National Aeronautics and Space Administration

tech transfer

From Concept to Completion

The SmallSat Edition

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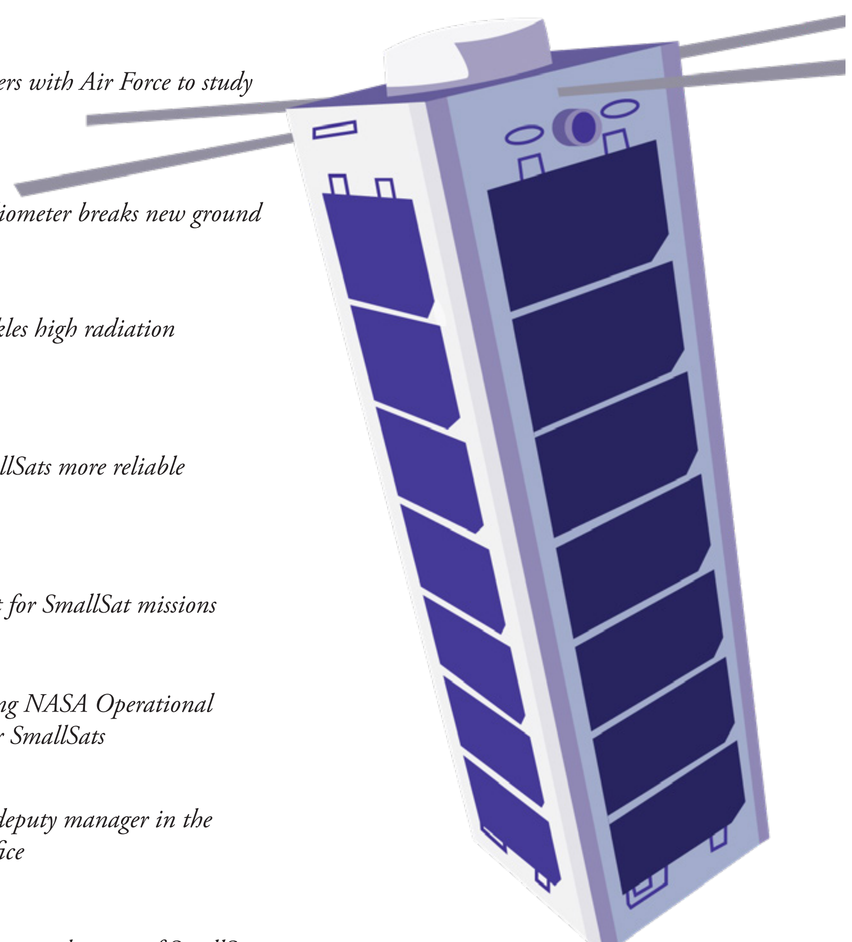

–STF-1

About the cover: CubeSats like IceCube (pictured) start out as rough sketches and end as fully realized, ground-breaking pieces of technology, ready to play a role in commercialization. In May, IceCube celebrated its one-year anniversary in orbit, producing the first global ice cloud map in the 883 Gigahertz band.

From the Office of the Chief

Nona Cheeks
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It takes a sizeable team to complete a successful small satellite mission. From the scientists and engineers who dream up the concept to the industry component manufacturers who provide the necessary parts, one CubeSat the size of a toaster represents thousands of hours of collaboration and effort.

At NASA's Goddard Space Flight Center, the Strategic Partnerships Office (SPO) is all about connections, and we're excited to share how NASA is using SmallSats to connect with resourceful people and organizations across the country. Just this year, Goddard licensed the Diminutive Assembly for Nanosatellite deploYables (DANY), a problem-solving innovation created for the Dellingr CubeSat mission. We're also celebrating one year in space for IceCube, a 3U CubeSat featuring a radiometer designed by Virginia Diodes, Inc. through a NASA Small Business Innovative Research (SBIR) contract. SPO encourages you to use this issue of GSFC Tech Transfer News as a guide to the abundance of SmallSat activity happening at NASA Goddard. Many of our innovators have generously shared their contact information in these pages to assist us in forging even more connections.

Among this issue's stories, we've included an interview with Tom Johnson, manager of Goddard's Small Satellite Project Office, as he discusses Goddard's unique role in providing small satellite services from concept to completion. We spoke with Mike Johnson, chief technologist of the Engineering and Technology Directorate at Goddard, to hear about his collaborations with industry and academia to form the Small Satellite Reliability Initiative. We also talked to Justin Morris, lead on the STF-1 CubeSat mission, about his work with NOS^3, a simulation software package soon to be open source.

We need all kinds of experts and innovators working together to keep the SmallSat industry running. Whether you are a small business owner or simply curious about the SmallSat community, this issue is for you.

CubeSat Mission Guide

Mission Guide

BurstCube

A 6U CubeSat searching for difficult-to-observe electromagnetic events called gamma ray bursts (GRBs), focusing specifically on short GRBs that are counterparts of gravitational wave sources

Projected launch date: 2021

Noteworthy because: it will increase the sky coverage for short gamma ray bursts and may serve as an interim instrument between larger missions.

Collaborators: TBD

GSFC technologies: 6U Dellingr bus; four cesium iodide (Csl) scintillators coupled with compact, low-power silicon photomultipliers (SiPMs); custom electronics

CubeRRT

A 6U CubeSat processing radio frequency interference (RFI) to filter out RF noise from NASA's microwave radiometers

Launch date: 2018

Noteworthy because: it can filter out RFI in real time from space, speeding up the data acquisition process in a world of increasing congestion regarding the RF spectrum.

Collaborators: Ohio State University, Blue Canyon Technologies, JPL

GSFC technologies: Design, development and testing for the Radiometer Front End (RFE) subsystem, which includes a broadband, compact, low-power microwave radiometer down-converter for SmallSat applications

Dellingr

A 6U CubeSat offering a reliable, robust and cost-effective design

Launch date: 2017

Noteworthy because: it will usher in a new era of science-based CubeSat missions.

Collaborators: None

GSFC technologies: Diminutive Assembly for Nanosatellite deploYables (DANY); thermal louvers; three magnetometers housed by the deployable boom for CubeSats; 6U Dellingr bus; mini ion and neutral mass spectrometer

GTOSat

A 6U CubeSat using geostationary transfer orbit to study high-energy bands surrounding Earth called the Van Allen belts

Projected launch date: 2021

Noteworthy because: it will require high radiation tolerance to survive the harsh environment of the radiation belts.

Collaborators: TBD

GSFC technologies: Dellingr-X bus

HaloSat

A 6U CubeSat measuring X-ray emitting gas in the halo surrounding the Milky Way galaxy in search of missing matter

Launch date: 2018

Noteworthy because: it is NASA's first astrophysics CubeSat.

Collaborators: University of Iowa, Blue Canyon Technologies

IceCube

A 3U CubeSat demonstrating the use of an 883 Gigahertz radiometer in space

Launch date: 2017

Noteworthy because: it produced the first global ice cloud map in the 883 Gigahertz band.

Collaborators: Virginia Diodes, Inc.

petitSat:

A 6U CubeSat examining density irregularities in Earth's ionosphere

Projected launch date: 2021

Noteworthy because: it could help scientists understand how the ionosphere affects long-distance radio communication such as GPS and radar signals.

Collaborators: Utah State University, Virginia Tech

GSFC technologies: Dellingr-X bus; mini ion and neutral mass spectrometer

STF-1

A 3U CubeSat demonstrating NASA simulation technologies and carrying three science experiments

Projected launch date: 2018

Noteworthy because: it will demonstrate the NOS^3 suite of programs on a CubeSat platform, running flight software on an emulation of a hardware model.

Collaborators: West Virginia University, West Virginia Space Grant Consortium

GSFC technologies: NASA Operational Simulation for Small Satellites (NOS^3)

Top 5 SmallSat Technologies

Technology Summary

Patents Granted

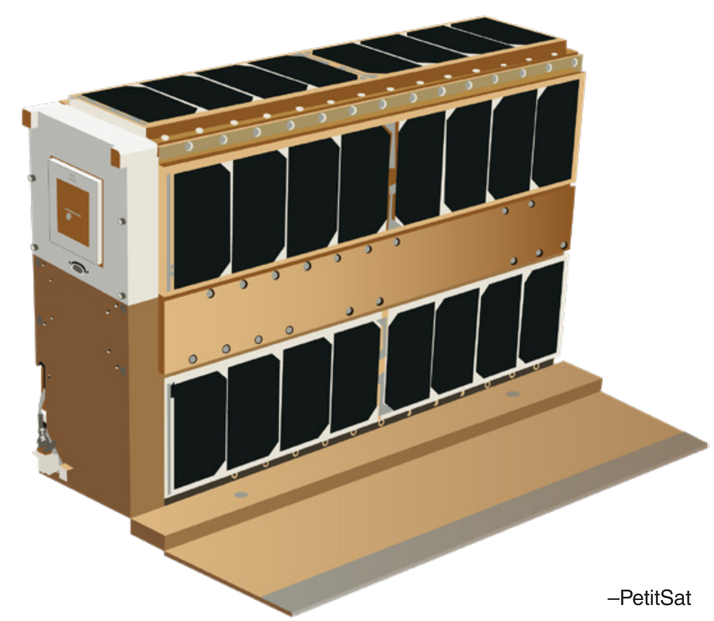
- GSC-16900-1: Diminutive Assembly for Nanosatellite deploYables (DANY) (GSC-TOPS-36)
  - Licensed to Thermal Management Technologies, Inc.

Patents Pending

- GSC-17152-1: Dellingr 6U CubeSat (GSC-TOPS-37)
- GSC-17034-1: CubeSat Form Factor Thermal Control Louvers (GSC-TOPS-40)
- GSC-175791-1: Deployable Boom for CubeSats

Disclosures, No Patent Filings

- **Detectors for BurstCube**
  - GSC-16991-1: Neutron Spectrometer for Inner Radiation Belt Studies
  - GSC-16969-1: High-Energy Instrumentation for Small Satellite Platforms
- **CubeRRT Microwave Radiometer Down-Converter**
  - GSC-18098-1: A Broad-band, Compact, Low-Power Microwave Radiometer Down-Converter for Small Satellite Applications
- **NOS^3 for STF-1 Mission**
  - GSC-17593-1: NASA Operational SmallSat Simulator (NOS^3)
  - GSC-17737-1: NASA Operational Simulator for Small Satellites (NOS^3)
- **Ion Neutral Mass Spectrometer [Dellingr, petitSat]**
  - GSC-17944-1: Mass Spectrometer with 360 deg FOV and keV Energy Range Project



–PetitSat

SmallSat Is Where It's At: Top 5 SmallSat Technologies

Goddard's innovators are constantly coming up with creative technology solutions to solve mission challenges. Through the Strategic Partnerships Office (SPO), companies can license those technologies, using NASA innovations to improve industry components. Below, SPO has compiled a list of the top SmallSat technologies available. For more information on how to partner with Goddard, please contact techtransfer@gsfc.nasa.gov.

1. Magnetic Shape Memory Alloy (MSMA) Actuator for Instrument Applications

Lead innovator: Umeshkumar Patel

Common CubeSat applications that use actuators include the manipulation of release devices, fast-steering mirrors, and optical positioning devices. Traditional actuators typically use temperature or voltage as control parameters, while the MSMA actuator is driven by a magnetic field. Magnetic-field-induced deformation is permanent and reversible, and because magnetic fields can be applied with very low response time, the actuators are capable of operating at KHz frequencies. Applications requiring power-off position hold, nanometer-level precision and high dynamic range will benefit from this development.

2. Novel Antenna Concept for CubeSat Platforms

Lead innovator: Manohar Deshpande

Current radio frequency (RF) antennas used on CubeSat platforms need packaging and deployment mechanisms, posing a failure risk to the mission. They also add extra volume and weight to a SmallSat's payload. Deshpande's innovation replaces railing rods in the CubeSat with rectangular waveguides that carry RF signals. These waveguides act as antennas, providing RF antenna functionality while also supporting the CubeSat structure.

3. Photovoltaic Lithium Ion Battery

Lead innovator: Eleanya Onuma

Lithium ion batteries and solar cells are often placed in separate sections of a SmallSat. Since space is at a premium on the SmallSat platform, Onuma's innovation integrates battery technology into solar cells, saving valuable space.

4. Optimetric Measurements over Coherent Free Space Optical Communication

Lead innovator: Guangning Yang

Yang's innovation uses optical communications technology to increase ranging and range rate accuracy by orders of magnitude, enabling high-precision tracking for CubeSats and deep space SmallSats.

5. Deployable Boom for CubeSats

Lead innovator: Luis Santos Soto

CubeSat components often need to be stowed before deployment into orbit. Faulty restraint mechanisms on components such as booms can add risk to a mission. Santos Soto's innovation allows a CubeSat boom to deploy itself with a double hinge system and torque springs.

NASA and Air Force Team Up

Jonathan Pellish
Electronic Parts Manager

Dr. Jonathan Pellish is agency electronic parts manager (Code 500) at NASA's Goddard Space Flight Center. He has a Ph.D. in electrical engineering from Vanderbilt University, and he has worked at NASA for 10 years.

NASA and Air Force Team Up to Study Market for SmallSat Electronic Components

Hundreds of CubeSats have launched into space over the past 15 years, and hundreds more missions are currently in the works. SmallSat developers keep pushing the boundaries of the platform, dreaming of missions beyond the confines of Earth's orbit.

The CubeSat platform in particular poses interesting challenges to satellite builders, especially when it comes to the manufacture of electronic parts. As NASA Electronic Parts Manager Dr. Jonathan Pellish says, "You can only cram so much functionality into such a small box."

Even though SmallSats are tiny, they have made a big splash in the market for Electrical, Electronic and Electromechanical (EEE) parts. Through an interagency agreement, NASA will work with the Air Force Research Laboratory to understand how the boom in SmallSat missions affects commercial suppliers of EEE parts, studying the impacts on the space industrial base as a whole. The partnership will also examine how to adjust the traditional approach to mission assurance when dealing with SmallSats.

Every EEE component on a SmallSat serves an important purpose, so when the pieces don't work or can't hold up to the harsh environment of space, they put the entire mission at risk. That's part of why Pellish wants to study the rapidly changing market for SmallSat electronics. As SmallSats adopt bigger and more significant goals, the reliability of these components grows ever more important.

"The SmallSat market for electronics has grown enormously," Pellish notes.

Though satellite parts go by many names, Pellish describes two broad categories of SmallSat components. He refers to the first as military or aerospace grade components. These parts go through significant review with independent requirements dictating how they're designed, assembled, tested and sold.

"The SmallSat market for electronics has grown enormously." —Jonathan Pellish, Agency Electronic Parts Manager

The other category includes EEE parts made commercially — those parts are also known as commercial off the shelf (COTS), which includes automotive and industrial grade parts. In this category, economic forces drive the availability of parts, not a third-party government authority like NASA or the Department of Defense. Alternative grade electronics have ballooned in the past few years, making it more challenging for assurance programs like the NASA Electronic Parts and Packaging (NEPP) Program to assess the viability of components.

"With the way the industry is changing, we need to expand the exploration of new methods of evaluation," Pellish explains.

Pellish is seeking answers to questions that have a direct impact on mission success for both small and large satellite missions. By studying the influence of SmallSat missions on EEE parts suppliers, researchers can learn how SmallSat activities might put pressure on companies that provide components to larger satellite programs, as well.

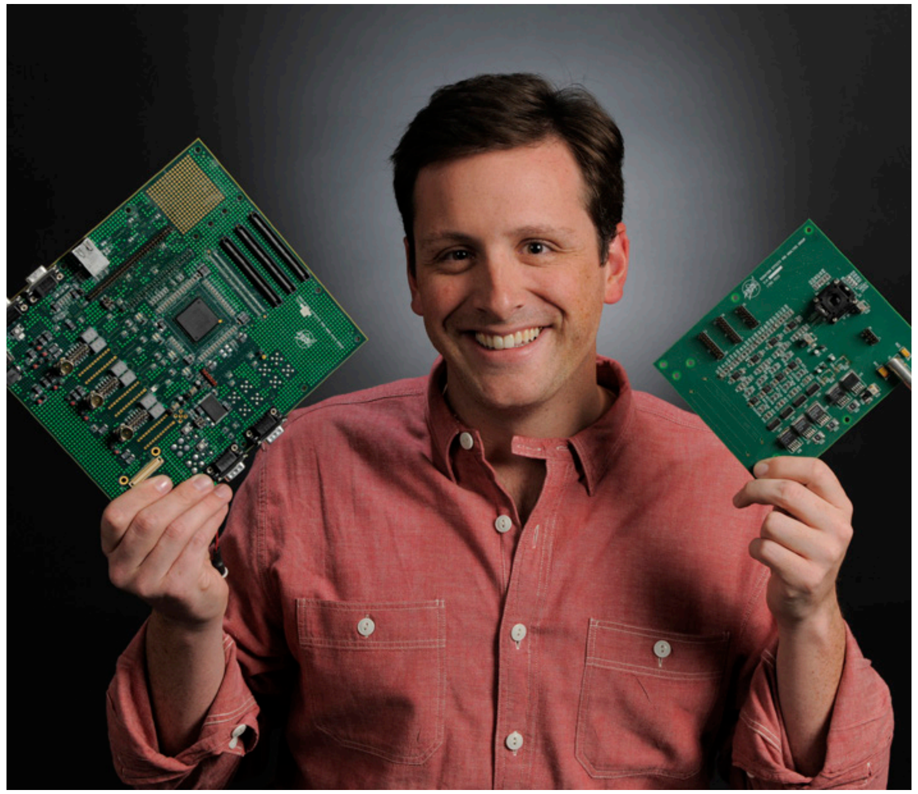
As for smaller missions with shorter timelines, it's important to have readily available components without sacrificing reliability.

The NEPP Program has supported analysis of SmallSat mission success for the past few years. These studies show relatively low mission success levels. "What guidelines can we provide to CubeSat developers to help raise the level of mission success so we have fewer dead on arrivals and early mission failures?" Pellish asks. "We have to figure out new approaches to delivering assurance for mission success in much more aggressive time scales and with fewer resources. It's an active area of research."

As the SmallSat community addresses how to tackle these challenges, Pellish encourages people to exchange data and other pertinent information.

"The NEPP Program thrives on these collaborations and partnerships," Pellish says. "At the end of the day, these will not be single organization solutions."

Those interested in learning more about these efforts can contact Jonathan Pellish at jonathan.pellish@nasa.gov. Other points of contact include NEPP Program Manager Ken LaBel (ken.label@nasa.gov) and NEPP Acting Deputy Program Manager Peter Majewicz (peter.majewicz@nasa.gov).



WHAT ARE EEE PARTS?

Electrical, Electronic and Electromechanical (EEE) parts include satellite components that use electricity, such as capacitators, microcircuits, relays, switches, transformers and transistors.

"The NEPP Program thrives on these collaborations and partnerships." —Jonathan Pellish, Agency Electronic Parts Manager

IceCube Mission Makes Strides

IceCube Mission Makes Strides in Advancing Radiometer Technology

Dr. Negar Ehsan (Code 555) clearly remembers the moment in 2017 when IceCube's instruments turned on in space, ready to collect data. As instrument system lead for the CubeSat project, Ehsan waited eagerly for the moment IceCube began transmitting.

When she was able to analyze the initial data set and confirm that IceCube was up and running, "I couldn't have been more excited," she shares.

By the time IceCube reached its one year anniversary in space, the CubeSat had demonstrated the successful use of an 883 GHz receiver in space. In addition to that, IceCube achieved the first global cloud-ice measurement from space at this specific frequency, producing usable data for scientists to study the climate effects of cloud ice on Earth.

This accomplishment involved a partnership with Virginia Diodes, Inc. (VDI), based in Charlottesville, Virginia. VDI has participated in NASA's Small Business Innovation Research program for more than a decade, collaborating with both NASA's Goddard Space Flight Center and the Jet Propulsion Laboratory.

While Ehsan and the rest of the IceCube team developed the instrument's antenna, intermediate frequency assembly, instrument power distribution unit, and instrument science and telemetry data acquisition board, VDI contributed the front end elements of the instrument, including the mixer and the local oscillator (LO) chain. These elements, Ehsan says, form the submillimeter wave part of the system. Once integrated, the 883 GHz heterodyne radiometer allowed IceCube to detect cloud ice from space.

"It was a very essential partnership," Ehsan says.

NASA missions tend to build on each other, and IceCube is no exception. Before IceCube, an airborne instrument named CoSSIR (Compact Scanning Submillimeter wave Imaging Radiometer), which flew attached to NASA's ER-2 aircraft, demonstrated the ability of the receiver to measure ice clouds.

> "Working with SmallSats can feel more like research than a mission. It's the best of both worlds." —Negar Ehsan, instrument lead on IceCube mission

Now that IceCube has successfully demonstrated the technology in space and increased its technology readiness level (TRL), Ehsan says the team hopes to use this type of receiver for future, larger missions.

Ehsan says partnering with companies like VDI can prove advantageous to missions like IceCube.

"You get to use the newest technology that we don't necessarily have the capability to produce," Ehsan adds.

Partnerships allow engineers at Goddard to work with the private sector on highly advanced technologies. When NASA and tech companies bring their joint expertise to the table, engineers can construct an instrument that otherwise would not exist.

–The front end elements of IceCube's radiometer came about through NASA's SBIR program.

Negar Ehsan
Research Electronics Engineer

Dr. Negar Ehsan is a research electronics engineer (Code 555) at NASA's Goddard Space Flight Center. She has a Ph.D. in electrical and computer engineering from University of Colorado, Boulder. She has worked at NASA for 8 years.

Currently, Ehsan is working on a planetary instrument called SELFI (Submillimeter Enceladus Life Fundamentals Instrument). If the team succeeds in increasing the instrument's TRL, their work could culminate in a new NASA mission: to search for certain chemicals fundamental to life in the plumes of water vapor that spray from the surface of Enceladus, a moon of Saturn.

Though she has worked on larger projects, Ehsan says she also enjoys the faster pace of smaller CubeSat missions. Because SmallSats can take on a higher level of risk than more expensive missions, team members have a certain amount of flexibility throughout the project. Teams are typically smaller, allowing people to take part in every detail.

"It can feel more like research than a mission," Ehsan says. "It's the best of both worlds."

–IceCube orbits the Earth in this artist rendition.

Q&A with Luis Santos

Luis Santos
Mission Systems Engineer

Luis Santos is a mission systems engineer on SmallSat projects (Code 599) at NASA's Goddard Space Flight Center. He has a bachelor's degree in mechanical engineering from the University of Puerto Rico-Mayaguez and a master's degree in systems engineering from Old Dominion University. He has worked at NASA for 13 years.

As a mission systems engineer at NASA's Goddard Space Flight Center, Luis Santos often juggles multiple missions at a time. Notably, two of Santos' primary projects launched to space over the past year. The first — Dellingr — is currently in orbit, and the second — HaloSat — made it to space inside a CubeSat deployer on May 21.

Though Dellingr and HaloSat are entering the later portions of their life cycles, Santos also works with younger missions. This includes GTOSat, a 6U CubeSat bound for the highly radiative environment of the Van Allen belts in 2021. As CubeSats continue to develop new capabilities, missions like GTOSat will demonstrate how SmallSats can stretch to accommodate the needs of the scientific community.

With GTOSat, Santos will help develop and find technologies capable of overcoming the barrier of radiation exposure. Santos discussed some of GTOSat's upcoming challenges in an interview with GSFC Tech Transfer News.

What is GTOSat?

GTOSat is a 6U CubeSat going to a geostationary transfer orbit (GTO) to study acceleration and loss of relativistic electrons in the Earth's outer radiation belt. This presents a big challenge because of the high radiation environment in comparison to our other CubeSat missions, which have featured low radiation environments, including low Earth orbit (LEO). The GTOSat concept is truly new. We're venturing into something we have done on larger spacecraft, but not necessarily on a CubeSat. We're currently working towards our mission requirements review (MRR).

What's usually happening at this stage of a mission?

As mission systems engineer for GTOSat, my main focus is looking at technical budgets and mission definitions. The first step involves defining requirements by talking to the scientists and understanding exactly what they're looking for. At the same time, we think about how we can do this from a resource-limited CubeSat/SmallSat perspective.

Since GTOSat was formulated a few years ago, we're also going back and revisiting the technical solution. Technology advances quickly and something may be available now that can do the work more efficiently or at a lower cost.

> "Radiation has become a hot topic in the last few years." — Luis Santos, Mission Systems Engineer, Code 599

What's unique about this mission?

The environment makes it unique and it's very challenging. We're going to GTO, which is a highly elliptical orbit. At its closest, GTOSat will be a few hundred kilometers from the Earth's surface. That orbit will run the satellite through the Van Allen belts, which contain high doses of radiation. Currently, the Van Allen Probes are studying the belts, and that mission will end soon, so GTOSat fills the gap between missions for certain types of observations. Based on GTOSat's success, we might fly multiple CubeSats to continue studying the radiation belts.

What are some specific challenges when flying a SmallSat through a harsh environment?

There are a few problems satellites encounter when flying through radiation. First, you have total ionizing dose, which is when a certain amount of radiation hits the satellite, and over time, it degrades components. Single event upsets also cause problems. That's when a high energy particle hits an electronic component and causes damage.

In terms of GTOSat, we want to make the core system — the C&DH board and the power system —radiation hardened, so it will be immune to single event upsets and can handle a high dose of radiation. For the peripheral components, the Small Satellite Reliability Initiative is currently working with industry to improve the reliability of individual components. We are currently evaluating available components.

How will you obtain the components you need?

Radiation has become a hot topic in the last few years, so vendors in the private sector have been working to improve radiation tolerance. Many of them are characterizing their current systems to radiation. They may not have designed their current systems for radiation initially, but some have tried to improve on those designs. They're not greatly radiation hardened, but they can be used for short missions. Right now, we're looking at peripherals that will comply with what we need, and we're trying to get as close as possible. We're also creating a vault so electronics are protected, and that reduces the amount of radiation that the inside of the box will endure.

We are evaluating some vendor radiation-tolerant power systems but the C&DH and power system baseline are internal developments. The rest will be vendor components, but we're not procuring parts or components yet.

Where do you see CubeSat missions going in the upcoming years?

Here at Goddard, we have four different science divisions: heliophysics, astrophysics, Earth science and planetary. While scientists can do a lot from Earth and from LEO, there are some questions that can only be answered by going farther. GTOSat will be sampling the core of the trapped radiation belt population from GTO, which can't be done from LEO. Right now, we see more proposals for LEO than for anything else, but missions beyond LEO will become more prevalent once more robust and radiation-hardened SmallSat technology is available.

What are the next steps for GTOSat after the mission requirements review?

After MRR, we have to work towards the flight solution. The next milestones are a baseline design and a final design review. We will be closing all the trades and perform analysis and simulations needed to confirm the baseline design meets the requirements.

What does it take to get to that next step?

We'll continue to do analysis and make sure everything is in place. We'll do some mechanical analysis to show that it will survive relevant environments. From a thermal perspective, we'll do some analysis based on our mechanical model, and we'll make sure it's going to survive the thermal environment and generate a final thermal design. It's the same for power — we'll size the solar panels and batteries to make sure everything works together. In addition, we'll do an attitude control system analysis to make sure we have the correct size of wheels, prove our algorithms and other similar actions. We will also perform the necessary analysis to demonstrate the selected communications system meets the requirements.

You're pretty much trying to show analytically and on paper that your system works. It's really more of the analysis side of the process. This stage can take anywhere from three months to a year. If we have a mission where we're reusing a bus, it can go faster, but like anything in the spacecraft world, it can vary depending on the challenges that arise during the process.

> "While scientists can do a lot from Earth and from LEO, there are some questions that can only be answered by going farther." —Luis Santos, Mission Systems Engineer, Code 599

PARTNERSHIP SPOTLIGHT

WHO: NASA's Goddard Space Flight Center and Thermal Management Technologies (TMT)

WHAT: Diminutive Assembly for Nanosatellite deploYables (DANY), a technology created for the Dellingr mission

WHEN: Licensing agreement signed May 2018

WHY: DANY uses spring-loaded metal pins, a circuit board and other innovations to securely stow and release deployable parts of a SmallSat, reducing risk deployment failure. TMT learned about this technology at the 2017 Small Satellite Conference and chose to license it.

Small Satellite Reliability Initiative

Michael Johnson
Chief Technologist

Michael Johnson is chief technologist for the Engineering and Technology Directorate (Code 500) at NASA's Goddard Space Flight Center. He has a master's degree in electrical engineering and computer science from the Massachusetts Institute of Technology. He has worked at NASA for 26 years.

Scientists at NASA's Goddard Space Flight Center have big ideas for SmallSat missions. Though SmallSat missions traditionally have stayed close to Earth, current NASA SmallSat concepts include a trip to Venus, a visit to an asteroid and a journey to one of the misshapen moons of Mars.

As missions grow more and more ambitious, the SmallSat community has initiated discussions about how to use technology to increase the likelihood of success for missions using this platform. Michael Johnson, chief technologist for the Engineering and Technology Directorate at Goddard, has played a key role in these discussions by helping form the Small Satellite Reliability Initiative.

The initiative aims to increase small satellite confidence by partnering collaboratively with government and private sector developers and stakeholders, defining approaches to achieve their objective.

GSFC Tech Transfer News caught up with Michael Johnson in his office at Goddard to learn more about the initiative.

How did the Small Satellite Reliability Initiative come about?

About two years ago, I met with some of my colleagues at JPL to discuss CubeSats, and we all realized that mission confidence of CubeSat-based missions often was not consistent with our needs. We decided some action was necessary to address this. Since no one else was doing anything, we decided we would.

What types of missions are you addressing, specifically?

We're talking about a range of missions. This initiative impacts everything from technology demonstration missions and LEO (low Earth orbit) missions to deep space missions. It's a challenge that we're trying to address because currently, we often don't know what we're flying. Therefore, it's challenging to have confidence that we'll meet our mission objectives. We're trying to define some approaches that will address this challenge. We're considering a range of approaches, because the risk posture for a tech demo mission is completely different from a Mars mission, for example.

What progress has been made since the initiative began?

First, pulling together a cross-agency, public-private team that works together effectively was quite an accomplishment. We didn't want this effort to be a government-only effort, and we realized we needed to work hand in glove with our colleagues from the private sector if this were to be successful.

Second, we've identified three approaches relevant to the mission confidence challenge. One involves defining best practices and design/development guidelines consistent with the confidence targets and resource (cost and schedule) constraints. The second approach is sharing knowledge. Communication barriers are often problematic within and across organizations. We find knowledge does not flow from one place to another because of those barriers. We're attempting to facilitate the effective flow of knowledge across the SmallSat sector so that developers, end users — anyone with a need — have ready access to the knowledge they require to consistently design missions that meet the confidence posture they're targeting. The third approach is a model-based approach to mission confidence.

We're still working on all three, and the two that will have the nearest term impact are the best practices and design/development guidelines approach, and knowledge sharing. The model-based approach is less mature. It has great potential, but it's going to take a bit more time to mature.

What took place at your most recent meeting?

We assembled about 40 people with roughly an equal split between government, industry and academia. We presented the approaches we've derived to date to and requested feedback from the attendees on whether or not we were on the right track. We also wanted to hear if there are approaches or actions we should be pursuing.

We received some good feedback. We've focused the design development guidelines to items the attendees think will have the greatest impact. We also received feedback on knowledge sharing approaches we should consider to improve this important area. There is still work to do with the model-based approach. We have to make sure the entry barrier for users is low. If the environment is a challenge to use, most people will not use it, so it has to be something fairly easy for the community to adopt.

> "What excites me most is working with smart people to expand the possible, doing things that could not be done yesterday." —Michael Johnson, Chief Technologist, GSFC Engineering and Technology Directorate

How does this apply to SmallSats specifically?

You want your processes to be consistent with the type of mission and platform, and SmallSats in general are about efficiency compared to "BigSats," so we want the systems and processes to be commensurately efficient. As I said, we don't want to break the model. SmallSats are cost efficient, schedule efficient, and agile. We don't want to change that.

What would success look like at the end of this process? What would be a successful outcome?

We would like to develop approaches embraced by the community that allow us to retire uncertainties in the area of SmallSat mission confidence. As a result, the entire SmallSat community will be advanced. Vendors will have guidance they can use and knowledge they can share to develop systems that are more consistent with users' desires. Developers will have tools they need to balance mission confidence and development constraints, and we will not break the SmallSat model. In the end, we will be able to achieve more science and other operational missions with these platforms. The possible has been expanded.

Could you explain the concept of mission confidence in more detail?

There's risk associated with any kind of mission we fly. However, we can take steps to intelligently reduce the risk, and in doing so, have an increased understanding of our confidence in mission success. We can be more intentional about the choices we make on what to do and what not to do. This effort intends to inform us on these choices given different types of missions in different environments at different price points. In other words, if you have a certain amount of funding, how should you spend it to most effectively reduce your mission risk?

How does mission confidence apply to SmallSats specifically?

Sometimes missions fail because of actions we take or have not taken due to a lack of information or knowledge. This is relevant to all space missions, but especially relevant to SmallSats given many members of the community are relatively new to spaceflight, and given greater cost constraints associated with these platforms.

Could you illustrate that with a specific example?

Assume we desire to fly a mission in a radiation environment, and we don't know the steps to go through to make the mission consistent with that environment. This initiative will provide design/development guidelines that tell us if you're flying in this environment, these are the sort of things you should do to increase the likelihood the systems will operate reliably. In addition, there will be a knowledge space that allows you to query what other components have flown in this environment, ground test results, and on-orbit performance.

Part of the knowledge space can be somewhat analogous to Yelp. For example, if a restaurant has one star, I'm not going to go there. Likewise, if we share knowledge and determine that the subsystem provided by ACME, Inc. has one star, users know they probably don't want to use that system. This also gives feedback to ACME by telling them about an issue with their system. Feedback will be beneficial from both user and provider perspectives.

How would users access this information?

We will use a website hosted by the Small Spacecraft Systems Virtual Institute (S3VI) (https://www.nasa.gov/smallsat-institute). One of S3VI's uses will be a knowledge repository, so people who go there will be able to query different topics, such as what components or systems have flown, their performance, radiation test results, and so forth.

> "Diversity of thought and collective competence allows us to expand what is possible." —Michael Johnson, Chief Technologist, GSFC Engineering and Technology Directorate

What is Goddard's role in this initiative?

Given our 55-year heritage in building spaceflight systems, we have a good understanding of what works and what does not. We bring to the table our collective competence and experience with spaceflight systems. We also realize that our experience has potential disadvantages. Our knowledge on how to build satellites that work might blind us to new, radical approaches to apply to these SmallSats. We need to be aware of this potential downside.

Goddard also brings to the table a push by our science colleagues to achieve compelling missions to environments where SmallSats have not flown and at cost efficiencies not achieved by most previous missions. This push drives us to innovate.

What are you most excited to see happen as a result of these collaborations?

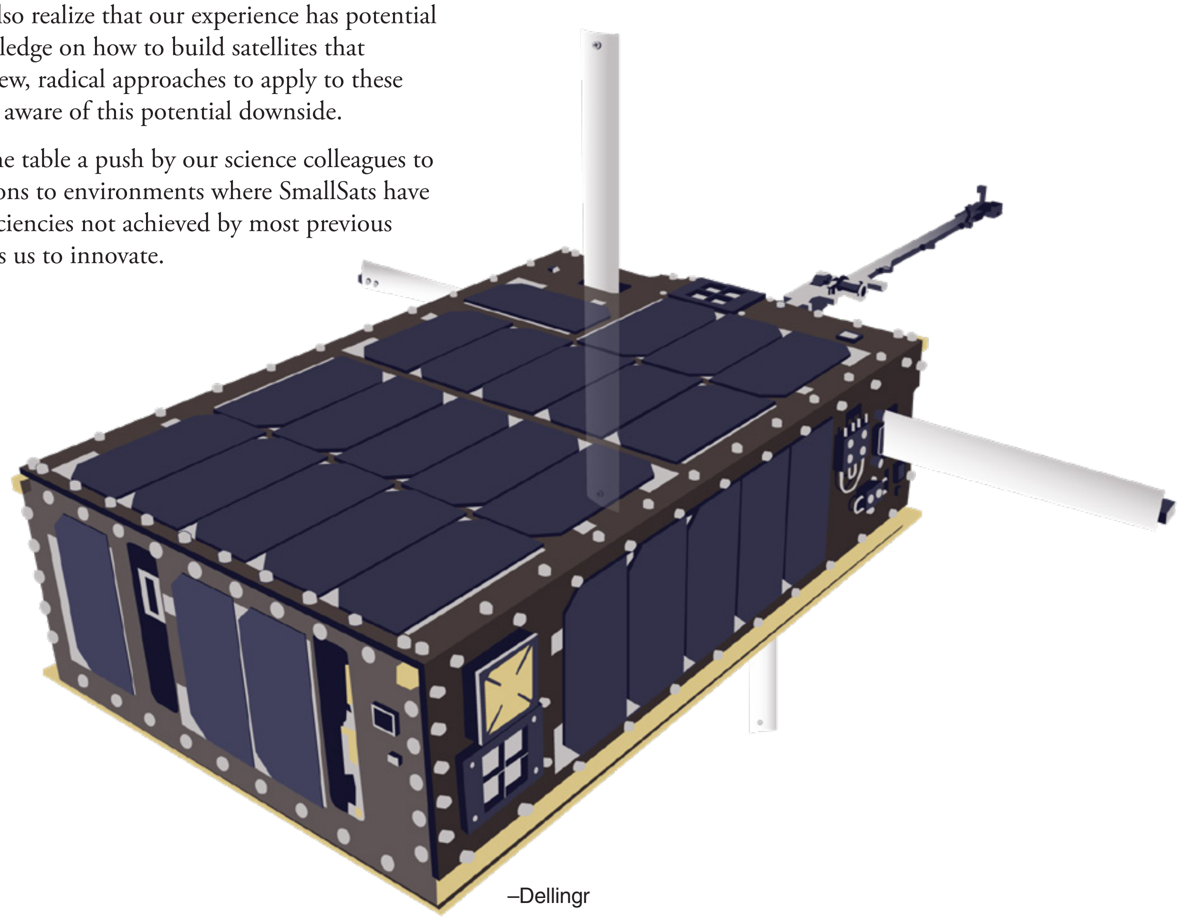
What excites me most is working with smart people to expand the possible, doing things that could not be done yesterday.

Is there anything else you'd like to add about this initiative?

This is not a closed initiative. We want to hear from industry, academia, and our colleagues in government. Diversity of thought and collective competence allows us to expand what is possible. We encourage folks who might not be involved now to be involved.

When is the next meeting or convening of the group?

We're meeting in early November. It's an invite-only meeting because it loses effectiveness if it gets too large. If someone would like an invitation, they're more than welcome to contact me at michael.a.johnson@nasa.gov.



–Dellingr

SmallSat Missions Get a Strong Start

Ben Cervantes
Lead, Mission Planning Lab

Ben Cervantes is lead of the Mission Planning Lab (Code 589) at Wallops Flight Facility. He has a bachelor's degree in computer engineering from California Polytechnic University, San Luis Obispo, and he has worked at NASA for 13 years.

William Mast
Lead Systems Engineer

William Mast is lead systems engineer of the Mission Planning Lab (Code 598) at Wallops Flight Facility. He has a bachelor's degree in mechanical engineering from Drexel University, and he has worked at NASA for 29 years.

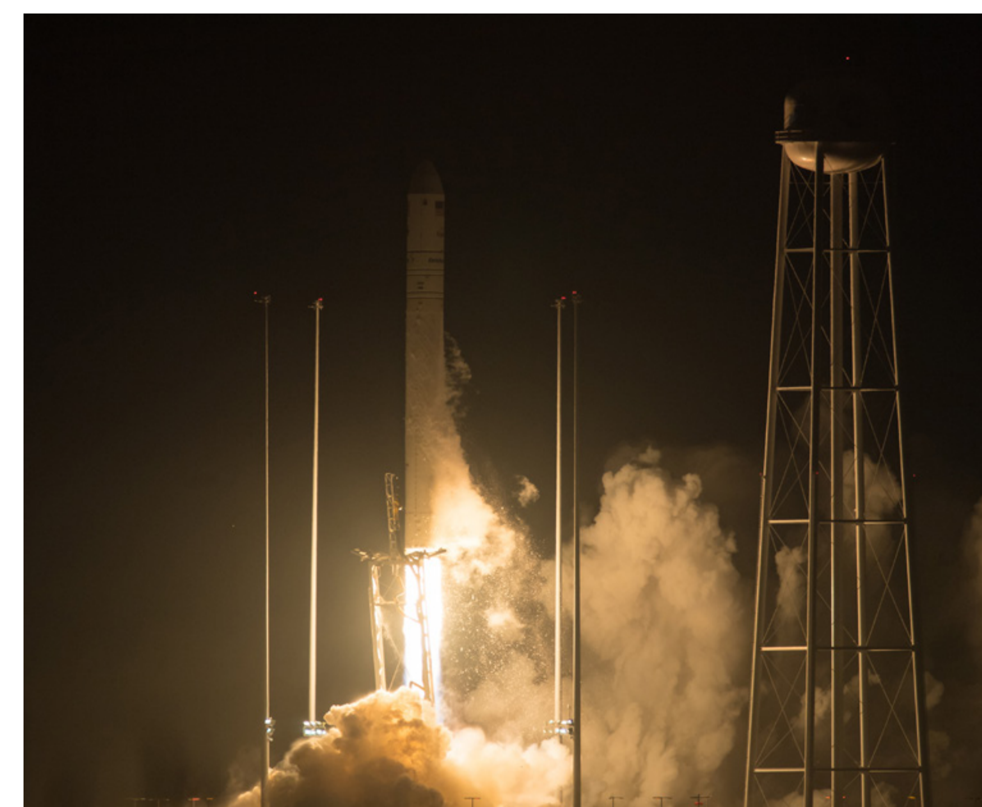
Mission Planning Lab Gives SmallSat Missions a Strong Start

In the early hours of May 21, Orbital ATK's Antares rocket roared to life as it launched spacecraft Cygnus skyward from NASA's Wallops Flight Facility. Bound for the International Space Station to deliver supplies, Cygnus carried with it an assortment of 15 CubeSats, including the University of Iowa's HaloSat, a 6U CubeSat designed to measure X-rays surrounding the Milky Way galaxy.

Four years ago, Wallops engineers Ben Cervantes and Will Mast played a role in HaloSat's early development at the Wallops Mission Planning Lab, where the mission went through a week-long study to turn a science concept into a feasible mission and give the CubeSat a solid shot in a competitive proposal market.

Since 2014, the Mission Planning Lab has worked with NASA SmallSat developers and their partners to provide services in systems engineering, 3-D modeling, simulation, flight trajectory formulation and more. Over the course of one action-packed week, engineers across a range of specialties come together to meet with a mission's science team and crunch numbers. At the end of the process, scientists gain a better understanding of how to achieve their research objectives, and they come away with a valuable packet of information detailing the technical specifics of their mission.

Mast, the lead systems engineer for Mission Planning Lab, says the process can add a level of certainty and refinement as a mission takes shape. "You gain the confidence to say this mission can be done," he shares.



–Orbital ATK's Antares rocket launches from NASA's Wallops Flight Facility.

PARTNERSHIP SPOTLIGHT

WHO: NASA's Wallops Flight Facility and Blue Canyon Technologies, Inc.

WHAT: Spacecraft bus for HaloSat mission

WHEN: HaloSat launched into space May 2018

WHY: Blue Canyon Technologies had previously contributed a spacecraft bus to the University of Colorado's successful MinXSS mission, which flew in 2016. Blue Canyon — based in Boulder, Colorado — builds spacecraft buses and components with a focus on small satellites.

Mission Planning Lab

Jumpstarting missions in one week

Even the tiniest CubeSat has a group of engineers, scientists, and other dedicated team members working to support it. In the early stages of a mission, scientists come to the table with specific research goals, but it's not always clear how best to use technology to accomplish those goals.

Labs like the Mission Planning Lab run missions through a collaborative process, seeking to fill in details by balancing variables such as estimated costs, risk areas, functional systems, and recommended future work.

"With this lab, you have the benefit of a whole team at your disposal working for you in a short period of time," explains Cervantes, lead for the Mission Planning Lab. "I would say that it's more cost effective for a PI to quickly get these products instead of having a few people work things out over six months."

> "With this lab, you have the benefit of a whole team at your disposal working for you in a short period of time." —Ben Cervantes, lead for MPL

Cervantes and Mast describe the week-long study as fun, dynamic, and fast-paced. "With each mission, you get to learn something new," Cervantes adds. "There's a different challenge each time."

Depending on the size of the mission, assembled teams can consist of anywhere from 10 to 15 people, each taking on a different aspect of planning. Cervantes pulls team members from both NASA's Goddard Space Flight Center and Wallops, bringing in the appropriate level of expertise needed for any given mission.

"It's nice to have all the resources of Goddard at our disposal," Mast says. "If we have an obscure or detailed technical question that needs answering, we can make some calls and get an answer in a couple of days."

When seeking assistance with leads, Cervantes and Mast often call on Jennifer Bracken, who manages the Integrated Design Center at Goddard. The Integrated Design Center's two components, the Mission Design Lab and the Instrument Design Lab, have provided resources to larger scale missions for nearly two decades, offering a wealth of institutional knowledge for the younger lab to utilize.

"They've done a great job of supporting us," Cervantes says. "While we're not a part of their organization, we appreciate how they look out for us."

The Mission Design Lab at Goddard typically handles studies of missions in Classes A, B and C, while the Mission Planning Lab takes on missions in Class D and below. This division of labor has helped the labs avoid duplicating their capabilities. As a result, the Mission Planning Lab has tackled more than 20 CubeSat studies, finding a niche in the small satellite world.

"The number of studies fluctuates from year to year, and that's partly due to proposal calls, because some of them are every other year," Cervantes explains.

In order to turn out useful results in only one week, Cervantes and Mast have to work quickly, and part of that involves some preparation in advance.

Teamwork at the Mission Planning Lab

Before a study starts, Cervantes and Mast rely on the mission's PI and the rest of the mission team to fill out pre-work forms, detailing the mission's high level characteristics, which include mission class, cost, target launch date, instrument and data requirements, mass and power. The team works through these forms a few weeks before the beginning of the study, helping the engineering team to hit the ground running from day one.

"On Monday, it's a lot of brainstorming and doing some out-of-the-box thinking," Mast says.

First thing Monday morning, the science team comes to Wallops and presents their mission to the planning team. The scientists walk through their mission, describing their scientific objectives and the instruments they'll need to accomplish them. The engineers

jump in with questions to tease out details and determine how the satellite's subsystems will need to adapt to the mission.

–Cygnus launched on May 21, carrying 15 CubeSats.

At this point, everyone involved works to determine the feasibility of the mission, an essential step in moving the project forward. If a satellite on an interplanetary mission needs to dump data every week, but the rotation of the planet prevents the satellite from transmitting 10 months out of the year, the team needs to reassess the objectives of the mission.

Mast says the team has a low-tech secret weapon to get the creative juices flowing – a double-sided white board. The science team descends on the board with markers, making sketches, graphs and charts while explaining the nuts and bolts of their mission.

"Having the team in the lab producing drawings in real time is invaluable to the process," Mast adds.

Ideally, by the end of Monday, the team has pulled together the baseline components of the mission. If all goes well, team members can proceed with reasonable certainty of functionality. The week flows best when at least one member of the science team is on hand to answer questions and participate in conversations as they unfold.

Refining mission details

On Tuesday, the engineering team drafts a preliminary baseline of the mission's components, including a CAD model.

Pieces start falling into place on the second day as the team considers requirements such as volume restriction, an especially applicable quandary when dealing with SmallSats and CubeSats. The shape of the satellite starts coming together as engineers decide where to place apertures, star trackers, solar panels or other components.

> "Having the team in the lab producing drawings in real time is invaluable to the process." —Will Mast, lead systems engineer for MPL

"If something is not going to close, we usually know that by Tuesday, and we can propose to the science team where to go from here," Mast says.

Sometimes PIs have to make difficult decisions about their missions. A science team might want to affix five instruments onto their SmallSat, but the limitations of their spacecraft mean they have to select only the instruments that will fit. As conversations slip into greater levels of technical detail, the team elucidates mission specifics.

For example, since CubeSat missions are often power limited, engineers must consider how the satellite will perform in terms of power consumption once in orbit. A satellite might need to recharge every other orbit, and scientists need to account for this.

"We walk through all those scenarios with the scientists, and those discussions sometimes slip into Wednesday," Cervantes says.

Wednesday brings what Mast calls the "Wednesday morning surprise," an unexpected road block that inevitably pops up in the middle of the study. The team addresses risks as thoroughly as possible and refines subsystem numbers, finalizing models and running analyses until Thursday, when the team convenes to tie up any loose ends. Cervantes and Mast make sure every team member stays in communication throughout the process.

"Even if we're all in the same room, sometimes wires can get crossed, so part of our job is making sure we're all on the same page," Cervantes notes.

> "On Monday, it's a lot of brainstorming and doing some out-of-the-box thinking." — Will Mast, lead systems engineer for MPL

More collaborations in store

On Friday, the engineering team presents their completed mission design back to the science team. The presentation begins with a systems-level overview of the requirements and a description of the spacecraft, the life of the mission, and a "day in the life." Each discipline engineer takes a turn presenting their work and giving the science tea a chance to ask questions and get clarification.

About a week later, the engineering team compiles all the fruits of the study in a package and presents the package to the PI. The package includes the presentation slides, along with a model of the satellite, images of brainstorming sessions from the whiteboard, charts, cost estimates and any ancillary information the science team might find valuable moving forward. From there, PIs have ownership of the study and its contents. If they choose to move forward with the mission, they pull together a proposal team and use the study in their proposal efforts.

Several CubeSat missions designed in the Mission Planning Lab have already flown, including HaloSat and BurstCube. In early 2014, MPL conducted trade studies and optimizations on the IceCube mission. To gain real world CubeSat experience, engineers from the lab went on to design, build, integrate and test the IceCube 3U CubeSat, eventually deploying it from ISS in May 2017. The IceCube mission, intended to last 30 days to test a radiometer in space, has flourished into a fully successful science mission continuing to map ice crystals in clouds over a year later.

Looking forward, Cervantes says he would like to see more interconnectivity between Goddard and Wallops, helping team members from the two centers communicate more effectively through interfaces such as interactive smart boards. Cervantes also sees potential benefits in establishing relationships with design labs at other NASA centers.

In terms of future missions, Cervantes wants the SmallSat community to know that the Mission Planning Lab can work studies with university PIs, as long as they are partnering with Goddard scientists. Additionally, the lab performs reviews on existing missions, serving to verify mission details and conduct trade studies. Those interested in working with the lab can reach out to Cervantes directly at benjamin.w.cervantes@nasa.gov.

While the studies can be demanding, Cervantes and Mast say they welcome opportunities to spend a week in the Mission Planning Lab.

"I really look forward to these studies," Mast shares. "I feel like I've been through a fascinating crash course by the end of each study."

"It's a very creative process," Cervantes adds.

–Wallops Flight Facility is located on Wallops Island, Virginia.

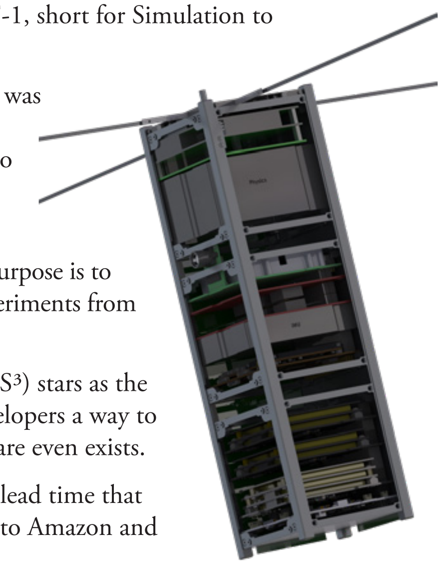
Open Source Software

Justin Morris
Lead, JSTAR Lab

Justin Morris is lead of the Jon McBride Software Testing and Research (JSTAR) Lab and the Independent Test Capability (Code 180) at NASA's Independent Verification and Validation (IV&V) Facility. He has a master's degree in electrical engineering from West Virginia University, and he has worked at NASA for 11 years.

Open Source Software Streamlines Process for Testing SmallSats

The very first spacecraft built in West Virginia reached completion this year, thanks to a collaboration between NASA's Independent Verification and Validation (IV&V) Facility, West Virginia University (WVU) and the NASA West Virginia Space Grant Consortium (WVSGC). The history-making CubeSat is called STF-1, short for Simulation to Flight 1, and it heads to space in 2018.



"We at IV&V were interested in SmallSats, and WVU was working on a proposal as well," explains Justin Morris, project manager for STF-1. "We thought, 'Why do two proposals when we can do one together and make it stronger?'"

STF-1 is a multitasking CubeSat — while its primary purpose is to demonstrate technology, it also carries three science experiments from WVU.

NASA Operational Simulator for Small Satellites (NOS^3) stars as the main character of the STF-1 mission. NOS^3 gives developers a way to emulate hardware in a virtual setting before the hardware even exists.

"Typically, commercial components have some sort of lead time that can take months," Morris explains. "It's not like going to Amazon and getting your product in two days."

While the team waits on CubeSat components to arrive or be built, they can continue moving the mission forward without the hardware. For example, using NOS^3, The STF-1 team modeled STF-1's electrical power system before receiving it from commercial company Clyde Space, and they ran flight software on the digital model.

"We modeled the system using vendor documentation, which let us work earlier and without the hardware in place," Morris says.

This flexibility led Morris and his team to finishing STF-1's software months before launch. With NOS^3, engineers can complete work earlier in a satellite's life cycle, saving valuable time and allowing multiple stages of development to happen in parallel.

> "We're pretty proud that this is the first spacecraft built in the state." —Justin Morris, project manager for STF-1

The package of software programs performs a number of tasks related to testing flight software, with NOS serving as the core technology. NOS is a framework that simplifies the often complicated process of setting up software development and test environments for missions. NOS^3 takes simulation concepts developed by IV&V's Jon McBride Software Testing and Research Lab for larger missions such as the James Webb Space Telescope and translates them to the SmallSat platform.

STF-1 demonstrates how NOS³ can benefit a SmallSat mission throughout its entire life cycle. In the case of STF-1, NOS³ has helped the team at IV&V work more smoothly with partners at WVU.

"In these types of collaborative projects, you're relying on folks for other pieces," Morris says. "We were able to give the WVU mechanical aerospace team NOS³ early on, enabling them to develop their instrument software."

STF-1's current launch window is set for summer 2018, when it will launch out of New Zealand aboard Rocket Lab USA's Electron orbital rocket.

While WVU contributed science instruments to STF-1, WVSGC used STF-1 to engage K-12 students in STEM by holding competitions and doing giveaways. Kids in West Virginia were challenged to build their own STF-1 models out of Legos, and WVSGC partnered with IV&V's student outreach program to promote the mission.

Several STF-1 team members grew up in West Virginia, another reason for fanfare surrounding the mission.

"We're pretty proud that this is the first spacecraft built in the state," Morris adds.

He praises the team that came together to facilitate the mission. From the spacecraft developers and students at WVU to the interns who helped with outreach, "it's not often you work on a project that goes to this level of exceptionalism," he notes.

As for NOS³, it's headed toward release as an open source software in summer 2018. Morris says the Air Force Institute of Technology wants to train students to use NOS³ by incorporating it into Air Force space systems courses. Two NASA interns who learned NOS³ recently transferred to the Air Force Institute of Technology (AFIT) to help integrate the technologies into space system coursework.

"It's always great when we can benefit others doing similar work," Morris says.

–The Jon McBride Software Testing and Research (JSTAR) Team gathers around STF-1.

Q&A with Tom Dixon

Tom Dixon
Deputy Project Manager

Tom Dixon is deputy program manager for the SmallSat Project Office (Code 851) at NASA's Goddard Space Flight Center. He has a bachelor's degree in computer science and a minor in biology from Loyola College (now University) of Baltimore, Maryland. He has worked at NASA for 29 years.

Small satellites have weaved their way throughout Tom Dixon's career at NASA, and now, he has a chance to work with them directly as one of two new deputy project managers with the Small Satellite Project Office (Code 851). The other new deputy, John Hudeck, is based at Wallops Flight Facility, while Dixon is based at NASA's Goddard Space Flight Center's Greenbelt campus. Dixon started out as a contractor at Goddard in 1987, converting to a civil servant in 1989. Over his nearly 30 years with NASA, Dixon says he's worked on a variety of interesting projects, but some of his favorite involve experimental platforms with relatively quick timelines.

Although Dixon had only been in his new position for three weeks at the time of this interview, he sat down with GSFC Tech Transfer News to share his perspective on SmallSats, including his thoughts on how the SmallSat Office might help to advance the platform.

How does your previous work connect to SmallSats?

There are a few connections. Back in the late 1980s, I was involved in a program called the Get Away Special program. Get Away Specials were small investigations. They could be science or technology focused, and they were flown in the cargo bay of the Space Shuttle. At the same time, there was a related program called Hitchhiker, and these were more advanced kinds of experimental platforms. Both Get Away Specials and Hitchhikers were flown in the cargo bay of the Space Shuttle. We flew many, many of those. It was a really exciting time. We had standard capabilities, but then we could also develop unique capabilities if required.

This is where SmallSats come in — there was a need to deploy small spacecraft. The Hitchhiker project was able to do that, because we could enclose small satellites into canisters, with opening door systems that would expose the satellites to space and then deploy them. That was my first involvement with small satellites, but since the Hitchhiker program ended, there has been a continuing need and desire for less expensive access to space for small investigations.

> "I don't want people to think that what we're doing is simply limited to CubeSats." —Tom Dixon, Deputy Project Manager, Small Satellite Project Office

As for connections to small instruments, I transferred from GOES-R to the PACE (Plankton, Aerosol, Cloud, ocean Ecosystem) Project two years ago on a detail. For PACE, Goddard was building an in-house bus as well as the primary instrument, the Ocean Color Instrument (OCI).

My job was to find a small, inexpensive instrument to supplement OCI science, and I ended up finding two that provide polarimetric measurements of the atmosphere and clouds. One of the two instruments is based on a CubeSat instrument named HARP (Hyper-Angular Rainbow Polarimeter) from University of Maryland, Baltimore County (UMBC). We took instrumentation from the CubeSat design and worked with UMBC to interface that instrumentation over to a larger spacecraft platform.

What attracted you to working with SmallSats?

Harkening back to the Get Away Specials and the Hitchhikers, it was just ridiculously fun. Almost all of us were very young engineers and technicians, and in some ways, we learned as we went.

PARTNERSHIP SPOTLIGHT

WHO: NASA's Goddard Space Flight Center and University of Maryland, Baltimore County (UMBC)

WHAT: Hyper-Angular Rainbow Polarimeter (HARP), a CubeSat instrument being adapted for a larger mission, PACE

WHEN: HARP-2 heading toward preliminary design review

WHY: The PACE mission needed small, inexpensive instruments to supplement its primary instrument, OCI. By collaborating with UMBC to use HARP, Goddard reduced costs and adapted a fully developed instrument instead of building one from scratch.

Q&A with Tom Dixon

Small satellites are a little bit different because most of the satellites are being built as a result of proposal calls. Since NASA funding is involved, there is a greater expectation of success. Still, the aspect of relatively quick turnaround, with multiple small satellites being worked at the same time, is very exciting.

For example, I was on the GOES-R project for 11 years, and there were people who worked on GOES-R for 15 years or more. It's very important because it's a national asset, but there's something to be said for being able to do multiple missions and working with different organizations. You learn a little bit about all different kinds of science. In the few weeks I've been here, I've learned about gamma ray bursts, Van Allen radiation belts, and challenges to optical communication beyond LEO. I'm not expected to be an expert, but I get to learn and be involved.

How would you describe your experience so far?

The SmallSat missions just keep coming. I have three people to call back today who all have potential ideas for proposals, and they all have their different take on the science they want to do.

"It's not the intent of our office to compete against commercial vendors, but instead to develop new small satellite bus capabilities." —Tom Dixon, Deputy Project Manager, Small Satellite Project Office

It's really good to be able to ask a lot of questions. You can't pretend that you know all the answers. That's probably the biggest thing. In the Get Away Special and Hitchhiker days, we worked with Wallops for a period of time, and I really enjoy working with that group of people and the culture. Greenbelt's roots were sounding rockets and balloons, and Wallops is carrying that legacy forward. I think that's a really positive thing.

As I mentioned earlier, we need to define and articulate what we are doing that's new and important to the science community. We're creating that right now. I'm looking forward to the whole creative aspect of trying to invent something that doesn't yet exist to help science.

What are the three missions you're managing?

One is called PetitSat, one is called BurstCube, and then there's GTOSat. BurstCube is a SmallSat studying gamma ray bursts. Seeing a gamma ray burst is an extremely rare event. There is an observatory up right now called the Neil Gehrels Swift Observatory. It's looking at the sky trying to capture gamma ray bursts, and it can view a certain percentage of the skyline, but not the whole sky. Having BurstCube up there increases the percentage of coverage, so you've got this multimillion dollar spacecraft, and for just a little bit more, you can expand the capability. It's a really nice investment.

GTOSat has a couple of different purposes. One is to study the Van Allen radiation belts, and the other is a technology demonstration to expand our CubeSat carrier capability. Finally, PetitSat will study irregularities in the ionosphere.

Are CubeSats currently the primary focus of this office?

I try to use the term SmallSat to refer to a wide range of small satellites. I don't want people to think that what we're doing is simply limited to CubeSats. There's a particular definition for CubeSats, and that's just part of our objective. We would like to explore the possibility of flying satellites larger than the traditional 6U or 12U CubeSat using streamlined processes to reduce cost, use disciplined engineering to selectively target risk reduction opportunities, and develop new capabilities not currently available for small spacecraft.

From my perspective, this is all pretty new. We are in the process of defining our office and its objectives. CubeSats, obviously, are the basis right now. IceCube was successfully launched, deployed and is operating on orbit. HaloSat is scheduled to launch on OA-9 in late May and deploy later in the summer. In my new job duties I've been given the responsibility for the three previously mentioned CubeSats from a project management standpoint. We are currently discussing possible collaborations with numerous potential CubeSat and SmallSat proposers. While we want to expand our potential CubeSat users, we also need to get into the SmallSat market. We have to identify what we bring to the table, and this is another area where I want to work. There are plenty of companies providing CubeSat systems. It's not the intent of our office to compete against commercial vendors, but instead to develop new small satellite bus capabilities. I think we've got some good ideas about what we can do to expand those capabilities.

What are your goals for this office?

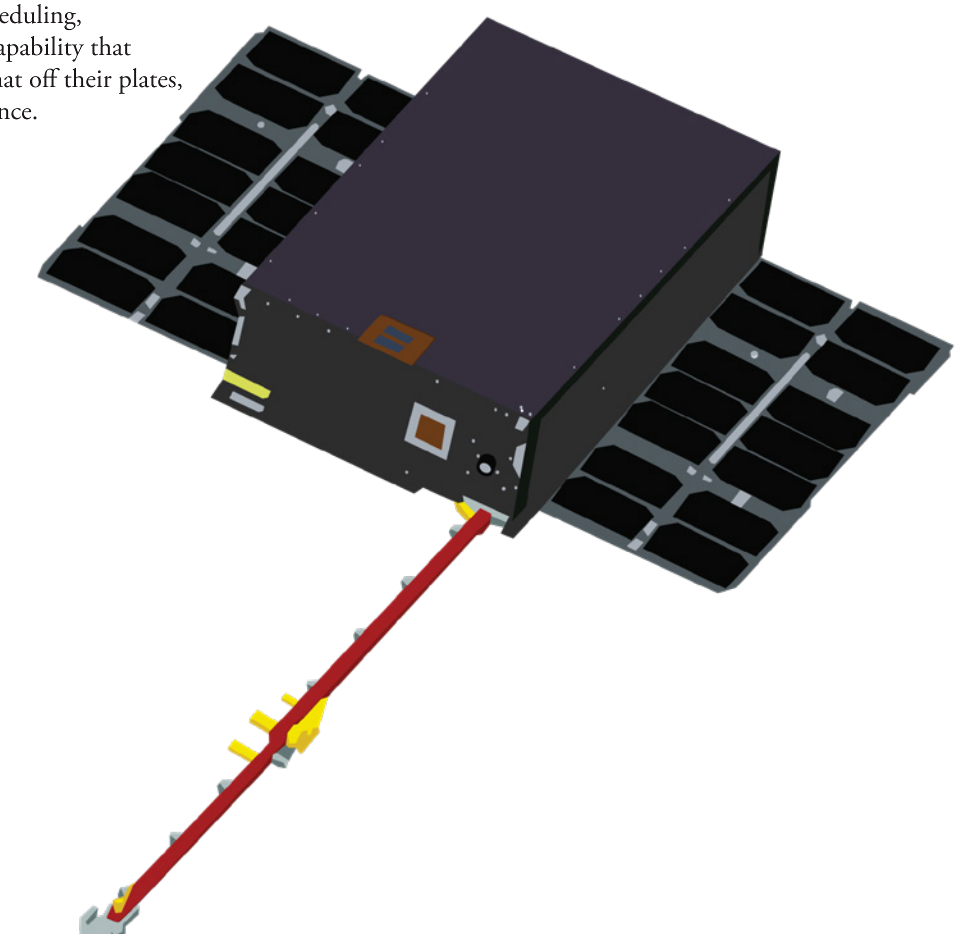
I want it to be fun. And so far, it's been pretty fun. I want to work with investigators to scale the level of reviews and involvement with our office to meet their expectations. I don't want to be a one-size-fits-all office. I'm going to make sure our hardware is bringing something to the table as a value-added or unique service. Also, our office itself should bring something to the table, rather than just adding another layer of management to their effort. That is in no one's best interest.

Right now I'm just working on the basics of a scheduling, configuration management and documentation capability that investigators can use. If I can help take some of that off their plates, then they can focus on their instruments and science.

Eventually, I'd like to have enough satellite users of our office services so that we can have a pool of engineering expertise that they could draw on. Each organization doesn't have every skill to the same level, so it would be great to bring in somebody that could help with thermal design, electrical design or radiation tolerance, for example. I want to fill in the gaps.

Is there anything else you would like the SmallSat community to know about this new role?

I want to avail myself to anyone who wants to talk at any point. Of course, currently we're working out our SmallSat Office definition, so I may not be able to answer all questions right now. Still, any questions provided give me input to know what to focus on, so it's very valuable. Even though I may not have an answer right now, the SmallSat community can help steer me toward things they want me to do.



–GTOSat

Small Satellite Project Office

Tom Johnson
Small Satellite Manager

Thomas Johnson is the small satellite manager for the SmallSat Project Office (Code 851) at NASA's Goddard Space Flight Center/Wallops Flight Facility. He has a bachelor's degree in engineering from the University of Maryland, and he has worked at NASA for 29 years.

"These SmallSats offer the opportunity to do science at a low cost that otherwise wouldn't be possible."
—Tom Johnson, Small Satellite Project Office Manager

Highlights from the Small Satellite Project Office

NASA's Goddard Space Flight Center launched one of its first successful small satellites in 1960, making spaceflight history when weather satellite TIROS-1 assumed orbit around Earth. Even though the spacecraft was built nearly 60 years ago, it had a mass of 122 kilograms, meeting the modern definition of a SmallSat. Much like SmallSats of today, TIROS-1 was a trailblazer, paving the way for advances in meteorology by using data collected in space to produce accurate weather forecasts.

"All our satellites were small to start out with, but then they began to grow in size as we moved through the 20th century," says Tom Johnson, manager of the Small Satellite Project Office at Goddard/Wallops Flight Facility.

Now, with the SmallSat movement fully in swing, satellites are sizing down again for reasons of cost and convenience. To address this, the Goddard/Wallops Small Satellite Project Office (Code 851) formed in 2017, tackling the boom of interest in small satellites across many groups, from government and industry to academia. The nimble SmallSat platform "democratized space," as Johnson puts it, allowing smaller companies and start-ups to enter the space arena and make contributions to advance the field.

It's a global phenomenon. Manufacturing companies in the U.S. produce CubeSat components, and even internationally, companies have joined in the SmallSat component fray.

Johnson hired two deputies to join the SmallSat Office in April 2018: Tom Dixon at Goddard and John Hudeck at Wallops. The three members of the SmallSat Office have a combined 86 years of NASA experience, and they seek to coordinate and simplify the tremendous amount of activity and partnership opportunities surrounding SmallSats. Johnson shared with GSFC Tech Transfer News his perspectives on the growing potential of SmallSat capabilities, the end-to-end services provided through the SmallSat Office, and the wealth of current collaborations churning at Goddard.

With at least 50 SmallSat missions being considered across Goddard, Johnson and his deputies will have plenty to keep them busy.

A promising platform

Goddard's involvement with CubeSats began in 2007, when Goddard formed a relationship with the National Science Foundation and its CubeSat program, which provides funding for student CubeSat projects. Wallops supports the program by offering technical and management support, and the facility lends a hand with integration, testing and documentation.

From there, Goddard's immersion in SmallSat projects has only grown, with interest from members of both the science and technical communities. SmallSats are an ideal spacecraft for both science and technology demonstrations, and increasingly, PIs have utilized the platform.

"Scientists want to do missions using small spacecraft, and these SmallSats offer the opportunity to do science at a low cost that otherwise wouldn't be possible," Johnson explains. "A larger mission might cost $200 million, but with SmallSats, you can get down to $15 million."

However, liability remains an issue, with some in the community siting CubeSat reliability at around 50 percent.

"The number is factual, but at the same time, it's overstated somewhat because a lot of these CubeSat missions are done by universities or other organizations focused on training students," Johnson says. "Our goal is to make them work in space."

Moving forward, scientists want to conduct SmallSat missions to planetary destinations, and in order to reach that goal, SmallSat developers need to build satellites with a high level of reliability. The effort to improve reliability started with the Small Satellite Reliability Initiative, a Goddard-supported group studying the risks of the platform.

The office aims to identify technology gaps and generate more partnerships with members of the SmallSat community. Additionally, the SmallSat Office seeks to connect the many moving parts of the SmallSat community and provide end-to-end services to scientists in pursuit of better coordinated mission support.

Goddard is the only NASA center that can serve a SmallSat mission from beginning to end.

End-to-end capabilities

Goddard is the only NASA center that can serve a SmallSat mission from beginning to end, according to Johnson. Goddard's scientists and engineers can support missions from concept, through launch at Wallops, and mission operations using the center's ground stations. The SmallSat Project Office provides overall project management and support through all stages of a satellite's life cycle.

A satellite's story usually starts with a concept or science goal. Scientists and engineers come together to develop a plan with the Mission Planning Lab at Wallops. The team generates a whole mission solution, including requirements, design and resources to support the creation of a proposal.

After submitting a proposal and sending it to NASA Headquarters, the proposal must be selected and awarded funds to move forward. If selected, Goddard can provide support to the mission in the form of project management, systems engineering and other services.

"We work across all divisions within Goddard, including Greenbelt and Wallops," Johnson notes, adding Goddard's Independent Verification and Validation (IV&V) Facility to the list of collaborators.

Small missions require the same support functions as large missions, but SmallSat teams can streamline paperwork processes and tailor them to cut back on cost. Goddard can provide management support, including scheduling and engineering staff for all spacecraft systems and science instruments.

Next, Johnson and his team offer review support, moving missions to the point where they then connect with an external launch provider, which takes care of interfacing with the launch vehicle.

"They assist with safety and range requirements, and it reduces cost significantly," Johnson says.

CubeSats typically sit inside a dispenser, powered off, until deployed from the rocket or ISS, depending on the deployment mechanism. Once in orbit, Wallops assists with mission operations

–Orbital ATK's Antares rocket prepares to launch from NASA's Wallops Flight Facility in Virginia.

using an 18m UHF Ground Station. Johnson says that currently, the facility supports NASA and NSF missions, although they frequently interact with other satellite developers.

"We get called on a fairly regular basis to try and find lost satellites," Johnson adds. "Folks will lose their signals and a lot of the time we can find signals that their stations aren't capable of detecting."

Missions and collaborations

Three missions in particular, HaloSat, CubeRRT and IceCube, demonstrate the importance of partnerships when tackling SmallSat projects.

HaloSat, managed by Wallops, took about two years to reach completion. It launched from Wallops on OA-9 in May 2018 and is expected to be deployed from ISS later in the summer. The mission broke ground by being NASA's first astrophysics CubeSat. It featured the development of a new science instrument, built to study X-rays in the ring surrounding the Milky Way Galaxy.

"We're really excited to get it operational," Johnson says.

HaloSat's PI, Dr. Philip Kaaret, works at the University of Iowa, and NASA partnered with the university to accomplish this mission. Colorado-based Blue Canyon Technologies provided the spacecraft bus for HaloSat and for CubeRRT, which launched alongside HaloSat in 2018.

> "We work across all divisions within Goddard and Wallops." —Tom Johnson, Small Satellite Project Office Manager

CubeRRT (pronounced Cube-ert), led by Dr. Joel Johnson of Ohio State University, detects radio-frequency interference, helping figure out how to filter artificial radio noise so scientists can identify natural microwave radiation. NASA's Jet Propulsion Laboratory and Goddard worked together to develop CubeRRT's instrument.

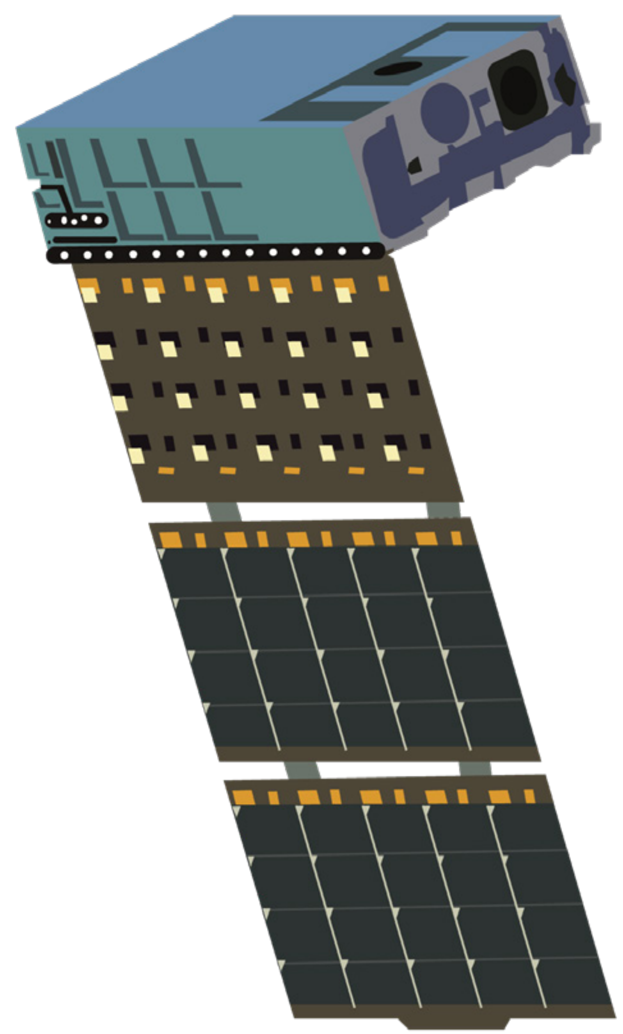
The third mission, IceCube, celebrated its one-year anniversary in orbit on May 16, 2018. The 3U CubeSat blew its one-month mission timeline out of the water, and it successfully collected cloud ice data during its year in space. IceCube's 883-GHz radiometer was developed under a NASA Small Business Innovative Research contract with Virginia Diodes, Incorporated. This key collaboration allowed IceCube to generate the first global map of ice clouds.

As IceCube nears the end of its mission, engineers at Wallops have begun formulating an end-of-life plan to collect any remaining science data from the spacecraft and choose which experiments to run before it reenters Earth's atmosphere. These experiments will push the capabilities of the spacecraft and learn more about its limitations, testing out high-risk operations before pulling it out of orbit.

"We're going to stress the communications system a little bit and put a lot of data through it to work it harder," Johnson shares.

From the initial idea that sparks the life of a SmallSat to its fiery end through the atmosphere, partnerships with academia and industry play an integral role in mission success. As SmallSat developers tackle ever more ambitious technology challenges, such as propulsion systems and radiation tolerance, the community will need to turn to collaboration to accomplish its goals.

"We're working hard to develop these technical solutions, and if we succeed, we'll see SmallSat science missions go out to Mars, the moon, asteroids and comets," Johnson adds.



–HaloSat

SPO in the Community

"Girls Who Code" Career Panel and Networking Session

January 29, 2018

NASA Goddard's Strategic Partnerships Office (SPO) participated in a "Girls Who Code" Career Panel and Networking Session for students at Calvert and Patuxent high schools in Maryland. SPO staff members shared stories about their backgrounds in engineering and marketing, emphasizing to the high school students how individuals from very different professional backgrounds can contribute to the NASA mission.

Annual Goddard Sciences and Exploration Directorate New Year's Poster Party

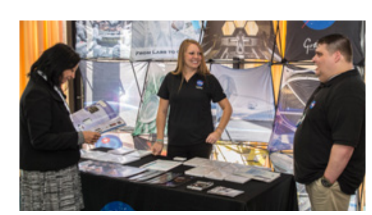
January 30, 2018

At the Annual Goddard Sciences and Exploration Directorate New Year's Poster Party, SPO took part in the festivities by displaying a poster about the importance of submitting New Technology Reports (NTRs) to protect inventions and generate licensing and partnership opportunities. SPO joined Earth and space scientists, as well as invited presenters from the Applied Engineering and Technology Directorate, in celebrating the year's accomplishments in research. During the event, more than 100 NASA employees dropped by to chat with SPO representatives.

Opening Ceremony for Prince George's County Economic Development Corporation

February 28, 2018

SPO exhibited at the opening ceremony for the Prince George's County Economic Development Corporation (PGCEDC), the county's new business development resource center. PGCEDC will provide local business services, some of which align with Goddard technology transfer commercialization activities. Fellow attendees included local government and members of tech startups.



56th Annual Goddard Memorial Symposium

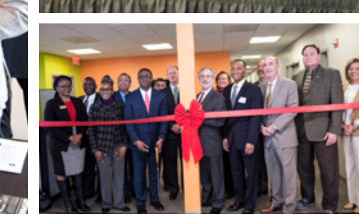
March 14-15, 2018

SPO participated in the 56th Annual Goddard Memorial Symposium in Greenbelt, Maryland. The theme of this year's symposium was "Exploration, Science, and Technology: Partnerships for the Next Decade," with emphasis on short-term initiatives as well as long-term projects and visions. SPO Chief Nona Cheeks moderated a panel titled "Innovative State Partnerships: Goals and Challenges" that featured industry leaders from Maryland, Virginia and West Virginia.

2018 Maryland Technology Transfer Summit

April 20, 2018

More than 200 people, including staff from SPO, attended the 2018 Maryland Technology Transfer Summit in April. Hosted by the Federal Labs Consortium (FLC) at the National Institute of Standards and Technology (NIST) headquarters in Gaithersburg, Maryland, the summit attracted policy makers, innovators, technology managers and other stakeholders from industry, academia and federal labs in Maryland. The day started with a panel featuring Maryland's state senators Chris Van Hollen and Ben Cardin. Maryland Governor Larry Hogan attended the summit with Maryland Commerce Secretary Mike Gill. Goddard Center Director Chris Scolese participated in a Maryland Federal Labs panel. They emphasized the importance of technology transfer for Maryland's industry and economy. SPO's technology transfer exhibit showcased several technologies and Goddard's unique abilities to local businesses and startups.



NASA Goddard *Tech Transfer News*
https://partnerships.gsfc.nasa.gov

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