camera capable of both imaging and low-resolution spectroscopy and a sensor that Earth scientists, led by Goddard colleague Emily Wilson, currently use to measure gases in Earth's atmosphere. With this consistent instrument suite, her team could study a variety of Sun-Earth orientations for at least part of a lunar day (up to two Earth weeks), or, ideally, over many months and possibly years.

To make the data analogous to exoplanet observations, EarthShine researchers would degrade the camera's high-resolution imagery to simulate what a next-generation planet-finding mission might observe. Meanwhile, Boyd's proposal team includes Earth scientists who will use the high-resolution imagery for their own investigations.

Scientists can compare the EarthShine data with simultaneous ground-truthing observations from orbiting heliophysics and Earth science missions. These comparisons would help scientists tease out

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Goddard's Core Flight Software Chosen for NASA's Lunar Gateway

Experts at Goddard are building on award-winning core Flight System (cFS) foundations to help create and certify essential software for Artemis Gateway — a lunar orbiting platform — and make it available to other Artemis vehicles and systems.

An illustration of the full Gateway configuration shows Orion approaching Gateway.

Conceived in 2004, the open-sourced software has been improved internally and by suggestions from independent developers around the world. In July 2020, cFS was named NASA's Software of the Year for its combination of "app store" delivery of solutions, stability, and adaptability.

"One of the really great things about core Flight System is that it's always evolving," said Jacob Hageman, team lead for the ongoing certification effort for Gateway. "And now with the Software of the Year Award, there's a lot of interest. We work on maybe two or three missions a year, but outside of NASA, people are trying it out, finding new ways to use it, and making suggestions for improvement."

Multiple NASA centers, industry partners, and international space agencies are developing Gateway. Goddard's Exploration and Space Communications Projects Division's technology and exploration offices and the Software Engineering Division are collaborating with NASA's Johnson Space Center in Houston to certify cFS as Class A: suitable for human-rated vehicles.

"We're working on making it easier to test, easier to trace requirements from mission applications and easier to adapt," Hageman said. "The Artemis program has been providing resources to help us improve the product, and that benefits everyone who uses it."

This flight software will be essential to Gateway's day-to-day operations. It will act as the brains of the spacecraft, allowing all instruments and modules to operate properly while maintaining core functions under any circumstance.

Gateway is part of the Artemis program to return humans to the Moon, Mars, and beyond, and to establish a sustained lunar presence. Gateway will allow astronauts to live and work in lunar orbit and provide a waypoint for lunar exploration.

With humans aboard, every system on Gateway must be at a high standard that ensures astronaut safety. Class A certification assures that all of Gateway's systems meet these rigorous requirements.

Heritage of Excellence

Gateway's software builds on cFS's dynamic development environment and component-based, adaptable design. Its flexible, layered architecture allows engineers to rapidly assemble a significant portion of a software system for new missions. This results in cost and time savings, as mission teams can avoid developing brand new software for each mission. NASA's Artemis program sees such benefit in the cFS, that the core software is a requirement in the International Deep Space Interoperability Standards.

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Jonathan Wilmot, a Goddard software architect, worked on cFS from the beginning, when he said the idea was born out of a need for efficiency. "We had two big missions in house at one time; we had the Solar Dynamics Observatory and we had Global Precipitation Measurement," he said. "There wasn't enough staff in house to do both independently, so we brought in all of the software people and the mission leads and established a set of requirements."

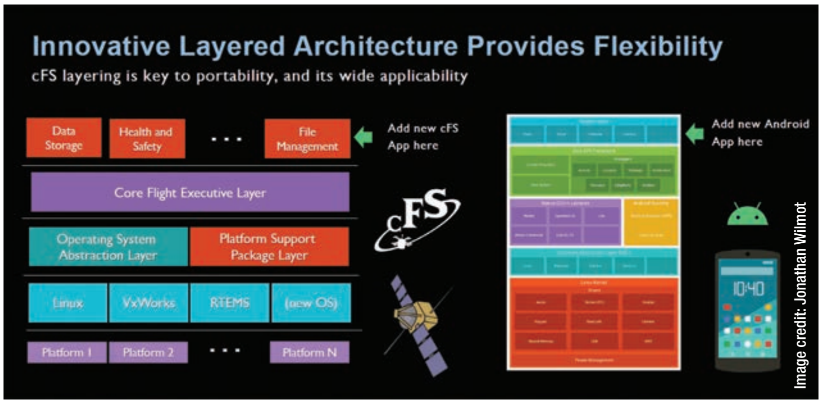

Image credit: Jonathan Wilmot

This experienced team defined the software framework and application suite common to NASA missions so that future missions just had to add their mission-unique functions, Wilmot said.

As early as 2004, a team of Goddard developers envisioned an independent, reusable software framework for routine spacecraft tasks, including telemetry, health and safety and stored commanding (*Tech Trends*, Winter 2006, P. 5). In 2008, the Lunar Reconnaissance Orbiter (LRO) launched, operating on the core Flight Executive – a plug-and-play foundation for what would become cFS. The project continued under the leadership of Barbie Medina to implementation in 2010 (*CuttingEdge*, Winter 2010, P. 5). Since then, NASA has employed cFS on missions like the Lunar Atmosphere and Dust Environment Explorer (LADEE), Global Precipitation Measurement (GPM), the Magnetospheric Multiscale (MMS), and more.

Currently, the Goddard software development team is certifying the cFS by testing it to make sure it meets the requirements set forth by the agency. After testing at Goddard, it will be delivered to Johnson for additional testing, possible modifications for Gateway-specific features, and final implementation. The development team will use the data and feedback from an independent effort at Goddard to prove the value of a software testing technique called fuzzing (see article, Page 8).

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Exoplanet, *continued from page 3*

features of life-related spectral signatures from environmental factors unrelated to life,

"Goddard is the ideal NASA center from which to pursue the design of this payload and the collection and dissemination of these data," Boyd said. "Here, we have scientists with expertise in Earth science, planetary science, heliophysics, and astrophysics."

The Allure of EarthShine Data

EarthShine's images of the changing Earth promise the same allure and fascination as images collected by Apollo astronauts, the Lunar Reconnaissance Orbiter, and other lunar orbiters, said Alan Smale, director of Goddard's High Energy Astrophysics Science Archive Research Center (HEASARC), which curates data products from dozens of astrophysics missions.

"Goddard has broad interdisciplinary science expertise to make sure the EarthShine data have immediate impact in the science community," Smale said, "and that its bounty of images and science data will be archived and available for generations to come."

Goddard also is home to the Sellers Exoplanet Environment Collaboration (SEEC), a multidisciplinary research program that applies knowledge of solar system objects to improve analytical tools to help scientists better understand the physical conditions on an alien world (*CuttingEdge*, Fall 2018, Page 13).

"The time is right to do the EarthShine mission now," Boyd said, "and Goddard is the place to do it."❖

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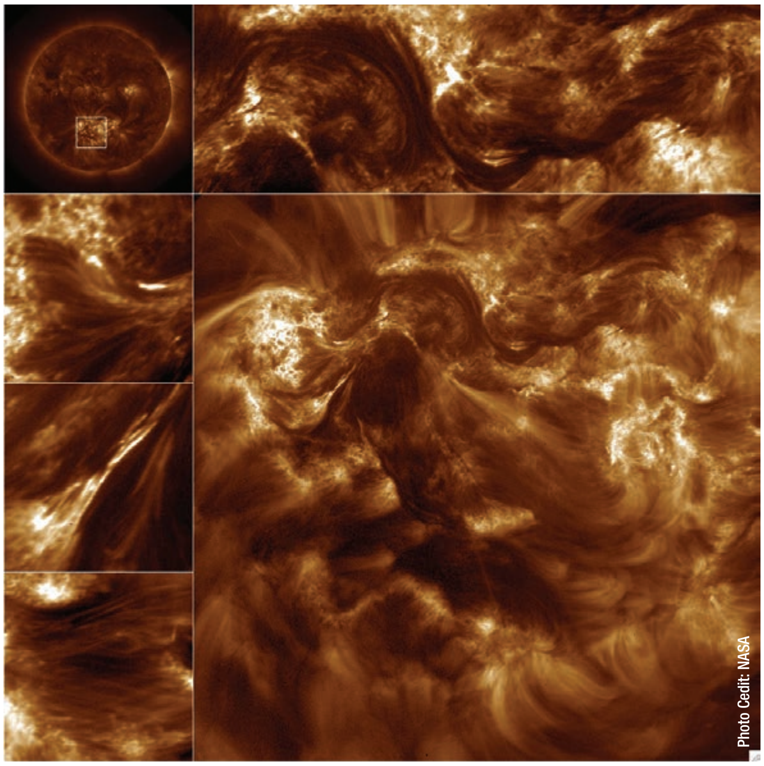
Uncooled Silicon Infrared Detectors Could Become a Hot Commodity

Silicon crystals, intentionally contaminated with other compounds, or doped, can make an uncooled, infrared detector that could advance Earth and planetary science, even if the scientists working on it are still trying to understand why it works.

Unlike the pure silicon crystals used in semiconductors, doped silicon is intentionally contaminated in the production process with gases or other compounds to encourage specific thermoelectric properties, said Electronics Engineer Ari Brown. He worked with Brook Lakew, Goddard's former associate director for planning, research and development, Solar System Exploration Division, beginning in 2013, to develop an infrared detector that will work outside the extreme cold of cryo-cooled environments.

"We have since built a prototype of our detector," Brown said, "but we don't understand fully the physical model of how it works. The performance of our current detector prototypes is not explained by theory or models."



The Hi-resolution Coronal Imager full resolution image shown here is from the solar active region outlined in the AIA image (upper left). Several partial frame images are shown including a portion of a filament channel (upper center/right), the braided ensemble (left, second from top), an example of magnetic recognition and flaring (left, third from top), and fine stranded loops (left, bottom). These Hi-C images were captured during a sounding rocket flight in 2012.

Versatility and Durability

Doped silicon can enable a high-performance uncooled thermal detector and one that is compatible with standard semiconductor fabrication processes, Brown said, adding that his infrared detectors will be cheaper and easier to produce than other uncooled detectors, and at least theoretically could last forever.

"This is a very versatile detector which can be used for many applications," Brown said, including monitoring the evaporation of water from the ground, volcanic studies, and snow-coverage measurements, as well as exploration of other planets.

Infrared telescopes like those built for the James Webb Space Telescope use advanced active and passive cooling systems to chill their infrared detectors to within a few dozen degrees of absolute zero, trying to eliminate any stray heat that might contaminate their data.

Uncooled detectors – operating at temperatures from 170 to 300 Kelvins – would enable smaller, cheaper, lighter missions, including CubeSats, to enter the infrared arena.

"Cooled detectors have a very high sensitivity," Brown said, "but by using uncooled detectors, you can save a lot in terms of size power and weight, making this ideal for nanosat applications."

Brown is working with a cadre of scientists in Earth and planetary studies as well as with the National Reconnaissance Office to develop this detector for different purposes. Swarms of CubeSats powered by small, low-power sensors could help answer questions about our planet and others. What they lack in sensitivity, they could make up for in the volume of passes and data collected by the swarm, he said.

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“This technology will get us close to the quality of data from Landsat’s cryo-cooled infrared detectors,” said Alicia Joseph, Earth scientist and principal investigator with Brown on the Internal Research and Development (IRAD) proposal for this detector. “The technology is cheap and small enough to accommodate whatever kind of constellations of satellites you could propose to fill in the data between Landsat passes.”

Landsat provides the world’s longest record of Earth science data from orbit, Joseph said. It provides data from any one location every eight days, provided the skies are free of clouds. Scientists interpolate the days and nights between passes using sophisticated modeling. Joseph looks forward to using data from these detectors to monitor the evaporation of water from the ground or vegetation.

Joseph works on the sensors with Brown and engineer Emily Barrentine – principal investigator for a related IRAD that would employ Brown’s detectors in the exploration of other planets..

Planetary Scientist Shahid Aslam said future missions to the gas giants, their icy moons, asteroids and comets would benefit from arrays of uncooled thermal detectors, featuring improved sensitivity and greater resolution of data with a faster turnaround.

He compared the technology to the thermal detectors used on the Composite Infra-Red Spectrometer (CIRS) on board the Cassini Spacecraft that orbited Saturn and its moons through 2017. “Observations of the south polar region of Enceladus showed the lack of sensitivity and spatial resolution of the CIRS far-infrared thermal detectors,” Aslam said. “However, a focal plane made up of an array of doped silicon detectors with smaller pixel sizes, higher sensitivity and a faster time constant would have enabled higher-resolution thermal mapping.”

Failing Successfully

A failed attempt to operate commercial-off-the-shelf infrared detector arrays at cryogenic temperatures sparked the idea that would become Brown’s silicon detector.

Brown and Lakew originally applied for funding to build their detectors from the Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) Program, and were denied, Brown recalled. He was encouraged to submit a NASA Goddard New Technology Report anyway, to pursue a patent on the idea of doped silicon IR detectors; then he developed a working prototype under Internal Research and Development, or IRAD funding.

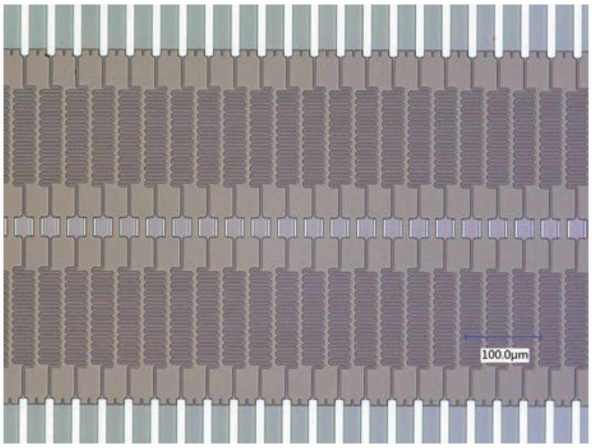

Photo credit: Ari Brown

This microscope image shows a cluster of doped silicon detectors.

Oddly enough, despite having built effective and successful detectors, Brown’s team is still working on understanding how and why they were successful.

“For the next stage, we want to figure out why it works, and how to resolve any problems with our current prototypes,” Brown said. “We’re also going to integrate broad-band carbon nanotube coatings that will allow us to see through things like smoke and dust, and other airborne materials.”

The coating will enable the detectors to sense visible, near-, mid-, and far-infrared emissions from 200 nanometers — the edge of the visible light spectrum — up to 200 microns, making them extremely versatile broadband absorbers.

However, the high temperatures used in carbon deposition tends to melt the aluminum conductors used between different elements of the detector — a hurdle his team is still working to overcome.

Brown is seeking funding from the National Reconnaissance Office and the Goddard Fellow Innovation Challenge to continue developing the technology.

Doped silicon provides a number of advantages over competing infrared-detection technologies that are difficult to purchase customized for NASA’s needs or may be less stable over time, Brown said. “Doped silicon will be stable over time, temperature, and even humidity. We believe it will work for a very long time, because silicon is such a stable material.” ❖

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Engineers Apply Fuzzing to Root Out Software Bugs


Photo credit: Rebecca Roth/NASA

Goddard software engineer Jose Martinez-Pedraza has proven that a testing technique called "fuzzing" would benefit NASA and help prevent potentially catastrophic software failures in spaceflight systems.

Space flight is hard, and despite everyone's best efforts, rockets occasionally explode dramatically on launch or fail in orbit. Goddard software engineer Jose Martinez-Pedraza believes a software testing technique called "fuzzing" could help eliminate weak links in software from the causes of catastrophic mission failures.

With funding from Goddard's Internal Research and Development (IRAD) program, Martinez-Pedraza applied this art of automatic bug finding to Goddard's core Flight System (cFS), a ubiquitous and reusable software framework and set of software applications for controlling and operating spacecraft.

Martinez-Pedraza's IRAD-funded experimentation proved NASA would benefit from the fuzzing technique used by tech giants to find problems in their own software, he said. An independent effort to adapt cFS for human spaceflight and the Gateway mission will also benefit from his team's data and analysis (related story, P. 4).

Fuzzing, A Nightmare Come True

The fuzzing technique automatically bombards computer code with random and unexpected inputs to specifically root out weaknesses that may not be uncovered with more traditional testing methods. For each input provided to the system, the fuzzing tool monitors the software being tested to determine if it runs successfully or if an unexpected event occurs.

"Current software testing consists of step-by-step functional tests," Martinez-Pedraza said. "Unfortunately they are limited by the programmer's imagination. Programmers must think of every situation where something can go wrong, come up with plausible inputs to cause these failures, and write an individual test for each."

Fuzzing gets around these shortcomings and is an ideal approach for testing cFS software, he said. It automatically inundates different software functions and interfaces with massive amounts of randomly

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Suspended Observations: Aeropods Win Industry Recognition

Aerodynamically stable and designed to hang from a kite string, Aeropods offer a low-cost, low-risk, opportunity for scientists and students to gather imagery and atmospheric data from an aerial perspective.

Geoff Bland, research engineer at Wallops, and his team won the 2020 Educational Institution and Federal Laboratory Partnership award from the Federal Laboratory Consortium for their Aeropod technology.

Aeropods can be fitted with sensors for aerial imaging, including color, multispectral and thermal imagery, and in-situ measurements such as temperature, humidity, wind speed, and wind direction, Bland said. "We look at the Earth from space and from aircraft. As we get closer and closer to the surface, we get higher-resolution data. In order to both get that resolution and capture the big picture, we need many measurements at many locations."

Aeropods offer an inexpensive, multi-measurement platform, reducing the barrier for those interested in entering into Earth science. Additionally, Aeropods require less training time than balloons or other unmanned aerial vehicles, Bland said. "The objective was to make a system where you can train somebody in a day; then they can go out and do meaningful science."

Looking back in time, Aeropods build on the ideas of people like Pierre Picavet. The Picavet camera mount developed in 1912 was a system of strings and pulleys to stabilize a platform for cameras or other devices. The Picavet, however, can not provide the necessary orientation for sensitive atmospheric measurements like wind speed. Bland and his team simplified the approach with Aeropods.

Goddard technician Ted Miles developed the original Aeropod under the Goddard Ignition Fund in 2009. The project continued with IRAD funding in partnership with the University of Maryland's Eastern Shore (UMES) Engineering and Aviation Science Department.

"We were able to show that Aeropods had suitability for introducing students to NASA's kind of observations," Bland said, "including in-situ measurements, remote sensing measurements: essentially mimicking satellites and aircraft."

The AEROKATS and ROVER Education Network is a NASA Science Mission Directorate Science Activation project allowing students at the middle school level and above to participate in data collection using Aeropods. Introducing science processes through kite flying at a young age makes science

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Software Bugs, *continued from page 8*

generated data to smoke out hidden bugs that could cause major failures in missions using cFS. These tests can last minutes, hours, or even days in one or more servers.

From his IRAD research, Martinez-Pedraza confirmed the technique works well for cFS, particularly important because so many Goddard-led missions employ these foundational software packages. Originally implemented into NASA's Lunar Reconnaissance Orbiter, cFS is now used by many NASA flight projects, saving time and money in software-development.

Pedraza also determined non-cFS software projects would benefit from the fuzzing technique.

For this research, Martinez-Pedraza said he tested several open-source fuzzing tools, including American Fuzzy Lop and libFuzzer, both used by Google's OSS-Fuzz. OSS-Fuzz, which Google used to uncover thousands of security vulnerabilities and stability bugs in its browser, is a distributed fuzzing system that allows a massive amount of simultaneous testing using high-power computers or clusters of computers, he said. Likewise, NASA could eventually test its software on the agency's cluster computers or even in the cloud, he said.

"Any bug found with this technique will be one less software engineers have to find and deal with manually, ultimately resulting in a safer and more useful product," Martinez-Pedraza said. "The truly radical part of this project is that, when successful, this technique could be applied to any software project across the whole of NASA, meaning that the entirety of NASA could benefit from this state-of-the-art testing methodology." ❖

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The Aeropod (inset), shown here being launched with a kite near Wallops Flight Facility, is a stabilized, suspended platform for Earth observations.

more accessible to a diverse and impressionable audience, Bland said.

It's easier to fly a kite than an unmanned aerial drone, which requires a higher budget and technical skill level, Bland said. "This is by no means a replacement for drones. Rather it was always intended as a beginning step. You start with kites, you go to other platforms such as balloons, drones, aircraft flown by people, sounding rockets, then satellites; it's a progression."

The Aeropod technology provides an entry point into Earth science for students, but the applications range much further. Bland and his team worked with NASA's Jet Propulsion Lab to use AeroPods to pioneer airborne in-situ gas measurements for volcanic emissions. They also flew an experimental methane sensor. "There's a broad application of the technology to capture several measurements of interest," Bland said, "specifically going after the local scale."

Aeropods provide multiple applications for a wide variety of consumers. "The Aeropod concept enables extremely low-cost in situ measurements in the Planetary Boundary Layer, an area of great interest in Earth Science," said Matthew McGill, Goddard's Earth Science technologist, "and as such, Aeropods provide a great opportunity for engaging educational institutions in NASA research. Geoff has worked tirelessly to develop and license the Aeropod technology and to engage with educational groups."

Adaptability to a wide variety of measurements, ease of fabrication, and simplicity of use are the key features of the Aeropod that enable widespread use, Bland said. "We want people to know that this investment will bring these capabilities into the hands of as many people as possible."

Kites as a lifting platform enable learners and researchers of all ages to get an aerial perspective, uniquely valuable in capturing the perspective of the world around us, he said. "This combination is a valuable tool, thanks to the vision and support of NASA's technology development and science support programs." ❖

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Staring at the Sun, You've Gotta Wear (Sun)shades

Space weather from our Sun affects everything from auroras to how we protect our power grid, satellites, and astronauts. However, the origins of space weather, including solar flares, coronal mass ejections and the solar wind, remain a mystery despite decades of study.

To study the solar atmosphere, or corona, just above the visible surface, scientists need a meters-wide sunshade to block out the massive amounts of light continually pouring from the surface itself, said Goddard heliophysicist Doug Rabin. Scientists also need an instrument that can sense extreme ultraviolet features that could be just a few miles wide, at the distance of the Sun — an angular resolution that no current Sun-observing satellites can match.

"In order to meet those needs, we are trying to make a distributed telescope," Rabin said. "The lens and the detector are on different spacecraft. Currently, 15 meters is about the maximum focal length of a single spacecraft with a rigid extensible boom. We're looking at enabling focal lengths of 50 meters, one kilometer, or more."

In its current iteration, his observatory concept features a lens, centered in a meters-wide sunshade, flying in precision formation with a detector 100 meters away. The two spacecraft could not drift out of alignment by more than a millimeter in the 100-meter focal length, or 10 to 20 microns — a fraction of the width of a human hair — side-to-side.

During the COVID-19 shutdown, Rabin worked remotely with Anne-Marie Novo-Gradac (lead), Philip Calhoun, Adrian Daw, Irving Linares, and Guan Yang on the problems of how to precisely measure the two spacecrafts' alignment (*CuttingEdge* Summer 2020, P. 2), as well as developing the sunshade mechanics.

Team member Anne-Marie Novo-Gradac conceived a novel sunshade concept that plays off tissue-paper fans often used as party decorations. The team's version substitutes a plastic material for paper and uses thin spring steel as structural ribs. The ribs and the plastic webbing between them begin their journey wrapped compactly around the lens tube itself. The team's sunshade is smaller

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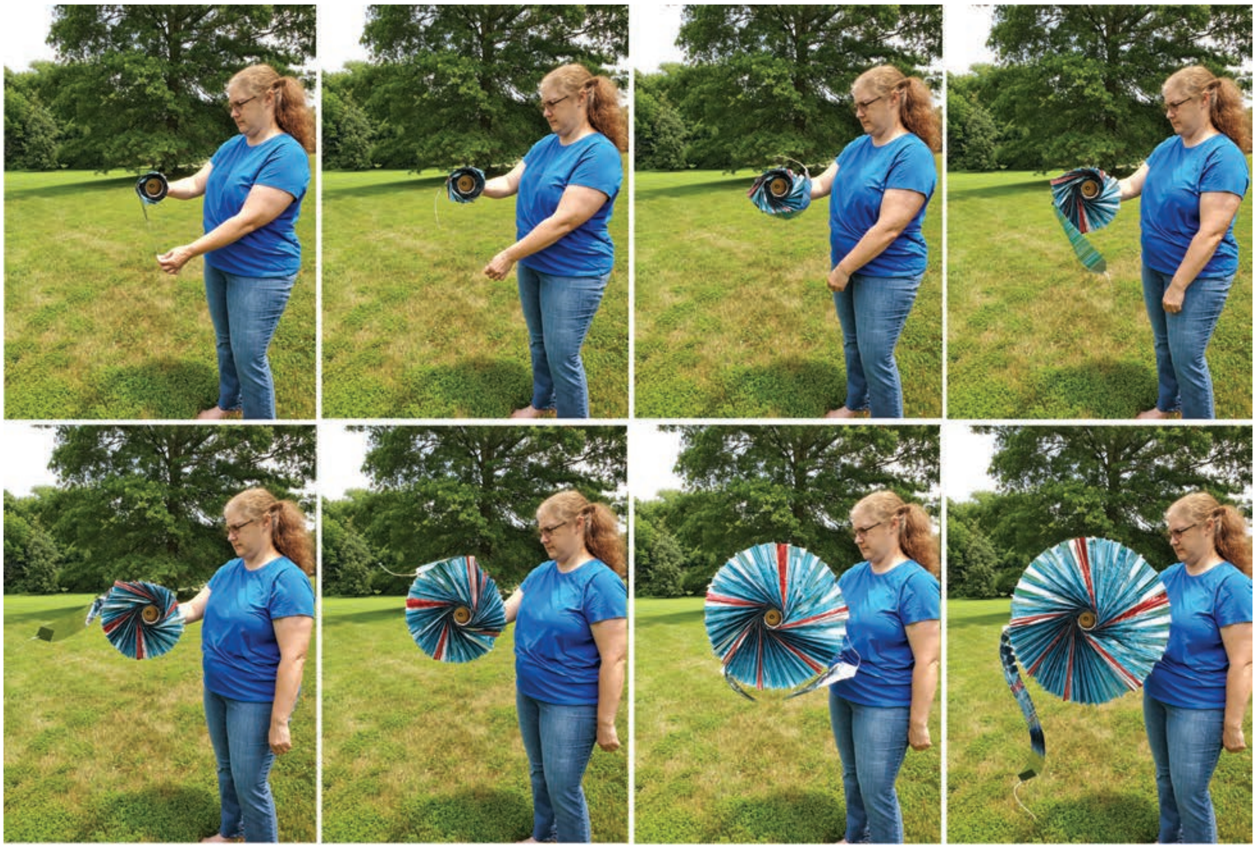

Anne-Marie Novo-Gradac tests the unfurling of a meter-wide proof of concept prototype sunshade in her back yard. Photo credit; Kevin J. Novo-Gradac and less complex than the 20- to 30- meter starshades planned by the Jet Propulsion Laboratory or Northrop Grumman for imaging faint exoplanets next to their stars light years away. While those designs use motors, tensioners or hinges to unfurl, this structure springs free on tension, unfurling a round sunshade two to three meters wide. The smaller, simpler sunshade would still be effective in imaging events next to our own star. In 2021, Novo-Gradac will lead a team to produce a half-scale functional prototype.

To image the inner corona of the Sun, a glass lens, as well as other conventional materials, blocks the extreme ultraviolet light he is seeking. A mirror won't work because it can't be made accurately enough, Rabin said. Instead, his lens will be a Fresnel-type diffractor, a solid plate with a circular pattern of slits or holes that will diffract, or bend the high-energy light to focus on the distant detector.

The questions his team expects these technologies to help solve are how the corona heats up and how solar flares and coronal mass ejections originate in this region, Rabin said. "It's an old question. We don't expect to solve it with a single observation. More and more the models and observations align to hint that these things take place on finer scales we haven't seen yet."

How fine?

Well, to begin with, there are 360 degrees in a circle and 3,600 arcseconds in a single degree. For reference, the Sun at a half of a degree measures 1,800 arcseconds across from here on Earth. The Solar Dynamics Observatory (SDO), launched in 2010, observes features as small as 1.2 arcseconds. The Hi-C sounding rocket instrument, launched in 2012, recorded features on the Sun at 250 to 300 milliarcseconds. Rabin is shooting for tens of milliarcseconds to be able to resolve solar mass ejections and solar flares near the surface of the Sun.

"Milliarcsecond resolution imaging may be the key to understanding the Sun's corona. It's the equivalent of seeing something the size of downtown Los Angeles on (or near) the surface of the Sun, 93 million miles away."

– Doug Rabin

"Milliarcsecond resolution imaging may be the key to understanding the Sun's corona," Rabin said. "It's the equivalent of seeing something the size of downtown Los Angeles on (or near) the surface of the Sun, 93 million miles away."

His distributed observatory would be a follow-on to the National Science Foundation's VISORS, or Virtual Super-resolution Optics with Reconfigurable Swarms, mission selected in 2019 under its Cross-cutting Initiative in CubeSat Innovations Program. VISORS comprises two 6U CubeSats that will fly in precise formation and acquire high-resolution 160 milliarcsecond extreme-ultraviolet images while blocking approximately 85 percent of direct light from the Sun's surface.

"However, lacking a deployable sunshade, VISORS will not achieve its full signal-to-noise potential," Rabin said. A one-meter sunshade would block 99.9 percent of the direct light.

Without the sunshade, diffraction is your nemesis, Rabin said. Other observatories like the Solar and Heliospheric Observatory, or SOHO, employ a physical occulter – a plate inside the observatory light path that blocks direct light from the Sun, enabling you to observe the fainter corona or solar wind. However, light can smear around the edges of a nearby occulter and increase the noise of the observations. "Light in the solar corona is much fainter than light from the Sun's disk, and we are looking at only a tiny piece of the corona" he said. "It doesn't take much light from the disk sneaking around your occulter to make noise. The way diffraction works, you need the occulter to be far away." ❖

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Cutting edge Goddard's Emerging Technologies

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