National Aeronautics and Space Administration

THE SPARK

TECH TRANSFER, PARTNERSHIPS, AND SBIR/STTR AT GODDARD

THE NEXT BIG THING

Where NASA Goddard is Going with SmallSat Development

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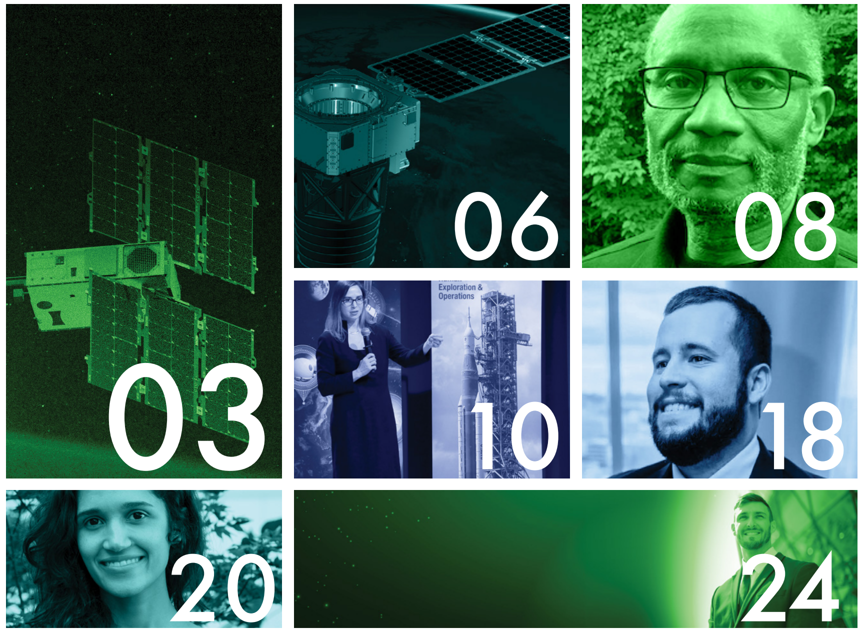
CONTENTS



ABOUT THE COVER

One of the Expedition 29 crew members captured a series of nighttime pictures from the International Space Station, including this one. It includes the airglow, the Aurora Australis, and a portion of the southeast Indian Ocean. A representation of the Dione SmallSat CubeSat by an artist is superimposed over the background image.

Photo Credit: NASA / Mike Fossum

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Photo Credit: Samantha Kilgore/GSFC

Today, we are on the cusp of a massive revolution in the space industry, where the growing commercialization of space is bringing new information with incredible uses to every sector imaginable – in communications, energy, Earth science, heliophysics, defense, cybersecurity, and more. Part of this shift is in the growing use and advancement of SmallSats.

Here at NASA Goddard, we are on the brink of seeing SmallSats execute exciting new missions, such as Pandora and Dione – which you will read about in this issue – that will change the way we see and understand our planet, enabling us to leverage space for continued research and exploration. As satellites continue to shrink in size, Goddard engineers are developing newer technological advances to make these SmallSats more effective.

For the past several years, NASA Goddard has been investigating Distributed Systems Mission (DSM) architectures and identifying some key technologies that will enable future DSM mission design, development, operations, and management. Here at Goddard, DSM is defined as a mission that involves multiple spacecraft to achieve one or more common goals. In this issue, you will read several articles about how future planned Goddard multipoint measurement DSM missions will provide significant advances in science returns. Coupled with recent technological advances, DSM is a growing trend in implementing future NASA Goddard missions.

However, we cannot do it alone and we don't have all the answers in-house. Partnerships have always been a critical component of NASA's missions. Goddard's Strategic Partnership Office (SPO) is always looking to engage and partner with private industry, academia, and non-profit laboratories to reach our audacious goals and to help you reach yours. Whether it is through the development and infusion of new SmallSat technologies or technology transfer for the public benefit, Goddard offers world-class facilities, technical expertise, and tech transfer resources.

In addition, many of the technologies developed for SmallSats have received patents and can be licensed by interested companies in the public or government sector. Through SPO, organizations like yourself can license patented technologies for your own use. So, instead of starting from scratch and "reinventing the wheel," we can help connect you with technologies that match your business niche, and free up resources for other parts of your mission. I invite you to learn more by visiting our NASA Goddard booth and talking to our folks here.

Darryl R. Mitchell, Chief

Strategic Partnerships Office
NASA's Goddard Space Flight Center

Photo Credit: Vecteezy.com

How's the Weather?

Dione: Meet NASA Goddard's New Space Weather CubeSat

Weather is among the most common topics of everyday conversation. Bad weather might inconvenience you for a few days and, less often, can spell disaster. But it's the climate that dictates what that weather might be. Climate sets our long-term living conditions and the broader conditions that have shaped human existence since we first appeared on the planet. The Earth's climate system depends entirely on the Sun for its energy. Solar radiation warms the atmosphere and is fundamental to atmospheric composition. The distribution of solar heating across the planet produces global wind patterns and contributes to the formation of clouds, storms, and rainfall.

Named after the ancient Greek goddess of oracles, Dione is a NASA Goddard-led mission dedicated to studying how Earth's upper atmosphere reacts to the flow of solar and magnetospheric energy into the ionosphere-thermosphere-mesosphere (ITM), where the Sun's energy first enters our atmosphere. The mission's objective is to help give scientists insights into these physical processes – which contribute to atmospheric drag, a process that causes low-Earth orbiting (LEO) satellites to prematurely reenter the atmosphere — and provide critical data needed to improve space weather forecasts.

"As more aspects of everyday lives depend on the predictable functioning of satellites in low-Earth orbit, the understanding and ability to forecast the impact of space weather on these assets has become a national security need," said Dione mission Principal Investigator Eftyhia Zesta and a scientist at NASA Goddard. "Measurements traditionally gathered by larger, more costly satellites must now be accomplished by thinking out of the box — or rather inside a CubeSat box. Dione will open the way for accomplishing exactly that."

The ITM is the gateway between Earth's atmosphere and space. It includes three critical overlapping regions: Earth's mesosphere and thermosphere, which consist of neutral atoms and molecules, and the ionosphere, which carries ionized particles from the atmosphere. Additionally, Earth upper atmosphere is where most LEO satellites reside, and their orbits are strongly affected by sudden density changes caused by space weather. NASA's Heliophysics System Observatory (HSO) is a fleet of solar, heliospheric, geospacer, and planetary spacecraft that are simultaneously studying the dynamics of the solar system. Presently there are over 100 missions ongoing and in orbit right now, producing some highly complex datasets.

When space weather like solar flares and solar coronal mass ejections reach Earth, it can cause trouble for anything in orbit. For example, in 2022 following the launch of Elon Musk's Starlink Satellites, 40 out of 49 satellites were unable to achieve orbit because of increased drag in the atmosphere caused by a geomagnetic storm that occurred at the time of launch.

Roughly the size of a large shoe box, the Dione 6U CubeSat is a pathfinder mission that is poised to demonstrate how key upper atmospheric measurements can be made in a small and inexpensive satellite. Dione will enable multipoint measurements from "constellations" of satellites that, when arranged into a variety of configurations, can make great improvements in space weather nowcasting and forecasting.

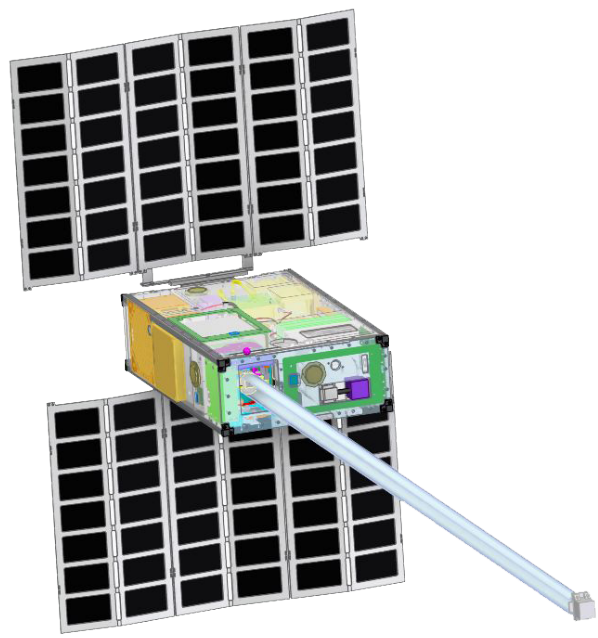
Zesta explained that Dione will address aspects of several key objectives of NASA's Geospace Dynamics Constellation (GDC). Expected to launch in 2030, GDC is a mission concept to study the coupling between the magnetosphere and the ionosphere/thermosphere (IT) system and explore how that coupled system responds to external energy input. As with GDC, Dione will address crucial scientific questions pertaining to the dynamic processes active in Earth's upper atmosphere.

The volume of space that needs to be covered for space weather studies includes almost all of Earth's near space. Therefore, a single satellite taking measurements is insufficient to capture the necessary physics for accurate space weather predictions. Multi-point measurements are critically needed. Until the emergence of CubeSats and the miniaturization of key instruments, that approach was cost prohibitive.

Zesta said the pathfinding Dione is designed to be the vanguard for an architecture known as the Distributed Systems Mission (DSM) concept. A DSM is a mission that involves multiple spacecraft to achieve one or more common goals. Some DSM development includes constellations, formation flying missions, or fractionated missions. The idea that DSM has an open architecture that allows anybody to join and contribute to the network is a crucial element and benefit of the system..

The goal, Zesta said, is for Dione to demonstrate the DSM concept by flying the CubeSat in a "constellation" formation with multiple similarly equipped spacecraft. "Our team wants to show we can do this type of measurement with a CubeSat and eventually fly Dione-type spacecraft in a constellation," she said.

Expected to launch in 2024, Dione will measure several key properties of space plasmas: the magnetic field, the charged particles that create the aurora, the drift of the plasma, and the neutral particles. Dione will operate in a circular low-earth polar orbit at an altitude of 400 to 550 kilometers, going over the auroral regions and high latitudes in every orbit. This enables the simultaneous measurement of both the magnetospheric energy inputs and the resulting responses from the atmosphere. Information about that relationship can be used to enable better forecasting and prediction of space weather, especially when applied to the DSM constellation concept.



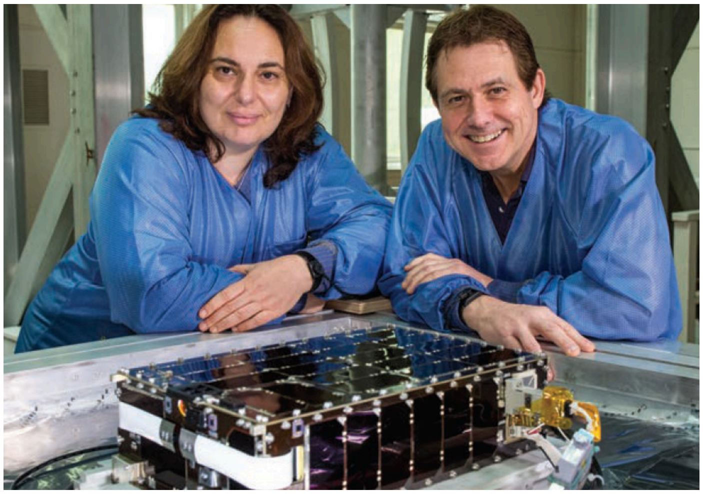
CAD rendering of Dione in its deployed state, Photo Credit: NASA/GSFC

Given the number of sensors and the constrained area inside the spacecraft bus, Dione is one of the more difficult spacecrafts of this size to design, build, and test. It has five science instruments.. Four of the instruments were developed with funding from Goddard's Internal Research and Development (IRAD) program. They include a flight-proven dual fluxgate magnetometer, the Neutral Mass Spectrometer (NMS), and the Dual Electrostatic Analyzer (DESA), which will directly measure a particular component of Earth's electrical field generated in the ionosphere. Dione also includes a technology demonstration instrument called the Spacecraft Potential Sensor (SPS), which will take measurements that will help to characterize a spacecraft's charging environment. The Air Force Research Laboratory (AFRL) and Virginia Tech are providing the fifth instrument, the Gridded Retarding Ion Distribution Sensor (GRIDS). GRIDS is designed to measure the distribution, motion, and velocity of ions.

Dione is designed to take measurements similar to the Defense Meteorological Satellite Program (DMSP), which monitors meteorological, oceanographic, and solar-terrestrial physics for the U.S. Department of Defense. Launched in 1962, DMSP is one of the most paramount space program missions dealing with meteorology and weather forecasting. "Dione is just like DMSP but in a small package," said Zesta. "It takes all of the same in-situ measurements as DMSP and does what."

Dione will gather the kinds of space weather data that has not been collected since NASA's dual-spacecraft Dynamics Explorer mission launched in 1981. Dynamics Explorer (DE1 and DE-2) was a two-satellite NASA mission, whose purpose was to investigate the interactions between plasmas in the magnetosphere and those in the ionosphere. The two satellites were launched together into polar coplanar orbits, which allowed them to simultaneously observe the upper and lower parts of the atmosphere.

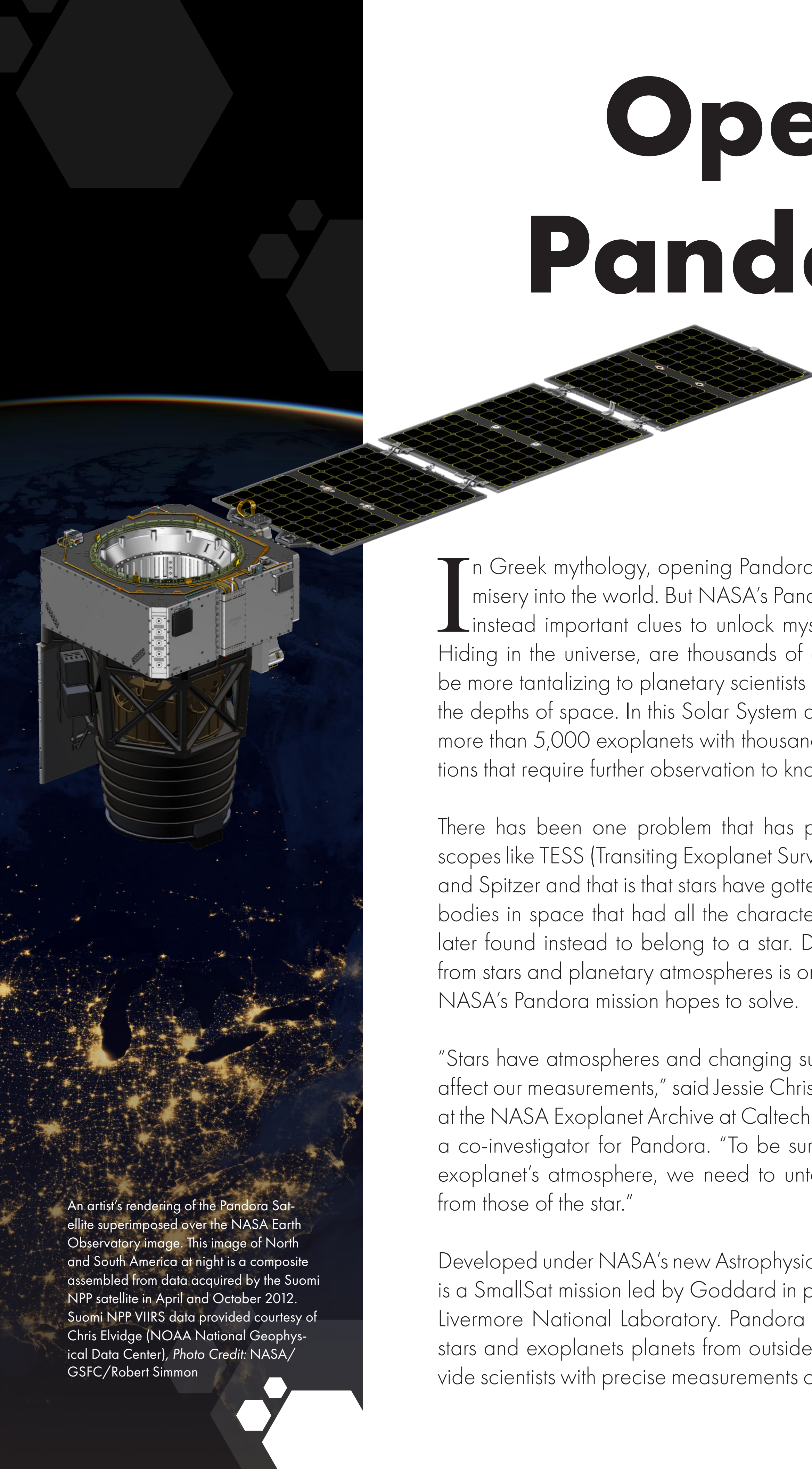
"Dione will provide the first set of energy input data and ionospheric-thermospheric data in more than three decades," notes Zesta. "With Dione, we will measure both energy inputs from the magnetosphere and upper atmosphere responses from the same platform and in small inexpensive package."



Dr. Eftyhia Zesta left and her colleague Todd Bonalsky, Photo Credit: NASA/W. Hrybyk/GSFC

Photo Credit: NASA/GSFC

Opening Pandora's Box



An artist's rendering of the Pandora Satellite superimposed over the NASA Earth Observatory image. This image of North and South America at night is a composite assembled from data acquired by the Suomi NPP satellite in April and October 2012. Suomi NPP VIIRS data provided courtesy of Chris Elvidge (NOAA National Geophysical Data Center), *Photo Credit:* NASA/GSFC/Robert Simmon

In Greek mythology, opening Pandora's box unleashed death and misery into the world. But NASA's Pandora mission seeks to unleash instead important clues to unlock mysteries of alien atmospheres. Hiding in the universe, are thousands of exoplanets and nothing can be more tantalizing to planetary scientists than uncovering what lurks in the depths of space. In this Solar System alone, NASA has discovered more than 5,000 exoplanets with thousands of more candidate detections that require further observation to know for sure.

There has been one problem that has plagued planet-hunting telescopes like TESS (Transiting Exoplanet Survey Satellite), Kepler, Hubble, and Spitzer and that is that stars have gotten in the way. Some potential bodies in space that had all the characteristics of an exoplanet were later found instead to belong to a star. Disentangling the signals sent from stars and planetary atmospheres is one of the many problems that NASA's Pandora mission hopes to solve.

"Stars have atmospheres and changing surface features like spots that affect our measurements," said Jessie Christiansen, deputy science lead at the NASA Exoplanet Archive at Caltech in Pasadena, California, and a co-investigator for Pandora. "To be sure we're really observing an exoplanet's atmosphere, we need to untangle the planet's variations from those of the star."

Developed under NASA's new Astrophysics Pioneers Program, Pandora is a SmallSat mission led by Goddard in partnership with the Lawrence Livermore National Laboratory. Pandora will study approximately 20 stars and exoplanets planets from outside of our Solar System to provide scientists with precise measurements of exoplanetary atmospheres.

Started in 2020, the Pioneers Program is intended to do compelling astrophysics science at a lower cost using smaller hardware such as SmallSats, major balloon payloads, and modest payloads attached to the International Space Station with a $20 million dollar cost cap. Pandora represents a new class of low-cost space mission that will achieve out-of-this-world science.

"Exoplanetary science is moving from an era of planet discovery to an era of atmospheric characterization," said Dr. Elisa Quintana, an astrophysicist at NASA Goddard, and the principal investigator for Pandora. "Pandora is focused on trying to understand how stellar activity affects our measurements of exoplanet atmospheres, which will lay the groundwork for future exoplanet missions aiming to find planets with Earth-like atmospheres."

Pandora's primary objective is to unscramble signals from space to understand which are from exoplanet atmospheres and which are from starspots, or bright spots on the surface of a star. The problem is starspots on some cooler stars may be cool enough to contain water vapor, like you would find on an exoplanet. A kind of virtual observatory, Pandora will use precision photometry simultaneously with near infrared spectroscopy to enable scientists to disentangle stellar activity of a star from the subtle signature of a planetary atmosphere.

The five-year Pandora mission, which is planned, will scan a variety of star types (mid-K to late-M) and planet sizes (Earth to Jupiter-size). The SmallSat will then locate exoplanets with atmospheres dominated by water or hydrogen and determine which planets are shrouded in clouds and haze. This will be the first NASA mission to accomplish that if it is successful..

The Pandora SmallSat would operate in Sun-synchronous low-Earth orbit, which always keeps the Sun directly behind the satellite. This orbit minimizes light changes on the satellite and allows Pandora to obtain data over extended periods. Pandora's instrumentation includes a half-meter all aluminum Cassegrain telescope with a 0.45m (micrometer) diameter aperture and an optical relay system that focuses the light into both an infrared (IR) and a visible detector. Pandora is an ESPA (EELV Secondary Payload Adapter) class SmallSat designed to launch secondary payloads on space missions. It is tentatively scheduled to be launched in March 2025.

Joining forces with NASA's larger missions, Pandora would operate concurrently with the James Webb Space Telescope (JWST). JWST will provide the ability to study the atmospheres of exoplanets as small as Earth with unprecedented precision, and Pandora will seek to expand the telescope's research and findings by observing the host stars of previously identified planets over longer periods.

"Pandora is the right mission at the right time because thousands of exoplanets have already been discovered, and we are aware of many that are amenable to atmospheric characterization that orbit small active stars," said Jessie Dotson, an astrophysicist at NASA's Ames Research Center and the deputy principal investigator for Pandora. "The next frontier is to understand the atmospheres of these planets, and Pandora will play a key role in uncovering how stellar activity impacts our ability to characterize atmospheres. It will be a great complement to Webb's mission."

"Pandora's long-duration observations in visible and infrared light are unique and well-suited for SmallSats," added Quintana. "We are excited that Pandora will play a crucial role in NASA's quest for finding other worlds that could potentially be habitable."

Distributed Systems Mission

"Expand the Possible"

Photo Credit: GSFC/Michael Johnson

In just a few minutes, a solar flare from the Sun can release enough energy to power the entire world for the next 20,000 years. Solar flares are thought to occur when stored magnetic energy in the Sun's atmosphere accelerates charged particles in the surrounding plasma. Gaining a better understanding of the magnetic reconnection that triggers these events could help scientists to provide better predictions of solar storms that can affect Earth-orbiting satellites and technologies.

If you want to understand where NASA Goddard is going with its future SmallSat missions, look no further its Magnetospheric Multiscale Mission (MMS). Launched on March 12, 2015, MMS is gathering information about the microphysics of magnetic reconnection, energetic particle acceleration, and turbulence – the processes that occur in many astrophysical plasmas. During its tenure in space, MMS has uncovered details about how magnetic reconnection works on small scales and opened insights into magnetic reconnection in nuclear and astrophysics, among other things.

What makes this NASA mission unique and futuristic is that MMS uses four identical SmallSats flying in a pyramid-shape "constellation" formation to measure magnetic field lines and charged particles in three dimensions. Using formation flying, the four SmallSats travel directly through areas near Earth known to be magnetic reconnection sites. The MMS SmallSats were developed at NASA Goddard.

"So, what we have been able to do with that architecture is make multipoint measurements simultaneously and that has allowed scientists to achieve science that could not be achieved with one asset," explained Michael Johnson chief technologist in the Engineering and Technology Directorate at NASA Goddard. "There has been some basic discovery-type science that has been achieved with MMS. And this is just with four birds, just imagine what we could do if we had many more satellites flying through those regions in space."

SmallSats are effective, schedule efficient, and agile. As NASA Goddard looks to the future of SmallSat missions and begins to use them for science exploration, these tiny satellites are a perfect match for what is known as the Distributed Systems Mission (DSM). Such assets may be a combination of multiple spacecrafts, unmanned air vehicles, ground observatories, balloons, sounding rockets or any other platform which is part of the system. Some DSM developments include constellations, formation flying missions, or fractionated missions. The goal now for Goddard, is to demonstrate the DSM concept by conceiving of, developing, and flying some of these multi-spacecraft missions.

"Distributed Systems Mission are the gateway to science objectives that you just cannot achieve with any other mission architecture and SmallSats are a critical component of that," said Johnson. "In engineering, we often talk about 'expanding the possible.' Because often we work in a box that is defined by science and by what is possible and that is determined by what we did yesterday. Sometimes, that box is smaller than it needs to be, and DSM allows engineers to share and expand upon that realm of possibility with the scientists."

Johnson said NASA Goddard's DSM SmallSat strategy is to enable compelling science – such as MMS's goal to study the Earth's magnetosphere – "by leveraging the most impactful technologies and capabilities that are available to achieve really compelling, winning science." Because SmallSats are cheaper and faster to develop, easier to launch, and offer more service flexibility, they are the perfect match for DSM concepts.

"If you look at how a lot of NASA Goddard's space architectures have been designed in the past, it is one member [satellite] that achieves an objective," noted Johnson. "Even if one member has several instruments on board, the goal of science is still being accomplished by one member orbiting the Earth. That is where SmallSats come in."

"The intent of DSM at Goddard is to have teams of SmallSats, where they communicate, where they collaborate, where they work as one unit, as one entity to achieve a common objective," he added, "So, the team members might all have the same skill sets or they might have different skill sets, but what is important is that they work together. That allows you to achieve science that is hard to achieve with just one network. "

Johnson said that NASA Goddard sees DSM combined with the use of SmallSats to be part of the immediate future of space science. "I would say that I consider SmallSats and DSM to be additional tools in our toolbox," he noted. "Where a good mechanic has more than one screwdriver and more than one kind of hammer or more than one kind of wrench. So, DSM and SmallSats are really a matter of matching the tool to the application and used them to achieve the science objective."

NASA Goddard has been developing and flying SmallSats since before they were even called SmallSats even before the first Conference in 1986. Today, Johnson said, engineers at NASA Goddard are working with private industry and academia to develop DSM concepts that add intelligence and autonomy to SmallSats. The goal is to enable them to communicate with each other, so that they can connect and achieve more complex, common objectives.

"The overarching goal in the very near future is to enable these smart DSM-based missions to allow new science that can only be achieved with this kind of architecture," said Johnson. "We are working on technologies that will enable DSM to operate robustly and account for any anomalies that might occur. We are building resiliency into the DSM to optimize the likelihood that the mission success will be achieved. We have ongoing programs to advance those capabilities and are going to be running some field tests within the next year or so to demonstrate them."

With many institutions beyond NASA increasingly delivering impactful capabilities and technologies critical for SmallSats, NASA Goddard is eager to explore potential DSM partnerships with private industry and academia. "There are many other entities and organizations that we would like to partner with and that we know can bring something to the table," said Johnson. "To 'expand the possible,' we know we cannot do it alone, partnering is critical."

Simulation of DSM using DIONE rendered SmallSat. Image Credits: NASA/GSFC

Q&A

with Goddard Center Director

MAKENZIE LYSTRUP

Photo Credit: NASA

On April 6, 2023, Dr. Makenzie Lystrup was sworn in by NASA Administrator Bill Nelson as the 14th NASA Goddard Center Director since the agency opened in 1959. She has made history as its first female center director.

"Makenzie is a natural leader, bringing to Goddard a scientist's drive for discovery along with a wealth of industry experience and knowledge," said Nelson. "As center director, she will lead a world-renowned team of scientists, engineers, and technologists focused on Earth and space science."

> *"I see SmallSats as being a part of the future."*

Before joining NASA Goddard, Dr. Lystrup was vice president and general manager of Civil Space at Ball Aerospace, where she was responsible for the company's portfolio of civil space systems that span all science fields, operational weather and Earth observation, and advanced technologies development objectives. In this role, she led Ball's contributions to several NASA missions, including the James Webb Space Telescope, Imaging X-ray Polarimetry Explorer (IXPE), Landsat 9, and the Nancy Grace Roman Space Telescope.

"With Makenzie as center director, Goddard will continue to make pivotal advancements in supporting commercial space, contributing to the science that is key to our Moon to Mars (Artemis) objectives, and continuing efforts to protect our planet," Nelson added, "We know, under her leadership, the Goddard workforce will continue to inspire, innovate, and explore the unknown for the benefit of all."

The Spark magazine caught up with Dr. Lystrup to learn more about her future vision of Goddard, SmallSat development, partnership opportunities, and Goddard employment and internship opportunities for young engineers. She also discussed Goddard's focus on Distributed Systems Missions and how and why this will be used in conjunction with NASA SmallSat missions.

Q: To the many attendees of this SmallSat Conference who may not know you, I would like to begin by offering you the opportunity to introduce yourself.

A: Let me begin by saying that I have a background both as a research astronomer, and as someone who worked on Capitol Hill [as an American Institute of Physics-Acoustical Society of America Congressional Fellow in the office of Representative Edward Markey]. I also have a good deal of experience working in private industry [at Ball] and managing a large portfolio of science missions across many NASA science areas. So, being at Goddard is really exciting for me personally and I look forward to being a steward of this organization.

Q: Do you also have a background working with SmallSats?

A: Absolutely. I have been involved in several SmallSat missions. In my former life [at Ball], I had a few CubeSat projects, one for earth science and one for planetary science. A SmallSat can be anything from 100 kilograms all the way down to a 1U CubeSat. Probably the largest SmallSat I worked on was the IXPE, a space observatory using three identical telescopes designed to measure the polarization of cosmic X-rays of black holes, neutron stars, and pulsars, which was kind of a dorm fridge-sized platform. I also worked on MethaneSAT, an Environmental Defense Fund space mission scheduled to launch in January 2024 that is designed to monitor and study global methane emissions to combat climate change. It is really a different kind of mission that could only be done using a SmallSat due to cost constraints. Over time, it has really been wonderful to see the progression and the use of SmallSats for many kinds of missions.

Q: Do you see SmallSats as the future of Goddard spacecraft missions?

A: I see SmallSats as being a part of the future. One thing about Goddard is that we focus on the end-to-end implementation of science missions. Now, that core capability of ours to manage and implement science projects means that we need to use the right tool for the job. For example, we need to understand how to manage the very large, low-risk weather satellites, but we also need to be able to manage smaller missions with a smaller cost cap. For that, we need to be comfortable with CubeSat programs. So therefore, SmallSats are part of the whole spectrum of tools used for the missions that we perform. I think SmallSats have come into their own and have proven that they can do science missions, so they will continue to be part of our future.

Q: What message or what picture would you paint for people outside of NASA about Goddard for the SmallSat community?

A: Right now, I am focused on Goddard 2040. What does Goddard want to be and need to be in 2040? We have a number of fantastic missions and commitments that we are going to absolutely execute right now. That is the bedrock of what we do—delivering on those missions. That current work is critically important, but we also need to be very future focused. I want Goddard to be working on the hardest problems in science, to be developing the technology for the next generations of science missions and be partnering with external entities more than we do now. And that includes commercial entities, academia, and the non-profit labs. I see us doing more partnerships in the future than we do now.

Q: Speaking of partnerships, as SmallSat missions grow bolder and more robust, the SmallSat community needs to develop technologies that enable those audacious goals. How can Goddard help them? How can private industry take advantage of what Goddard has to offer?

A: It is the same question that I would also pose back to them. Tell us what they can use and what they need from Goddard. Right now, early in my tenure, I've had the opportunity to listen. I am listening to our workforce, our internal and external stakeholders, and to our partners. So, what I want to hear from folks is: What do you want and need from Goddard.

Q: One of the important aspects of the SmallSat Conference is that it provides Goddard with the opportunity to identify new partners to work with on several fronts. That includes not only the ability to license patented SmallSat technologies, but also the ability to utilize Goddard facilities and equipment. Is that right?

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A: Absolutely. The question is: where and how can people use our Goddard facilities for the greater expansion of the space community and the space economy? We have things that are unique and maybe not available in the commercial world, so we need to help organizations to be successful. I think the transformation [to use Goddard's labs and environmental test and launch facilities through partnerships, collaborations and formed agreements] at the Wallops Flight Facility is a really great example of how we have been able to increase partnership activity with commercial industry. Our operating cadence at Wallops has increased and it is going to increase even more. I think Wallops is a great example of how we can provide value to the entire space community and stay really relevant and important. Wallops is important to the Goddard community and to NASA; it is not going anywhere. We have the facilities, we have the know-how, but the one thing that I love about the SmallSat Conference is the ability to go out and make connections with potential new partners.

Q: As the home of innovative earth science, astrophysics, heliophysics, and planetary science, Goddard offers dozens of job and internship opportunities each year. Many attendees at the Conference are seeking employment or internships. Why should they consider Goddard? What does Goddard have to offer?

A: My goal for the Goddard workforce is that when they come to work every day, they are going to be working on some of the most exciting technologies and missions out there. Being at Goddard in particular, that is as close to a NASA mission as you are going to get. It is exciting to be a part of the nucleus of all these fantastic missions. That is one of the value propositions. In addition, we want Goddard to be one of the most inclusive workforces that we can be. That includes the usual dimensions of diversity that we often think about. And that also means the diversity of background, of thought, and of educational institutions, bringing the best people from across the country. That is an exciting thing to be a part of, which means we bring in people who think differently from each other to solve hard problems.

Q: With so many experienced engineers and scientists, Goddard is also dealing with a workforce where many employees are now reaching retirement age.

A: Like NASA itself, Goddard has a lot of retirement eligible employees, so we are looking at a large number of senior folks who have enormous amounts of experience and knowledge built up that are going to be moving on to the next phase of their lives. Looking at that, how do we keep all that knowledge from just walking out the door? We need to be focused on mentoring the next generation of engineers and scientists in a technical manner. So, we need to bring in folks who are just coming out of school, or who are maybe coming from other types of organizations. And they need to have direct contact with our most senior engineers. That also is a big draw here, because you are working with the best of the best. So, we look for people to bring their ideas and energy, coupled with experience, so we can accelerate a person's career to become a technical leader.

Q: For those readers who don't know, what is Goddard 2040?

A: What does Goddard look like in 2040? I see this as a workforce that is highly skilled and dynamic, and a workforce that is focused on solving some of the hardest problems and developing some of the most cutting-edge technologies. So, if I think about NASA missions that are critical, the first ones I think about are the Habitable Exoplanet Observatory [a concept for imagery that can search for signature habitability on planetary systems, such as water and gases in the atmosphere indictive of biological activity], and the next generation of large space telescopes beyond the James Webb and Nancy Grace Roman Space Telescopes. These are exactly the kinds of missions that Goddard can lead, convene a partnership, and implement in an impressive mission. That is one of my priorities. Also with Goddard 2040, I see us being at the center and hub of climate and earth science, both for the modeling and measurements. This does not mean we do all this work ourselves; it means that we put together the partnerships and that our workforce is doing the things that the government should do. We need to be doing the kinds of things that industry and commerce are not yet doing or maybe don't want to do. So, Goddard 2024 is about leveraging our capabilities and then having our workforce really focused on achieving the kinds of things that only Goddard can do while leaving the rest to our industry partners. That is the way that we are going to have Goddard do more.

Q: So, does this mean we will produce a Goddard 2040 White Paper to lay out a new plan?

A: Exactly. Since I am coming in new, these ideas are still evolving, but shortly we will be talking more about specifics for that vision. Again, it is evolving as I learn more about what the space community both internally and externally wants to see Goddard 2040 look like. It will address things like: What are the workforce needs? What are the facility needs? What are the partnership needs? We all need to a part of this vision for Goddard 2040.

Q: Goddard is on the forefront of developing architectures to support the Distributed Systems Mission (DSM) concept with SmallSats. How and why is Goddard positioned to be one of the leaders in DSM?

A: Yes, we are developing Distributed Systems Mission for constellations and formation flying, but again, I really want to focus on what are some of those hard problems to solve that have not been solved yet. I do think that Goddard has a role to play in developing and demonstrating DSM smartly, particularly for science missions. As one of our core capabilities is managing and implementing end-to-end missions, we must be skilled in all the tools like DSM that are required to carry out NASA's mission. I absolutely see Goddard working in this area.

Q: Regarding Goddard and SmallSats, any final thoughts?

A: I would have to say that the SmallSat endeavor – the industry and the players – has really evolved over time. Some years ago, there were people who had the vision that SmallSats were going to be important, and they really helped kick off this innovative sprint that we've had to get SmallSats in orbit and performing missions. Those are the kinds of innovations that I hope this community keeps pushing so that space capabilities move forward. I love all the innovation I have seen in the SmallSat community.

Finally, I want to take this opportunity to thank Utah State University and SDL [Space Dynamics Laboratory Workshop] for the work that they do organizing the SmallSats Conference every year. They do a fantastic job. Unfortunately, I cannot be out at Logan, Utah this year, but members of our Goddard leadership team will be out there in force.

GSFC Center Director Makenzie Lystrup speaks at Town Hall.
Photo Credit: N4 Solutions

Goddard SmallSat Strategy-Engineering and Science perspective

Constellations are the Next Science Frontier for SmallSats

Understanding how mass, energy, and momentum from the Sun enters, propagates through, and dissipates within the Earth's magnetosphere and upper atmosphere is a major goal of many heliophysics spaceflight missions. However, a single or small cluster of spacecrafts can only examine relatively localized aspects of the global magnetosphere. Statistical studies can provide a broader understanding of global dynamics, but do not generally represent any one instantaneous state.

From a science perspective, Goddard is pursuing SmallSat missions of all types, including a current focus on developing architectures to support the Distributed Systems Mission (DSM) concept. Such assets may be a combination of multiple spacecraft, unmanned air vehicles, ground observatories, balloons, sounding rockets, or any other platform that is part of the system. Some DSM developments include constellations, formation flying missions, or fractionated missions. The goal now for Goddard is to demonstrate the DSM concept by designing, developing, and ultimately flying some of these multi-spacecraft missions.

"You are not going to be able to fly a major magnetospheric constellation with a good old-school 500-kilogram spacecraft, it is not feasible from a cost standpoint," said Dr. Antti Pulkkinen, director of the Heliophysics Science Division at NASA Goddard. "So, you are going to have to go small and you are going to rely heavily on small satellite platforms to deploy these major constellations to do the next generation science in heliophysics. So, a good portion of the future of heliophysics will be with SmallSats."

A constellation of satellites taking simultaneous, distributed measurements throughout the magnetosphere will help to answer many long-standing heliophysics questions. Looking like strings of pearls, a constellation-type

Engineering is the Engine that Leads SmallSat-Driven Science

Launched on August 7, 1959, from Cape Canaveral, Florida, Explorer 6 became the first scientific satellite under the project direction of NASA's Goddard Space Flight Center. Weighing all 142 pounds, the small, spheroidal spacecraft was designed to study radiation, geomagnetism, and radio propagation in the upper atmosphere. It also tested a scanning device designed for photographing Earth's cloud cover.

Since then, Goddard has played an integral role in hundreds of NASA missions. Prior to the construction of what is now NASA's Johnson Space Center in Houston, Texas, Goddard managed the beginnings of the Mercury project. Goddard operated the tracking and communications networks for NASA's manned space missions during the Mercury, Gemini, Apollo, and space shuttle programs through to the present day.

Ever since the early days of aeronautics and spaceflight, engineering has been the backbone of NASA's greatest accomplishments. NASA engineers continue to represent the leading edge of human innovation as the agency moves forward with ambitious plans to return humans to the Moon, enhance our understanding of the universe, and advance technologies for aircraft and spacecraft.

"NASA Goddard has been doing this for decades," said Michael Johnson, chief technologist in the Engineering and Technology Directorate at NASA Goddard. "We have a cadre of scientists that is unequaled anywhere else on the planet. We've got engineers who are the best on the planet so we can certainly help potential academic and industry partners who come to us to achieve some objective that they might have. At the same time, they might bring something to us where again, by virtue of what they bring, would allow us to achieve something that we could not achieve on our own."

mission of SmallSats would provide a means of examining and monitoring the response, dynamics, and coupling of the magnetosphere processes.

Through past missions such as the Solar Terrestrial Relations Observatory (STEREO), the Solar Dynamics Observatory (SDO), and Time History of Events and Macroscale Interactions during Substorms (THEMIS), NASA has been able to study flows from the Sun and their interaction with the Earth's magnetic field leading to energy releases from the magnetosphere known as substorms. These phenomena intensify auroras near Earth's poles. Using four identical spacecraft flying in a tetrahedral formation, the Magnetospheric Multiscale (MMS) Mission is another recent NASA robotic space mission to study the Earth's magnetosphere and the magnetic reconnection process. Now utilizing major constellations of SmallSats, Goddard is now poised to take the next big leap.

Today, Goddard is leading the development of Geospace Dynamics Constellation (GDC), which is a 6-spacecraft low-Earth orbit mission to study the important upper atmospheric region that among other impacts can lead to changes in orbital drag. Goddard is also spearheading the next generation Magnetospheric Constellation (MagCon) concept. This concept is a constellation mission made up of approximately three dozen spacecraft orbiting the Earth to study the mesoscale structures in the Earth's magnetospheric. With its distributed network of observing stations, the magnetospheric constellation concept could become the ultimate tool for unraveling the mysteries of magnetospheric energy storage, and ultimate release and transport leading to phenomena such as auroras.

"Another major constellation concept we are working on pertains to three-dimensional imaging of solar phenomena," explained Pulkkinen. "The idea with the concept is that we will get imaging of explosive solar atmospheric phenomenon taken from ten to 12 different viewpoints. When these eruptions of the Sun take place, there is a heavy interaction between these transients and the background solar wind and right now we don't have a good fully three-dimensional understanding of the interaction taking place. This is critical to understand because ultimately that will be the structure that gets imposed and introduced to the Earth's magnetosphere. The idea of gaining a three-dimensional view

"It all begins and ends with science, but engineering is the engine that gets us there," added Dr. Joanne Hill-Kittle, deputy director of the Engineering and Technology Directorate at NASA Goddard. "What we do from the engineering and technology side is figure out how to deliver the science that the principal investigators (PI) want to achieve and look at how to do that within the small volume of a SmallSat. Building off the knowledge that we have obtained from building bigger satellites, we are now taking that to the next level by using these small satellites to really deliver the big science."

To achieve the goal of delivering the science to SmallSat missions, Hill-Kittle said NASA Goddard is focused on doing three things: collaboration, innovation, and delivering. "It is important for us to collaborate with industry and academia," she explained. "Innovation is how we strive to deliver the big science. Ultimately, we need to understand the needs of the science and then collaborate and innovate to deliver that science. That is what it is all about."

SmallSats are spacecraft that weigh less than 500 kilograms and can be as small as a shoebox. They offer many advantages over traditional large satellites, such as lower cost, faster development, easier launch, and more flexibility. However, SmallSats also face some unique challenges and opportunities in their design and engineering. Among the challenges are SmallSat's small size and mass, and Goddard has been adept at finding creative ways to pack more functionality and efficiency into smaller packages. Other challenges include power and energy, communications and data handling, and reliability and testing to withstand the harsh environmental conditions such as vibration, shock, thermal cycling, and radiation.

"Reducing the size, weight, and power are critical to getting the best science that we can from SmallSats," said Hill-Kittle. "So, we are using inventive techniques and new technologies to be able to get bigger science out of these smaller volumes. What we are looking at into the future is establishing and improving the methodology for implementing these SmallSats to be more efficient."

Hill-Kittle said the biggest engineering and technology achievements at NASA Goddard have been in the miniaturization of payloads and sensors to fit into SmallSats platforms, while still providing significant mission capabil-

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of these major eruptions coming from the Sun is that it will ultimately help us to predict them."

Another heliophysics mission using the constellation flying formation concept that Goddard is exploring is the Coronal Microscale Observatory (CMO). Why the Sun has a tenuous upper atmosphere some 1,000 times hotter than the photosphere is a fundamental open question in space plasma physics despite decades of study. The CMO will determine the physical mechanisms that drive primary heating events (nanoflares and wave heating) in the solar corona and help to understand the formation of the solar wind.

To achieve its science objectives, the CMO is proposed to fly three spacecrafts with specialized instrumentation, including a cluster of six extreme ultraviolet (EUV) telescopes at the Sun-Earth L1 Lagrange point. "The three CMO spacecraft need to fly in very, very precise formation to ensure the proper alignment of optical and sensor elements flying on different spacecraft," said Pulkkinen.

In terms of partnerships, Pulkkinen said Goddard scientists have worked with private industry and academia on multiple levels. Goddard scientists have served as co-investigators on mission development and proposal efforts and provided the science support to formulate the key science questions. Goddard has also worked with external principal investigators to develop instrumentation capabilities needed for SmallSats.

"We are providing leadership with our external partners in terms of understanding what are the next generation science questions that we need to answer," said Pulkkinen. "We are also providing the leadership in terms of understanding how we can use major constellations to go after these big science questions. For example, many of our scientists contributed to Decadal Survey White Papers that help the SmallSat community craft the next generation science stories."

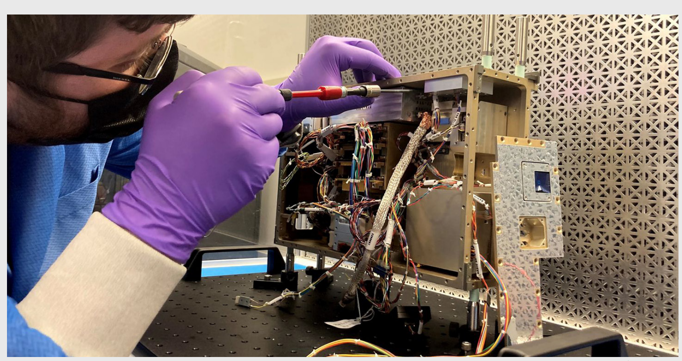
From a science perspective, as Goddard looks to the future of SmallSats, Pulkkinen believes that constellation-based missions will play a major role. "Deep space is another new frontier for us, and that is another area where we are going to be deploying major constellations," he predicted. "SmallSat constellations show huge potential in heliophysics, and they are going to be growing more numerous over the next decade."

ity. SmallSat NASA missions such as BurstCube, GTOSat (Geosynchronous transfer orbit satellite), and SNoOPI (SigNals of Opportunity P-band Investigation) will produce high-quality scientific results, support for operational missions, and opening partnership opportunities in space.

While NASA Goddard is getting good science from its present SmallSat missions, Hill-Kittle said among the next steps are developing intelligent decision making and collaborative systems. One area Goddard is exploring to support is the use of Distributed Systems Missions (DSM). A DSM is a mission that involves multiple spacecraft to achieve one or more common goals. Some DSM development includes constellations, formation flying missions, or fractionated missions. A key component and advantage of DSM is the idea that this is an open architecture where anyone can join and contribute to the network.

"When we talk about Distributed Systems Missions, we are talking about having communications between the SmallSats and having them share information and make decisions based on that information," said Hill-Kittle. "So for example, if one SmallSat observes something really interesting, it then has the capacity to share that information so the other SmallSats in a constellation, allowing them to potentially do different measurements over the magnetic spectrum."

Hill-Kittle said in terms of partnerships, NASA Goddard is really wanting to look at technologies that are being developed by private industry and academia. She said, "We want to understand what the SmallSat community is developing so that we are not reinventing the wheel. For example, there are companies that are developing AI solutions for smart decision making, and that could be important partnerships to us. We want to fill in the gaps between what they can provide and what the scientists need and then really bring in those partnerships together to build on with industry."



GTOSat fit check. Photo Credit: NASA/GSFC

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Simulation Tool Helps Increase SmallSat Reliability

SmallSats can be very complex systems, harnessing many components within multiple subsystems that must mesh together perfectly for the spacecraft to operate for years. If it breaks down in space, there is no prospect for repair. Considering the cost and time involved in designing and building a SmallSat, every developer must answer a critical question: Will what they've designed on the drawing board – before they have any of the physical hardware components – actually work?

"What you don't want to happen," said Luis Santos Soto, chief engineer of the Small Satellite Project Office at Goddard, "is to put all your components together to complete the SmallSat only to find there is a problem. Although having no issues during I&T [Integration and Testing] is incredibly difficult to achieve, the risk can be considerably reduced from the software standpoint if we have a digital equivalent for the system to enable early software development."

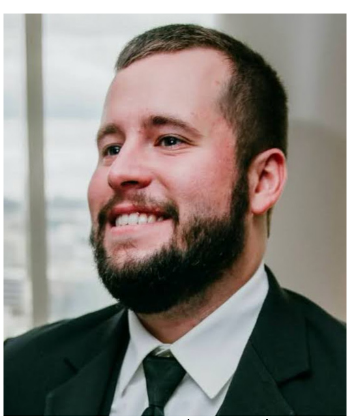


Photo Credit: NASA

John Lucas, deputy lead of the Jon McBride Software Testing and Research (JSTAR) team, mission systems engineer for the [Geostationary Transfer Orbit Satellite] (GTOSat) mission and computer engineer at Goddard's Katherine Johnson IV&V Facility has the answer. He and his JSTAR team have developed the NASA Operational Simulation for Small Satellites (NOS³), which is a suite of software tools that allows a SmallSat developer to verify and validate all the test flight and ground flight software and component hardware in the spacecraft before it is built and assembled. NOS³ is a Goddard technology that holds several patents and is available commercially for licensure.

"What NOS³ allows you to have is a spacecraft in your laptop," said Lucas. "Instead of having the full physical SmallSat or without having to actually build an entire spacecraft, you can run and simulate your entire spacecraft, including orbital dynamics, ground and flight software as it fits in space, just on any old laptop that is laying around. NOS³ is just another tool in your toolbox to really do your design and testing of the spacecraft."

NOS³ was born seven years ago out of NASA's Simulation to Flight (STF-1) CubeSat mission. Under NASA's CubeSat Launch Initiative, Goddard teamed with West Virginia University to build and launch the STF-1 spacecraft. The main goal of the mission was to fully demonstrate the Operation Simulation technologies in the NOS³. All the needed software development, mission operations/training, verification and validation, test procedure development, and software check-out systems grew from a background of developing simulations on the James Webb Space Telescope, the Global Precipitation Measurement mission, the Juno spacecraft mission to Jupiter, and the Deep Space Climate Observatory.

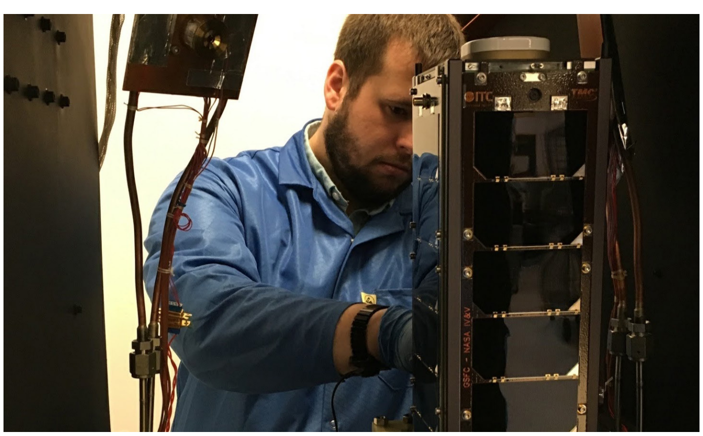
"NOS³ is really an augmentation for your development flow," said Lucas. "We've built spacecraft before and we've had this kind of technology and simulation capability, but NOS³ really allows us to expedite the development process. Now, we don't have to [physically] break things to see their response on the spacecraft."

"The other beauty of NOS^3 is you can actually have the hardware in the loop as well," added Santos Soto. "You can start with all the software simulation and everything that can be done on your laptop. But eventually, when you get all of your components, you can potentially plug them into the NOS^3 system as well. So, you can have a combination of real hardware and simulation software talking to everything on the NOS^3."

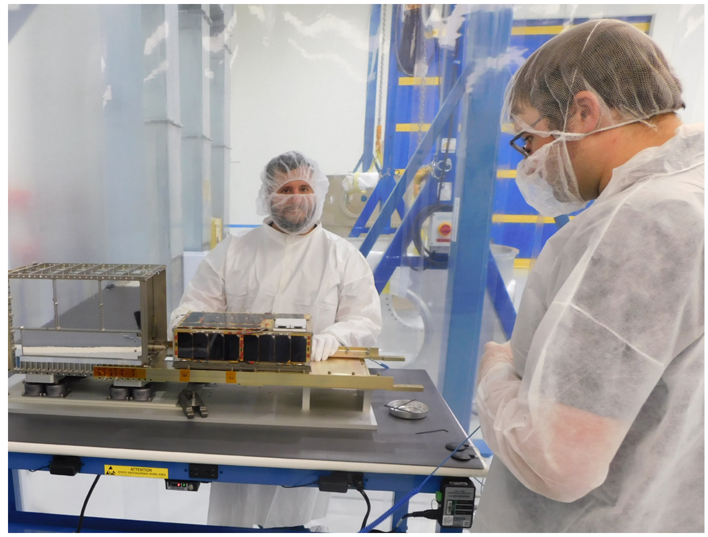
One of the other advantages of NOS^3 was during the COVID-19 pandemic, when commercial off-the-shelf parts for satellites were delayed due to production and shipping issues, and developers had to wait months for products. Using NOS^3, satellite developers could simulate components until they arrived.

"The really nice thing about NOS^3 is it has allowed NASA to continue satellite development during the pandemic," stressed Lucas. "That was extremely critical during COVID because we did not get a single component delivered on time due to the nature of the world. NOS^3 allowed us to basically start doing all the coding for both the flight and ground software, as well as run the spacecraft simulation for the developers at all of the NASA centers so they could continue to do SmallSat development and build spacecrafts."

NOS^3 also saves time and money. "Now, you don't have to wait until the hardware components show up to start coding," said Santos Soto. "When they arrive, all you have to do is test the developed software with the actual components and there are no unforeseen issues."



John Lucas, Photo Credit: NASA



John Lucas in the lab, Photo Credit: NASA

Flight and Ground Software Components That Interact with NOS^3

NOS^3 is an open-source software that integrates with a variety of key flight and ground software tools, as well as hardware simulation platforms such as:

- NASA Operational Simulator of Small Satellites (NOS) is the core technology for NOS^3 that provides the connectivity between the flight software and the simulated hardware components.
- NASA's Core Flight System (cFS) is a reusable flight software framework that is used as the base system for flight software.
- Simulated hardware components serve as a virtual hardware model that connect to the NOS engine and provide the hardware input and output to the flight software.
- Oracle VirtualBox and Vagrant allows a computer to set up the virtual machinery necessary to run the applications associated with the NOS^3 suite.
- COSMOS (Open Source Managed Operating System) is a ground system software used to provide command and control of the flight software.
- OIPP (Orbit Inview and Power Prediction) is a planning tool developed by members of the NASA IV&V team that allows the ground station to know when the satellite will be in view, as well as when the satellite will be in direct sunlight. This allows the IV&V team to plan power usage and communication times.
- 42 is a NASA developed visualization and simulation tool used for spacecraft attitude and orbital dynamics. 42 provides magnetic field and positional data inputs to the magnetometer and GPS simulators.

Engineer Spotlight

Important innovations are on the horizon for SmallSats. Young engineers are the future and will play a key role in inventing and developing SmallSat technologies of the 21st century. We reached out to three of our young engineers to find out who they are, why they think SmallSats are important, and why they decided to join NASA's Goddard Space Flight Center.

Hasnaa Khalifi

Why did you choose to work at NASA Goddard?

I grew up in Morocco, where space exploration and research are not a hot topic. When I was a child, I would not have been able to name the planets in our solar system because I was not aware of their existence. I remember one moment though when I was a kid, watching tv and a news feed came on with NASA scientists talking about evidence of water and possibly life on the red planet. That truly intrigued me. I had so many questions, I was wondering whether the entire planet was red? How far is it from Earth? And can we go to it? Unfortunately, I was not able to get my many basic questions answered nor my intrigue satisfied.

I was incredibly lucky to attend college in the United States. I took a few introductory engineering courses and found myself most intrigued by the aerospace field. It was and still is a world of unlimited and exciting information that I take true joy in learning, researching, and applying. When summer came, a few of my classmates were so excited about an upcoming internship at NASA. I was so happy for them, but I knew that it would be a faraway dream for me; I never believed that it was impossible though.

I thank my father for teaching me by example to reach beyond our own perceived limits. With a hanging dream, perceived to be so far away, I chose to focus on the various university research projects I was involved with. My research path has eventually led me to work on a SmallSat project and prepared me for the work that is to come.

At the end of my PhD, I was very curious about the work happening at NASA, especially in my field of interest. I visited Goddard once, with no expectation to be hired in the future, and spoke with individuals about the current ongoing work. From that moment, I truly believed that I could be a great fit—that I could both contribute my limited knowledge and grow intellectually beyond those limits. I chose NASA Goddard because I wanted to directly contribute to the future of space exploration and work side by side with the brightest minds in the field, so perhaps one day I could come close to their level of expertise.

What do you enjoy most about working on SmallSat technologies?

Working on SmallSat technologies allowed me to have hands on contact with spacecraft components, which is not easily achievable with larger missions. Learning the purpose and functionality of each spacecraft component, as well as developing algorithms to extract and use the obtained information from them provides one level of satisfaction. Getting to test the code my team and I developed and verifying that the components and the system are behaving as expected provides another level of satisfaction. I enjoyed being able to learn about each spacecraft subsystem at a faster rate due to the fast turnaround time of the project. I also enjoyed the small team aspect of the SmallSat mission, which fostered a collaborative atmosphere, seamless communication within my team, and created an environment conducive to learning from all members of the mission, who each brought unique expertise in their respective fields.

What have you learned most from working at Goddard?

Working at Goddard, I have learned the importance of being thorough with an attentive eye to detail as well as the importance of not skipping critical mission and system processes and steps, especially related to analyses and testing. I have learned the importance of being a team player, to listen and act on every input or concern, and that only together we can reach further. I have learned that my work and my thoughts matter, even if my contribution to the whole is miniscule.

Why do SmallSats matter; why should people in the industry pay attention to them?

SmallSats provide a highly viable platform for space exploration. Their low cost and fast turnaround time from conception to launch and operation allow for a faster performance verification of new instrumentation and technologies and for advancing scientific research and studies at a faster rate. Their low cost also enables more groups of people, students, scientists, and engineers to investigate and perform space-based science and observation. They often employ commercial off-the-shelf components, which are rapidly gaining flight heritage and therefore trust. SmallSat capabilities will continue to grow; now is the best time to invest in them and build a strong foundation for the future.

What work experiences prepared you for your role?

Attending graduate school, being involved with various research projects and university clubs prepared me for my role today. During my undergraduate studies, I had a plan to pursue a master's degree because everything I had learned was very general and I wanted to delve deeper into a few topics of interest. Additionally, since my sophomore year of college, I was always involved in a research project with a faculty member and committed to volunteering with a few engineering clubs throughout my educational years. I enjoyed both the theoretical and hands on experiences during my academic journey. I have cherished the opportunity to translate theory into practice, conducting experiments and research, and applying my knowledge to real world scenarios. My academic experiences had fueled my desire to gain more specialized knowledge and skills in my field of interest, which led me to pursue a PhD. I am incredibly fortunate to have been guided by exceptional mentors throughout my educational journey. Their support and guidance have played an instrumental role in shaping my career trajectory.

Lucia Tian

Why did you choose to work at NASA Goddard?

Goddard was the perfect way to combine my passions in aerospace engineering and observational astrophysics. Now I get to help build spacecraft that investigate the cosmos and push the bounds of human knowledge!

What do you enjoy most about working on SmallSat technologies?

I love being part of a small, dynamic team tackling sky-high goals in a fast-paced environment. Every day is a unique adventure, and it's so fun and eye-opening to put on different hats, from hardware testing to data analysis to flight operations planning. The science is also super exciting – our 6U BurstCube satellite will be hunting for the most powerful explosions in the universe! I'm always amazed to enter the lab and see a full astronomical observatory sitting in front of me, complete with batteries, reaction wheels, star tracker, and other components, all packed into the size of a shoebox.

What have you learned most from working at Goddard?

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I have lots of good practices in hands-on work, systems engineering, and team leadership! I've found that there's no such thing as "too many" notes, photos, or recordings – documentation is everything and will be a lifesaver in the long run. Since I work closely with Goddard scientists, I've also been learning about high-energy astrophysics and gamma-ray bursts.

Why do SmallSats matter; why should people in the industry pay attention to them?

As new technologies continue to mature and shrink, it's clear that SmallSats are an excellent way to perform substantial cutting-edge space research, tech demos, and services in a relatively fast and cost-effective manner. They also provide early-career folks with invaluable experience in the full project lifecycle and the opportunity to explore different subsystems and interfaces – everything is so real and accessible.

What work experiences prepared you for your role?

I'm fortunate to have diverse experiences to draw upon in my role as BurstCube's science instrument lead. I started out as a pre-med student in the biotechnology sector working with cell DNA and RNA, which was great practice in precision lab work, experimental design, and technical writing. My degree in astrophysics and computer science helps me understand our scientific goals and the data pipeline to achieve them. Finally, working as an intern at three other NASA centers established strong aerospace foundations in spacecraft design, flight hardware development, space systems engineering, etc. It also allowed me to gain familiarity with NASA's various programs, processes, terminologies, and acronyms.

Dakotah Rusley

Why did you choose to work at NASA Goddard?

I had wanted to work at NASA since grade school, and Goddard was a natural fit for my passion for science and engineering. NASA Goddard exists at the confluence of groundbreaking engineering and impactful science, and with NASA renewing their push for lunar exploration, it's an incredibly exciting time to be a part of the team.

What do you enjoy most about working on SmallSat technologies?

SmallSats offer a unique opportunity for early-career engineers to gain exposure to many different parts of a spacecraft system, something that ranges from very difficult to nigh impossible on larger missions. This multidisciplinary exposure makes for a phenomenal start to a career.

What have you learned most from working at Goddard?

At Goddard, it seems that every day is a learning opportunity. From the multitude of seminars and colloquia to having experts in spaceflight four offices down, resources abound. One of the more eye-opening pieces I've learned is just how many moving parts and stakeholders there are in even the simplest mission. The adage "it takes a village" certainly applies!

Why do SmallSats matter; why should people in the industry pay attention to them?

SmallSats are a fantastic platform to do R&D and advance the readiness of new technology. With a relatively low-cost, high-risk tolerance mission profile, we can make design decisions and incorporate novel components, mission architectures, and scientific instruments that may not be palatable to a larger mission's design requirements.

What work experiences prepared you for your role?

My educational background is in computer engineering, which certainly has helped me in my current career path to bridge the communication gap between electrical engineers and software developers. Learning to speak both languages, so to speak, has been a fantastic skill to develop.

Dr. Robert H. Goddard and a liquid oxygen-gasoline rocket in the frame from which it was fired on March 16, 1926, at Auburn, Massachusetts. Photo Credit: GSFC

Five Ways to Work with Goddard's Strategic Partnership Office

Helen Keller once said, "Alone we can do so little; together we can do so much." There are many ways industry can work with Goddard's Strategic Partnership Office (SPO) and take advantage of the technology resources available to accomplish your goals. The following list of options is a great place to start:

1 **License Goddard technology.** If you think patented or patent-pending SmallSat technologies found in this magazine or on our website, http://partnerships.gsfc.nasa.gov, may meet your technology needs, contact SPO to learn more and begin the licensing process. First, get in touch with a Goddard technology manager to troubleshoot your requirements and agree on a suitable technology to fit your requirements. Then, fill out an application through NASA's Automated Technology Licensing Application System (ATLAS). After submitting your application in ATLAS, a staff member from Goddard's SPO will get in touch for next steps.

2 **Apply for Startup NASA.** Startup companies can take advantage of additional benefits by participating in our Startup NASA initiative. NASA waives licensing fees for participants, removing some of the barriers encountered by tech entrepreneurs looking to secure intellectual property rights. Learn more about this opportunity by contacting the SPO office at techtransfer@gsfc.nasa.gov.

3 **Check out our online software catalog.** Goddard has 143 programs available online to fulfill your software needs, free of charge. Categories include business systems and project management, environmental science, and data and image processing. To request NASA software, go to https://software.nasa.gov/ and select the "Software Catalog" button. Some codes and mobile apps offer direct download, while others require a completed request form for processing through Goddard's Software Release Authority.

4 **Explore Space Act Agreements.** Established in 1958, the National Aeronautics and Space Act allows NASA to form Space Act Agreements (SAAs) with various partners to make progress on shared goals. SAAs facilitate advancements in numerous industries—for example, in 2016, Virginia Electric and Power Company signed an SAA with Goddard to allow researchers to study the effect of Geomagnetically Induced Currents (GICs) on the U.S. power grid. SAAs can play a role in license agreements by allowing Goddard scientists to support technology transfer as long as it doesn't interfere with their job responsibilities. This arrangement also permits partners to reimburse Goddard for its time.

5 **Leverage your Small Business Innovation Research or Small Business Technology Transfer (SBIR/ STTR) award.** Companies with SBIR/STTR awards or government contracts can utilize Goddard technology to enhance their research objectives. Your contracting officer or contracting officer representative can assist you in adding new technology to your list of Government Supplied Equipment.

To learn more about the **Strategic Partnerships Office**, please visit https://partnerships.gsfc.nasa.gov.

To connect with a technology manager, send an email to techtransfer@gsfc.nasa.gov.

Careers and Inter NASA Goddard

NASA's Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, leads the world in scientific discovery and understanding. Goddard is the home of innovative Earth science, astrophysics, heliophysics, and planetary science. The center's diverse and talented team is responsible for each breakthrough emerging from Goddard laboratories.
From high school interns to accomplished Nobel Prize winners, each member of the Goddard team plays a vital role in mission success. If you are interested in applying for employment with NASA's Goddard Space Flight Center and need special assistance or an accommodation to apply for a posted position, contact our Human Resources department at 301-286-7918.

Civil Servant Career Opportunities

NASA's Goddard Space Flight Center has a variety of opportunities for scientists, engineers, technicians, and other professionals that range from student to senior career levels. Follow the links below for more information.

- External applicants: https://www.nasa.gov/careers
- Current NASA employees: https://hr.nasa.gov/
- Current NASA Goddard employees: https://ohcm.gsfc.nasa.gov/

Student Career Opportunities

The NASA Pathways Intern Employment Program (IEP) is open to students that are currently enrolled or accepted for enrollment in a qualifying educational program. The Pathways IEP provides opportunities to work and explore careers while still in school. Pathways IEP appointments may be for indefinite periods without not-to-exceed (NTE) dates or appointments with NTE dates of up to one year. If you successfully complete an appointment without an NTE date at NASA, you may be converted to permanent employment or term employment of up to six years. For more information, please visit https://www.nasa.gov/careers/pathways.

To be eligible for NASA's IEP, you must:

- Be a U.S. citizen
- Be at least 16 years of age
- Be enrolled or accepted for enrollment on at least a half-time basis
- Be pursuing a degree or certificate
- Currently have and maintain a 2.9 grade point average
- Be able to complete at least 640 hours of work prior to completing your degree/certificate requirements
- Meet any other requirements described in the announcement (some IEP positions require you to be pursuing specific majors)

nships at

To find opportunities:

- Federal agencies must post Intern opportunities on https://www.usajobs.gov/. You may go directly to https://www.usajobs.gov/ to begin your search.
- You may review current NASA IEP vacancies at https://www.nasa.gov/careers/pathways
- You may also create an account on https://www.usajobs.gov/ and sign up to be automatically notified about vacancies meeting your interests.

Non-Civil Servant Career Opportunities

- https://goddard-contractors-association.org/
- https://www.nasa.gov/centers/goddard/jobs.html

Doing Business with Goddard

- Goddard Space Flight Center Procurement
  For information on doing business with Goddard, contact the center's Procurement Office by telephone at 301-286-4379, or visit its Web Site: http://code210.gsfc.nasa.gov/procure.htm. This site is part of the NASA Acquisition Internet Service (NAIS). The purpose of this site is to provide Goddard-specific procurement information to the business community. From that site you can get to the NASA Acquisition Internet Service (NAIS). If this is your first time visiting, you may want to look at the https://my.nais.org/s/all-faqs for answers to frequently asked questions. After you've browsed the NAIS pages, fill out the NAIS Feedback form so they can better serve your needs.

- Strategic Partnerships Office
  The Strategic Partnerships Office (SPO) fosters technology spin-out and spin-in to benefit both NASA and the Nation. The SPO actively seeks out Goddard research and development that can meet industry and national needs; documents newly developed technologies; patents Goddard-developed inventions; promotes Goddard technologies, facilities, and capabilities to potential partners; and negotiates partnership agreements for technology transfer. Visit the Web site at https://partnerships.gsfc.nasa.gov/ for information about available technologies and important resources for partnerships and licensing.

- Technology and Partnership Questions
  The mission of NASA's Goddard Space Flight Center is to expand knowledge of Earth and its environment, the solar system, and the universe through space-based observations. Goddard is committed to excellence in scientific investigation, in the development and operation of space systems, and in the advancement of essential technologies. To find out more, call the general Technology Line at 301-286-5810 or visit https://partnerships.gsfc.nasa.gov/about-spo/mission-programs/.

THE SPARK

Goddard's *The Spark* shares stories about technology transfer at NASA and the innovative people who make it all possible. The Strategic Partnerships Office at NASA's Goddard Space Flight Center publishes the magazine quarterly.

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

Send suggestions to:
techtransfer@gsfc.nasa.gov

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