

“The CubeSat and SmallSat initiative at NASA Goddard is enhancing the potential for deep space, long duration, and “beyond LEO” applications.”

—IMAGE BY NASA

# CubeSat/SmallSat

VOLUME 12, NUMBER 3 | SUMMER 2014

## IN THIS ISSUE:

- |    |   |    |                          |
|----|---|----|--------------------------|
| 2  | From the Chief                          | 17 | SBIR/STTR Success Story  |
| 3  | CubeSat development at NASA Goddard     | 19 | Patenting Perspectives   |
| 7  | Interviews with NASA Goddard Innovators | 22 | NASA Goddard in the News |
| 15 | CubeSat Commercialization Opportunities | 24 | Related Technologies     |

# tech transfer



Nona  
Cheeks

## [ FROM THE *Chief*

# From the Chief

Since our last issue of *Tech Transfer News* featuring the CubeSat platform (Spring 2013, Vol. 11, No. 2), the state of the art has progressed so much at NASA Goddard and in the larger arena that we felt a follow up issue was in order. To acknowledge the substantial opportunities made possible by the broader small satellite platform, we have expanded the scope of our feature to include both CubeSat and SmallSat projects. We are also excited to release this CubeSat sequel in anticipation of the 2014 Small Satellite Conference. We hope this magazine will inform its readers and stimulate conversation amongst conference participants.

Last spring, I began the CubeSat issue with this statement: “Doing more with less—in these days of tight budgets and limited funding, that has become a way of life.” If that was true then, it is even more pertinent now that NASA Goddard find ways to maximize resources with in-house projects and collaborations with outside partners. As you will read in the multiple interviews with NASA Goddard scientists and SmallSat experts, the “more with less” philosophy is intrinsic to the platform. This means not only finding ways to be innovative within our own capabilities, but also taking advantage of commercially available “off-the-shelf” components and talent from universities, institutes, and industries working to advance the field.

At NASA Goddard, we are proud of our accomplishments in the small satellite arena, and hope *Tech Transfer News* does its part once again to showcase the CubeSat/SmallSat platform. On the cover, NASA Goddard’s Firefly, a CubeSat designed to study lightning, was launched on November 19, 2013 and made its first transmission when a NASA team at Wallops Flight Facility established contact on January 6, 2014. As part of NASA’s ongoing CubeSat Launch Initiative, NASA Goddard’s CeREs CubeSat, a compact radiation belt explorer, was selected this past February. We continue to be on the cutting edge of instrument and process design, and through our own initiatives such as the CubeSat Architecture Study, we are providing leadership for the future of the small satellite platform. Our goal is to get NASA Goddard technology into the growing market for more reliable SmallSats, where commercial applications like land imaging and communications are emerging as clear opportunities for tech transfer.

Fittingly, the theme of this year’s Small Satellite Conference is “The Commerce of Small Satellites.” This serves as a perfect example of successful tech transfer from science and research into new markets and commercial applications. What began in the lab with the purpose of advancing knowledge and inquiry, now has the potential to transform the ability of communities in the most remote parts of the world to access information. Or with SmallSat-generated imaging, energy companies will be able to utilize data much more effectively in mobilizing assets while also monitoring climate change. Maximizing resources in a responsible manner, doing more with less, is a philosophy the CubeSat/SmallSat platform can help commercialize.

### **Nona Cheeks**

*Chief, Innovative Technology Partnerships Office (Code 504)*  
NASA Goddard

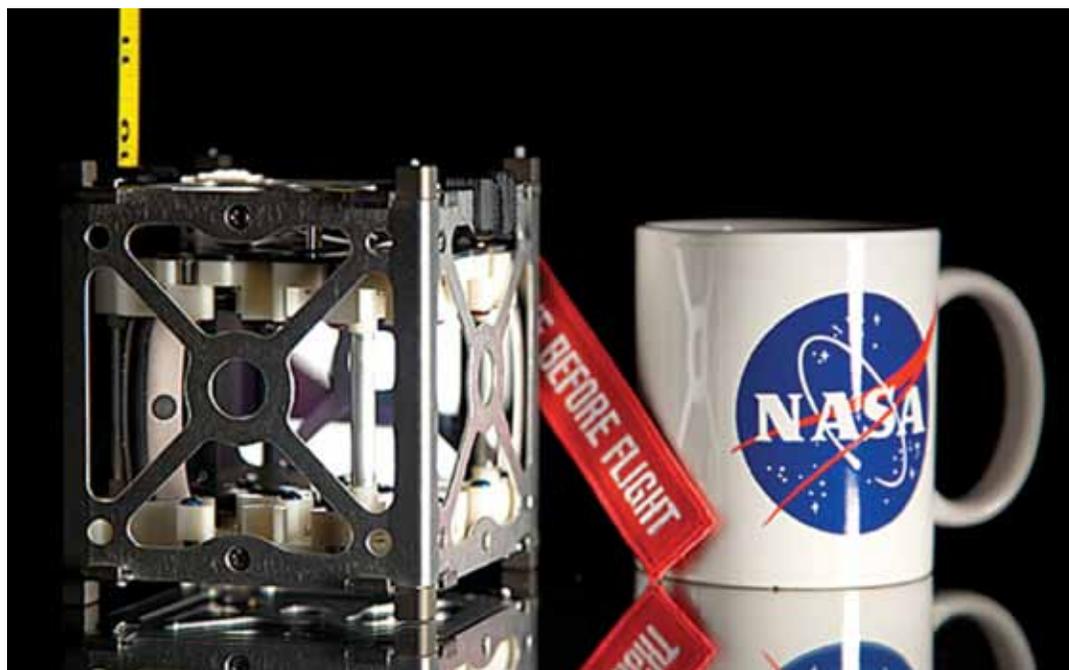
# CubeSat Development

**A**lthough the CubeSat standard was originally developed primarily for academic purposes, there has been growing interest in adapting CubeSat instruments to perform important scientific observations and commercial applications. Researchers are actively working on making CubeSats more robust and versatile, to fully explore and develop the potential this platform offers. NASA Goddard is a significant partner in this effort, with several projects underway based on CubeSat standards. In addition, NASA Goddard innovators are helping to extend CubeSats into deep space.

This article presents a quick overview of CubeSats. We then review several examples of NASA Goddard projects based on the CubeSat platform.

## CubeSats: From the classroom into space

In his paper, “The CubeSat: The Picosatellite Standard for Research and Education,” Dr. Jordi Puig-Suari, Professor of Aerospace Engineering at California Polytechnic State University, explains how the CubeSat standard was initially conceived in 1999, through a collaboration between Cal Poly and the Space Systems Development Laboratory (SSDL) at Stanford University [[http://cubesat.calpoly.edu/images/More\\_Papers/cps2008.pdf](http://cubesat.calpoly.edu/images/More_Papers/cps2008.pdf)]. Its primary function was to provide students a way to gain hands-on experience with designing and building operational satellites, without incurring the high costs historically associated with satellite development.



▶ A 1U CubeSat.

—PHOTO BY NASA

To do this, two important characteristics were defined for CubeSats:

- Volume is confined to a 10 cm cube, with a mass not to exceed 1.33 kg. This defines a “1U” CubeSat; the specification has subsequently been amended to include larger devices.
- Projects are built from readily available off-the-shelf components.

To further reduce cost, CubeSat projects have now been launched as secondary payloads carried aboard other scheduled missions. The first CubeSat was launched in 2003 on board a Russian rocket. Since then, dozens of other CubeSat projects have been placed on orbit. (For more information about CubeSats including latest news, see the CubeSat Project web site at <http://www.cubesat.org/>.)

Originally, CubeSat functionality was relatively modest; its goal was to provide “Sputnik-level” capabilities. But as students familiar with this platform graduated into professional careers, they began to look to CubeSats to perform important scientific applications associated with their job responsibilities. In this regard, CubeSats offer some important advantages in terms of cost and development time. To exploit these advantages, the science and engineering communities are actively examining ways to enhance CubeSat functionality and overcome some of its inherent limitations.

## CubeSats and Wallops Flight Facility

One key challenge to using the CubeSat platform for serious science and commercial applications is propulsion. As noted earlier, CubeSat missions have historically been launched only as secondary payloads. The CubeSat community is now looking for a dedicated launch capacity for placing CubeSat projects onto Earth orbit and beyond.

The National Science Foundation (NSF) selected Wallops Flight Facility in 2008 to collaborate with their CubeSat activities, a collaboration that is ongoing. Currently, the services that Wallops Flight Facility provides to the NSF and their CubeSat teams include the following:

- Mentoring to CubeSat developers from the Wallops Flight Facility engineering staff.

- Use of lab test facilities such as GPS simulation, antenna testing, and vibration testing.
- Interfacing with the launch vehicle provider.
- Ground station support with a 60-foot dish. This allows CubeSats to transmit at up to 200 times the typical data rate.

“The value-added support that we provide to the CubeSat community is an extension of the support we provide to the suborbital community,” states Scott Schaire (former Small Satellite and Orbital Payloads Projects Manager for Wallops Flight Facility, Suborbital and Special Orbital Projects).

There are now numerous CubeSat proposals in the works. For example, the DoD and NASA are looking for a dedicated launch vehicle for CubeSat that can place satellites in orbit for \$2 million and under. Some proposed vehicles are currently in development. According to Mr. Schaire, “CubeSats provide a method for placing instruments in orbit quicker than with conventional satellites.”

Ben Cervantes (Mission Planning Lab Lead, Wallops Flight Facility) echoes this theme. “Wallops has a lot of experience in suborbital flight, usually involving



► The Orbital Sciences Corporation Antares rocket launches with the Cygnus spacecraft onboard, Sunday, July 13, 2014, at NASA's Wallops Flight Facility in Virginia. Along with supplies for the International Space Station, Cygnus also contains 32 CubeSats.

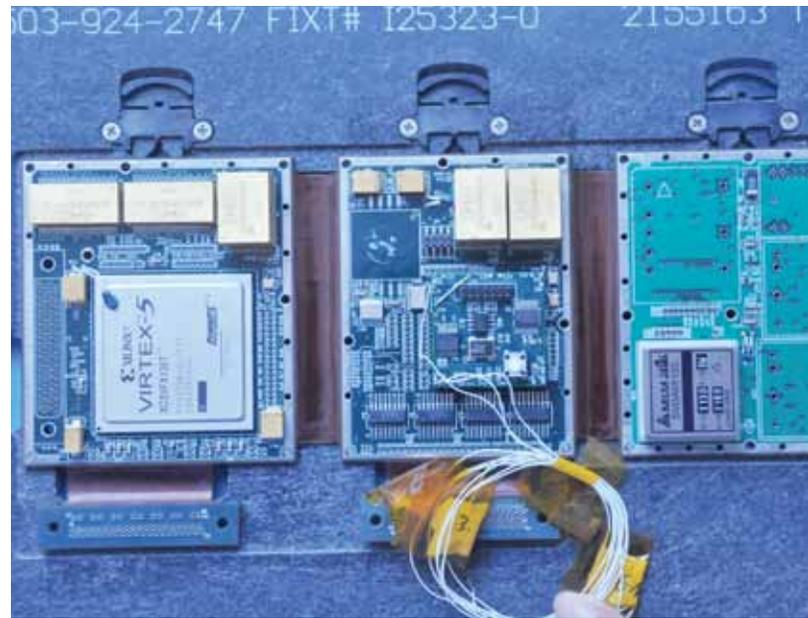
—PHOTO BY NASA

satellites or other UAVs [unmanned aerial vehicles]. CubeSats fit nicely into this niche, and aligns very well with what Wallops does, which primarily involves low-cost missions. We're developing technologies to be more and more miniaturized, to fly on UAV missions. When a technology is sufficiently miniaturized, it can fly on a CubeSat to gather science data.

Propulsion technologies beyond rocketry are also being examined. "We're looking at other ways to launch CubeSat projects, including high-altitude balloons" notes Mr. Cervantes. "For example, there's a program called High Altitude Student Payload, or HASP for short. This program involves teams of students developing balloon-borne projects. So far we've launched somewhere between 12 and 16 payloads, using a gondola structure. One project involved launching a number of instruments over Antarctica. These devices were in the air for 50 days, reaching altitudes of 115,000 to 130,000 feet. That's above 99.9% of the Earth's atmosphere, so for all intents and purposes they were in space."

## NASA Goddard helps expand CubeSats into deep space and "beyond low earth orbit" orbits

Beyond propulsion, a major limitation in the CubeSat standard's potential as a deep-space and long-duration "beyond LEO" science platform is its current lack of robustness and reliability. NASA Goddard is playing an important role in addressing this limitation. "We're attempting to increase reliability of the CubeSat platform through the development of a scalable, highly reliable bus," states Thomas Flatley (Branch Head, Science Data Processing Branch). "The avionics subsystems will be made using highly reliable parts and our 'flight' design processes, like our regular satellites. We're working with universities, other government agencies, and private companies to identify who is (or can be) providing quality components. The goal is to take a combination of the best existing DoD/commercial components, plus new components that we design at NASA Goddard, and use them to build a bus that can meet all of our performance requirements. Both deep space projects and long duration Earth orbiting missions (LEO, polar, MEO, GTO/GEO) will need highly reliable CubeSats to be successful."



► *SpaceCube Mini.*

—PHOTO BY NASA

Another NASA Goddard effort is SpaceCube Mini, a miniaturized version of the SpaceCube 2.0 high-performance data processor small enough to be used on CubeSat missions. As Mr. Flatley explains, "one proposed synthetic aperture radar instrument on a mission to Mars could fill up its onboard data recorder with nine minutes of data. With SpaceCube a mission could process raw data in real-time and only store processed data or extracted information, yielding significant savings in on-board storage and downlink bandwidth, and enabling 24/7 operations."

This technology can offer similar advantages in Earth science, in applications such as hyperspectral imaging and lidar. SpaceCube provides both data reduction and onboard "situational awareness." For example, a SpaceCube processor could detect events such as a forest fire or algal bloom on-board in real-time, and then send live images to on-site firefighters or research ships at sea.

Other areas in which NASA Goddard can provide special value to the CubeSat effort include electronics miniaturization, where NASA Goddard has a large and diverse body of dedicated technical expertise; and communications, especially in S-band and X-band.



► NASA selected the Compact Radiation Belt Explorer (CeREs) mission as one of 16 small satellites to receive funding under its CubeSat Launch Initiative. CeREs Principal Investigator Shri Kanekal holds an early version of one of the mission's solid-state detectors.

—PHOTO BY NASA

## CubeSat missions at NASA Goddard

Several CubeSat projects are currently in development at NASA Goddard. Among these is the National Science Foundation Firefly mission, launched on November 19, 2013 from the Wallops Flight Facility. Firefly is exploring the relationship between lightning and so-called Terrestrial Gamma Ray Flashes (TGFs), a phenomenon first discovered in the 1990s.

Firefly is investigating which types of lightning produce TGFs, to help scientists better understand the cumulative effect that terrestrial lightning has on the upper atmosphere and near-Earth space environment.

Another NASA Goddard CubeSat project is the Compact Radiation Belt Explorer (CeREs). This is a 3U CubeSat that will be placed in a high inclination LEO. CeREs will study charged-particle dynamics in Earth's Van Allen radiation bands, and provide details about the electron burst phenomenon—short bursts of electrons that precipitate into the Earth's atmosphere and their role in the loss of electrons in the radiation belts. Expected to launch in 2015, the CeREs CubeSat will carry a novel sensor called the Miniaturized Electron and Proton Telescope to augment the science of the Van Allen Probes, a major flagship mission. CeREs was selected by NASA's CubeSat Launch Initiative and developed in part with Goddard Internal

Research and Development (IRAD) program funding. It follows on the heels of the successful launch and operation of Firefly.

A new CubeSat is in the works at NASA Goddard with the goal of providing a reliable bus to the research community for future missions. The Dellingr CubeSat, emerging out of the Heliophysics Science Division and the Geospace Physics Laboratory, is a 6U satellite that will continue the efforts at NASA Goddard to miniaturize instruments and develop highly reliable components for accommodation on CubeSat and SmallSat platforms. In striving to create more robust technologies for CubeSat missions, the Dellingr team is looking at adhesion processes (for instance, between solar cells and the solar panel board) and altitude control systems, which require specific orientations for optimal data capture and transmission.

## NASA Goddard and the future of CubeSats

As we've seen, NASA Goddard is playing a critical and growing role in helping extend CubeSat capabilities. The ultimate goal is to develop CubeSat technologies that deliver high accuracy, lower power, multi-node, and distributed operation suitable for deep space. In this way, NASA Goddard innovation has become an important driver behind the ongoing evolution of CubeSat from a teaching tool to a robust platform for contributing to the advancement of Earth and space science.

### Takeaways

CubeSat is a standard originally developed to provide students hands-on experience with small satellites. In recent years, the CubeSat standard's purpose has expanded to include science applications. NASA Goddard is actively helping CubeSats evolve into a more robust platform suitable for applications outside the classroom. For example, Wallops Flight Facility is enabling innovative new missions via value-added services for the CubeSat community. The SpaceCube initiative at NASA Goddard is designed to enhance CubeSats for potential deep space, long duration, and "beyond LEO" applications. NASA Goddard is also adopting CubeSats for several upcoming missions, including CeREs, Dellingr, and IceCube.

**M**any people at NASA Goddard are involved in CubeSat related projects. Much of this work is designed to help advance the evolution of CubeSats from a relatively limited standard intended primarily for student and educational purposes to a rugged platform suitable for significant science research and even commercial applications. NASA Goddard is actively working on enhancing CubeSats propulsion, positioning, onboard intelligence, power, and many other areas required for deep space.

In this interview, several NASA Goddard innovators discuss their ongoing work with CubeSat projects, and how this platform may be of significant interest and value to the future exploration of space.

**Q.** *How did NASA Goddard become involved with SmallSats?*

**Michael Johnson:** Goddard has a long history with SmallSats, dating back to the Small Explorer Office we established in the early 90's. So we've understood the potential to achieve compelling Earth and Space science via small spacecraft for quite some time.

**Q.** *What is NASA Goddard's interest in SmallSats?*

**Michael Johnson:** The capabilities of miniaturized systems are rapidly increasing while the resources (mass, volume, power) they require are decreasing. At the same time, NASA's fiscal environment motivates competitive projects and missions to achieve compelling science at lower cost and schedule than usual. We see small spaceflight instruments hosted by small spacecraft as a potential response to this challenge.



**Michael Johnson**  
**AETD CHIEF  
TECHNOLOGIST**

**Code:** 500

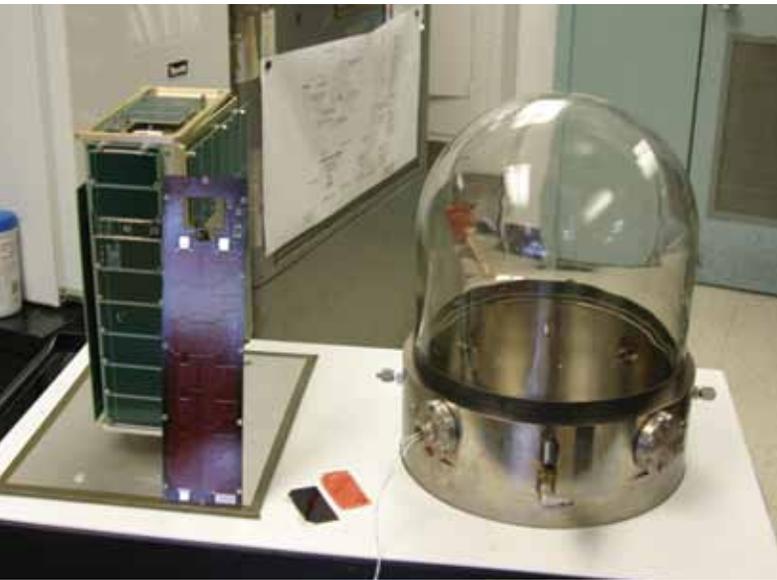
**Years with NASA:** 21

**Education:** BSEE, MSEE, EE, Electrical Engineering and Computer Science, Massachusetts Institute of Technology

But our interest is not only in the "what"- the SmallSat. It's also in the "how"- the end-to-end systems and processes used to develop these satellites. So we're defining what we call "scalable lean processes" that will support delivery of SmallSats that exhibit higher levels of reliability, yet at lower cost than your typical small satellite. These processes will result from merging two high performing, yet different Goddard workforces- that at our Wallops Flight Facility, where we have years of expertise and excellence building suborbital platforms, with that at our Greenbelt campus, where we've built numerous spacecraft as well as developed and successfully flown more science instruments than any other organization on the planet. We're convinced that merging these cultures has the potential to advance the performance/cost calculus.

**Q.** *What SmallSat projects are active at NASA Goddard?*

**Michael Johnson:** We have a few missions in the works, including the Compact Radiation Belt Explorer (CeREs), a CubeSat project led by Shrikanth Kanekal that will study primary



► *Mock-up of a CubeSat solar panel bonding experiment, and bell jar used for de-gassing adhesives.*

—PHOTO BY NASA

radiation belt energization, and IceCube, a wave radiometer that will investigate ice clouds and climate change, spearheaded by Dong Wu. We're also developing what we call the Goddard Modular SmallSat Architecture, a SmallSat framework that that will maximize resources available for the spacecraft payload by minimizing those required for bus systems. Its attributes will yield a scalable performance, modular, flexible, and extensible small satellite, and facilitate cost and schedule efficiencies across all mission phases.

**Q.** *What are the primary limitations in the current SmallSat platform?*

**Michael Johnson:** The primary limitation is platform capability. Although the capabilities of these platforms are significant and are increasing rapidly, there is science we would like to achieve where they fall short. Advances in precision pointing and propulsion would be key mission enablers.

**Q.** *What can NASA Goddard provide to overcome these limitations?*

**Michael Johnson:** Expertise. Goddard's expertise is deep and crosses numerous spaceflight systems competencies. But at the same time, there are a lot

of really smart people outside of our fence who have skills relevant to overcoming these limitations. So we're always eager to establish partnerships, joining forces with industry and academia to leverage their capabilities.

**Q.** *What are the most exciting components to the SmallSat program?*

**Michael Johnson:** We're on the leading edge of a transformative time in spaceflight and exploration. But we'll never realize the full potential of SmallSats with conventional thinking. Instead, innovative approaches to instrument miniaturization, bus systems development, and mission implementation will lead to unimagined science. I like to tell an anecdote of when I was just starting my career and wanted to make a procurement. Soon after I submitted the paperwork, my boss comes and tells me that his boss's boss wants to talk to me. When I met with the big boss, he asked me why I wanted to buy this thing. The punchline is the "thing" was an IBM personal computer! At that time, the potential of this new technology wasn't understood. Likewise with SmallSats, there are yet to be imagined capabilities and applications they will deliver that will transform life as we know it. It's an exciting time.



**Doug Rowland**  
ASTROPHYSICIST

*Code:* 674

*Years with NASA:* 9

*Education:* Ph.D.,  
University of Minnesota

**Q.** *How did you become involved with CubeSats at NASA Goddard?*

**Doug Rowland:** We had been discussing the scientific potential of CubeSats early, but at the time the platform seemed too small and limited to be significant for NASA Goddard missions. What happened is that the universities took the lead and really turned the technology into some promising missions over a span of six or seven years. With good progress being made, the National Science Foundation opened up a funding source for science-focused CubeSat programs. Before the NSF got involved, most of the projects

were oriented toward basic performance experiments—let's see if they can fly and last in a space environment. As NSF funding coincided with university work, NASA Goddard saw a real opportunity for future missions.

### **Q.** *What is the status of the Firefly CubeSat?*

**Doug Rowland:** Well, we launched successfully in November of last year [2013] and established first contact in January. We have been in regular contact with the spacecraft since then, going about three weeks out of every six-week period without contact, due to its orbital flight path. During contact periods we monitor the satellite between 8am-5pm, Monday through Friday. We have command of the spacecraft and have been able to download data consistently.

### **Q.** *What challenges have you experienced with Firefly?*

**Doug Rowland:** The biggest problem so far has been the spacecraft itself. It has its bad moods and its good moods—and it can be frustrating when we just don't know what's happening up there. It might reset and go offline, but it's difficult to diagnose what the problem is because the operational modes are uncertain. We have a box on the ground to decode messages, which are then sent to computers at NASA Goddard and Sienna College, where we command the CubeSat remotely. It is important for us—one or two at Goddard and a team of three at Sienna—to take shifts and agree ahead of time so that we are learning as much as we can about the spacecraft during periods of communication. It's as if we're sucking data through a thin straw.

Since its launch, we've also had more issues than we anticipated with the software that sits on the ground and is used to command the spacecraft. We tested it thoroughly prior to launch, and it was working; but we discovered some serious bugs in the software once we established contact. Our team has done an excellent job diagnosing and fixing the problems. Initially, Firefly was sending one download a day, but we weren't getting that full download because of the deeply hidden bugs. Now, we're downloading six or seven "snapshots" a day, which are what we call the bits of data captured by the satellite. Firefly's mission is to record lightning and the effects of gamma ray flashes. Each lightning flash lasts only a couple of milliseconds, and a full download gives us 20 milliseconds of measurement. Imagine all you see in a single day is the opening of your eyes for 20 milliseconds—that's the extent of the data.

### **Q.** *How does NASA Goddard command Firefly?*

**Doug Rowland:** We have been working closely with our partners on the Firefly project, Sienna College (in Loudonville, NY) and Wallops Flight Facility. It continues to be a very engaging collaboration, and we all plan together and frequently have brief discussions about the spacecraft and its data. Wallops tracks the CubeSat and lets us know about potential overhead passes so NASA Goddard and Sienna can coordinate transmission. In order to communicate with Firefly, Wallops has to physically position the hardware of an 18-meter dish on the ground, figure out where the spacecraft is in the sky, and then track its path. Then, using our software, we can send a command load which accomplishes a number of tasks. We prepare an automated sending routine that checks the health and status of the spacecraft, program time scripts for experiments, and negotiate a time-share for all operations to ensure we don't run out of power. The CubeSat has so little power that it becomes imperative to save as much as possible by turning certain functions on and off according to their use requirements. It's not like a phone that you can just look at all the time. We're still learning how to drive it.



**Scott Schaire**  
**FORMER SMALL SATELLITE PROJECTS MANAGER, WALLOPS FLIGHT FACILITY, SUBORBITAL AND SPECIAL ORBITAL PROJECTS DIRECTORATE STAFF**

*Years with NASA:* 8

**Education:**

MBA Georgia State University,  
MSCS Polytechnic Institute of New York, BSEE Cornell University

### **Q.** *How did NASA Goddard become involved with CubeSats?*

**Scott Schaire:** In 2008 the National Science Foundation chose Wallops Flight Facility to collaborate with their CubeSat activities. Wallops continues to support the NSF CubeSat program through various ways, such as mentoring CubeSat developers, providing lab test facilities, and interfacing with the launch vehicle provider. We also offer ground station support that allows a CubeSat satellite to transmit at up to 200 times the typical data rate.

**Q.** *What aspects of CubeSats are of most interest to NASA Goddard?*

**Scott Schaire:** The Department of Defense also has a strong interest in CubeSats. CubeSats provide a method for placing instruments in orbit quicker than with conventional satellites.

**Q.** *What types of projects is NASA Goddard considering for CubeSats?*

**Scott Schaire:** There are numerous CubeSat proposals in the works. For example, the DoD and NASA are looking for a dedicated launch vehicle for CubeSats that can place satellites in orbit for \$2 million and under. Some proposed vehicles are currently in development. Recently, there are proposals for CubeSat devices up to 6U. The NSF allows for 6U proposals, although at this point, no 6U CubeSat has ever flown.

*[Editor's note: the size of a CubeSat satellite is defined in terms of "U," where 1U is the basic 10×10×10 cm package.]*

**Q.** *What are the primary limitations in the current CubeSat platform?*

**Scott Schaire:** Right now a key challenge is a propulsion system for CubeSats. CubeSats are currently not permitted to fly with propulsion.



**Allison Willingham**

**AEROSPACE  
ENGINEER**

*Code:* 596

*Years with NASA:* 1.5

*Education:* Master's Degree in  
Aerospace Engineering

**Q.** *How did you become involved with SmallSats at NASA Goddard?*

**Allison Willingham:** I first became involved with Goddard during an internship in 2009, working with Doug Rowland on the Firefly CubeSat. That led to a second internship with Tom Flatley [*Branch Head*,

*Science Data Processing Branch—read his interview in this issue*] on the TechCube project. These were the first CubeSat partnerships between Goddard and universities, so I was excited to be part of this new program. I had experience working on nanosats as a structures lead at Georgia Tech while I was in graduate school. The UNP7 nanosat fit onto a Lightband ring as a secondary payload, with a 50 kilogram weight limit. Being familiar with this small platform made it a smooth transition into CubeSats, with a maximum limit of six U, or around eight kilograms. [A "U" is the standard unit of dimensions used in CubeSat design: 10x10x10 and weighing less than 1.33 kg per U.]

The initial internships at Goddard turned into a summer Co-op in the Components and Hardware branch, where I learned more about spacecraft. I participated in a balloon mission and gained more structures experience, which led to my current position in Components and Hardware. I was also picked by Mike Johnson [AETD Chief Technologist—read his interview in this issue] to participate in a CubeSat Architecture Study, intended to address the introduction of new types of spacecraft at Goddard, and how to use our traditional expertise in the SmallSat arena. When you have a culture used to a certain spacecraft platform, there are distinct challenges in adapting skills and resources toward a new direction.

**Q.** *What aspects of SmallSats are of most interest to Goddard?*

**Allison Willingham:** Since I have been here there has been incredible progress made in SmallSat instruments. In particular, we're working on various heliophysics instruments such as a particle detector for the CeRES [Compact Radiation belt Explorer] mission that can be shrunk to meet CubeSat size specifications. We also plan on investing a lot of time and energy into problem areas like communication. There have been issues with S band and X band communication in SmallSats, and we need coordinated efforts with instrument design and engineering, along with ground stations and transceivers to ensure optimal data transmission. In addition to these communication challenges, we have had issues with thermal control, and are trying to innovate SmallSat production by combining structure and thermal control together. An example of this is an IRAD project for miniaturized thermal louvers, which can provide passive thermal control, gaining or releasing heat on command without power requirements. We're also working on booms for small spacecraft, and have a Dellinger team developing a boom for magnetometers. The trick

is using our existing technology and expertise to innovate on SmallSats, which is a different issue than universities face, since they are mostly using SmallSats as an educational tool for students. We're constantly asking: how do we shrink this technology down into a smaller envelope?

**Q.** *What types of projects is Goddard considering for SmallSats?*

**Allison Willingham:** There are a lot of proposals related to heliophysics and Earth science, and again, we have some very exciting instruments in the works that can perform in extreme environments and meet the size and weight restrictions for the CubeSat platform. We are committed to making parts on board the satellites rad-hard, and have been collaborating, for example, with NSF CHREC at the University of Florida to put components on board CeRES that are higher reliability in heavy radiation conditions. Our goal is to develop more rad-tolerant components, because one of the main limitations of commercial off-the-shelf components is that they are only somewhat rad-tolerant, and a stray high-energy particle can fry the hardware on a CubeSat after only one month in operation. In contrast, NASA Goddard wants components that will last one to two years, which translates into significant data capturing capacity.

**Q.** *What are the primary limitations in the current SmallSat platform?*

**Allison Willingham:** The universities that are active in the SmallSat arena are primarily using CubeSats for demonstration. They are not concerned if the commercial off-the-shelf components fail after a short duration, since they are not designing CubeSats for multi-year missions. Goddard has been so active recently in this area because we are looking beyond mere demonstration, and thinking about the future of spaceflight. The limitations have largely been issues of robustness over time, and this is a particularly interesting problem because it requires a balance between long-term space missions where everything has to be perfect on the spacecraft, and a balloon mission or sounding rocket that is launched much more quickly and with a much smaller budget. We want to make satellites that can travel into space with less resources, but that retain the advantages of traditional missions as far as duration and data capture.

**Q.** *What can Goddard provide to overcome these limitations?*

**Allison Willingham:** One of the exciting prospects dealing with the issue of balancing smaller budgets with performance is the idea of sending fleets of spacecraft on missions. Instead of dumping all our resources into a single spacecraft, we can split the time and money of a project into 50 spacecraft, where even if five or ten fail, the mission goals can still be accomplished. This is an entirely new realm that Goddard is dealing with, a completely new vision of spaceflight. Understandably, there has been caution with the process, because you are also talking about changing the culture of Goddard. How do you set up a lab to build 50 spacecraft? You need a combination of old expertise and resources, and new university partners not afraid of failure. You need to make sure that scientists have confidence in the SmallSat platform, so early testing becomes very important. When you launch 50 SmallSats or CubeSats, you are ultimately launching data points, and if one or two or ten fail, then you've lost those data points. Looking toward the future, if we ask how many data points do we want, the obvious answer seems to be: the more the better!

**Q.** *What collaborations/partnerships have been most rewarding in the R&D of SmallSats?*

**Allison Willingham:** As I've alluded, universities are where CubeSat culture originated, so as you'd expect, a lot of our most rewarding partnerships have been with universities. In these relationships, we can often learn by proxy what works and what doesn't, so learning from the universities' experience has been very helpful to improve the science of SmallSats. Our relationships with commercial vendors have also been productive in regard to payload and pointing control. We have worked with some reaction wheel companies, and other companies have come to us by way of SBIR projects. We have even been approached by companies who found us through our research and publications, especially in the area of CubeSat architecture. There are some companies that make deployables that are worth working with to help us catch up as fast as we can. Even as we are becoming leaders in the arena, we are aware of how we can still improve through collaborations.

**Q.** *What are the most exciting components to the SmallSat program?*

**Allison Willingham:** For me, it is especially rewarding to take what we know and create a whole new niche with our expertise, taking components and making them functional in a smaller envelope. I have been fortunate to be a part of the CubeSat Architecture Study and given the opportunity to imagine what the SmallSat platform will look like in ten years. Will we be sending up giant fleets? Interplanetary fleets? Maybe SmallSats that are deployed from a mothership? There are great ideas of where we want to go, and now we just need to bridge the gap by enabling the present technology to get us there. SmallSats are the cellphones of spacecraft; the potential for the platform keeps increasing and is not slowing down. The first CubeSats were developed by universities who thought the technology would never leave. When Goddard caught wind, it just began to snowball into what is possible for the future.



**Robert MacDowall**  
**CHIEF, PLANETARY  
MAGNETOSPHERES  
LABORATORY**

**Code:** 695

**Years with NASA:** 22

**Education:** PhD in Astronomy, University of Maryland, College Park; MA Astronomy, BA Physics, Univ. of Maryland

**Q.** *What types of projects is NASA Goddard considering for CubeSats?*

**Robert MacDowall:** CubeSat standards are being evolved so they can perform in deep space. One CubeSat project under consideration will use infrared spectrometry to detect water and water analogs on the moon. Another idea is to use CubeSats as impactors. CubeSats could also be used as support satellites for larger satellites. A big mission could deploy CubeSats as “assistants” to perform specific tasks.

**Q.** *What can NASA Goddard provide to overcome these limitations?*

**Robert MacDowall:** NASA Goddard is developing a standard for a “modular” approach to building deep-space CubeSats from components that could be assembled like Legos or Lincoln Logs. This would be a first step in creating deep-space CubeSats, which would be a major positive for NASA.



**Thomas Flatley**  
**BRANCH HEAD,  
SCIENCE DATA  
PROCESSING  
BRANCH**

**Code:** 587

**Years with NASA:** 27

**Education:** BS Engineering, Loyola College

**Q.** *What types of projects is NASA Goddard considering for CubeSats?*

**Thomas Flatley:** CubeSat projects are useful for validating new technologies. You can use a CubeSat mission to demonstrate proof-of-concept for all kinds of systems and instruments. Some of the science that could be done by CubeSats might be to fly constellations of satellites, and measure particles and plasma fields. CubeSats could be part of a hybrid mission involving a large “mothership” satellite and a number of smaller CubeSats. The smaller satellites can be controlled by the main satellite to perform tasks that may be difficult or risky.

**Q.** *What are the primary limitations in the current CubeSat platform?*

**Thomas Flatley:** One of the problems with CubeSats is that up to now they haven’t been completely reliable. Up to 50% of all CubeSat missions fail on orbit. This may be due in part to how CubeSats have been designed, often as student projects using components whose reliability may be questionable in the space environment.



## Nick Paschalidis

**SENIOR PROJECT SCIENTIST FOR TECHNOLOGY ADVANCEMENT, HELIOPHYSICS SCIENCE DIVISION**

**Code:** 670

**Years with NASA:** 2

**Education:** PhD in Space Science and Technology; Demokritos Univ. of Thrace, Greece

**Q.** *What can NASA Goddard provide to overcome these limitations?*

**Nick Paschalidis:** NASA is playing an important role in pushing CubeSats into space. We're helping create a need for CubeSat projects, which in turn is driving the development of new technology. Some of these technological developments include attitude control, propulsion, and positioning outside the GPS system. The goal is to develop CubeSat capabilities that deliver high accuracy, lower power, multi-node, and distributed operation. NASA Goddard is driving the science and building CubeSat instruments.

**Q.** *What are the primary limitations in the current CubeSat platform?*

**Nick Paschalidis:** At this point, CubeSats really aren't ready yet for deep space missions. However, it is ideal for low earth orbit projects designed to advance the science of heliophysics. CubeSat standards are mature enough to perform remote sensing of the sun, and to perform in situ observations of Earth. The government needs frequent access to space. CubeSats may be able to provide this access in many situations. One thing we're still missing, however, is the full capability to put a CubeSat mission into orbit on its own.

**Q.** *What types of projects is NASA Goddard considering for CubeSats?*

**Nick Paschalidis (Senior Project Scientist for Technology Advancement, Heliophysics Science Division):** In my group, we're looking at CubeSat

projects to operate in low Earth orbit, to perform ionosphere measurements for heliophysics. This technology is being developed in part through the NASA Innovative Advanced Concepts [NIAC] program. Also proposed is a project designed to study the Van Allen belts. This instrument will measure relativistic electrons in this region. In addition, we are exploring the use of multiple CubeSats working together as a grid, performing multi-point simultaneous measurements.



## Ben Cervantes

**MISSION PLANNING LAB LEAD**

**Code:** 589

**Years with NASA:** 8

**Education:** B.S. Computer Engineering, California Polytechnic University, San Luis Obispo

**Q.** *What types of projects is NASA Goddard considering for CubeSats?*

**Ben Cervantes:** Some of the ideas being considered include sending swarms of CubeSats into space, all communicating with each other. Wallops Flight Facility has the capability to launch sounding rockets from many different locations. It may be possible to marry this capability to CubeSat launches. The challenge will be to develop this capability to the point where we're launching CubeSats into orbit. Currently, sounding rockets are only capable of sub-orbital flight.

**Q.** *What can NASA Goddard provide to overcome these limitations?*

**Ben Cervantes:** Wallops Flight Facility has a lot of experience in sub-orbital flight, usually involving satellites or other UAVs [unmanned aerial vehicles]. CubeSats fit nicely into this niche, and align very well with what Wallops does, which primarily involves low-cost missions. We're developing technologies to be more and more miniaturized, to fly on UAV missions. When a technology is sufficiently miniaturized, it can fly on a CubeSat to gather science data.



## **Pamela Clark**

**SCIENTIST,  
SCIENCES AND  
EXPLORATION  
DIRECTORATE**

**Code:** 695

**Years with NASA:**  
Three decades at various  
centers and in various roles

**Education:**  
Ph.D., Remote Sensing

### **Q. What aspects of CubeSats are of most interest to NASA Goddard?**

**Pamela Clark:** With budget cuts, it's harder to finance large missions. CubeSats offer a standardized bus, off-the-shelf components, and quick development. With a standardized bus, the most expensive part of a CubeSat project is the instrument package. And it's already familiar to many universities and students, providing them a low entry point into space.

The DARPA vision for CubeSats can be described as "a bunch of SmartPhones running a bunch of apps." These projects are designed to be small and smart. CubeSats come with a well-established constituency, based on 10 years of support.

### **Q. How did NASA Goddard become involved with CubeSats?**

**Pamela Clark:** CubeSat started out as a standard for student projects, using off the shelf components and launched as secondary payloads to scheduled missions. CubeSat can be built very cheaply, on the order of tens of thousands to hundreds of thousands of dollars per device – vastly cheaper than a regular satellite which easily costs a half-billion dollars or more. CubeSats provide students with hands-on experience constructing satellites. More recently, there's been interest in using CubeSats to do science-driven missions as well as tech demos.

### **Q. What types of projects is NASA Goddard considering for CubeSats?**

**Pamela Clark:** The CubeSat architecture is already being considered, and proposals being requested, for projects in heliophysics, astrophysics, and Earth applications. More recently, some of us have started to consider CubeSats for deep space exploration. Currently, we are internally funded at NASA Goddard to look at CubeSat missions for the moon and inner solar system. The moon is of particular interest as a "stepping stone." Over half of the white papers generated for the most recent decadal survey in planetary exploration focused on the moon as the primary target. The moon can serve as a good testbed for deep space exploration technology, since its rugged polar regions provide analogs for most of the surfaces in the solar system. And it offers one of the most extreme environments known in the solar system.

There are lots of things about the moon we still don't understand. For instance, is there water on the moon, and if so, how much? CubeSat projects can help us find out. We're looking at CubeSats to place an observatory on the lunar surface, to do sub-millimeter astronomy. One challenge with working on the moon is how to provide energy in cold temperatures.

### **Q. What are the primary limitations in the current CubeSat platform?**

**Pamela Clark:** To extend the CubeSat architecture into space, we need technology development in certain areas in particular -- propulsion using efficient, compact systems and minimal energy trajectories (flight dynamics); compact, efficient communications; compact instrument systems; and onboard intelligence. If we're going to take full advantage of these small systems, they need to be able to fly themselves to their destinations to reduce the resources required for external (ground) control. In other words, they need to be not only small but smart.

As explained elsewhere in this issue of Tech Transfer News, the CubeSat standard was originally created as an academic tool. Since its introduction in 1999, CubeSat has gradually transitioned into a more full featured standard that can also be used to perform important science applications. A by-product of this transition is that CubeSat has also begun to emerge as a platform around which private companies can build a business.

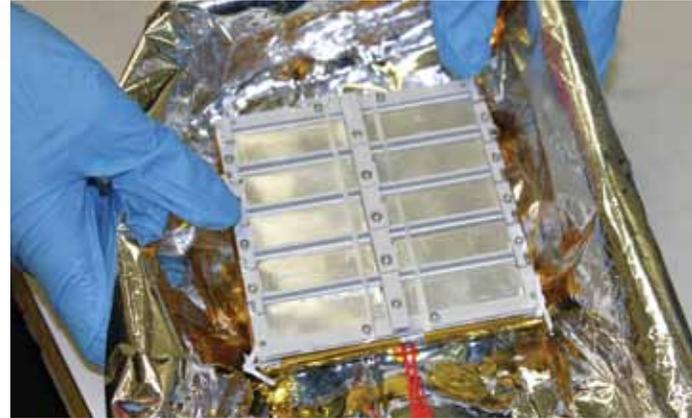
In this article, we briefly examine several ways in which CubeSats and their related technologies may offer a variety of potential commercial opportunities.

### A “laboratory in space”

One application for which CubeSats have already been used involves testing technologies in space. A CubeSat mission provides a relatively inexpensive way to place a new technology into a space environment, and then observe how the technology performs. In this way, a CubeSat can serve as a “laboratory in space,” helping to validate a technology. A number of CubeSat projects have been designed for this purpose, testing technology both for NASA and the private sector.

### The CubeSat components market

As the number of CubeSat missions and applications expands, the demand for CubeSat-compliant components comprises a small but growing niche industry. The CubeSat.org web site lists a number of vendors who sell CubeSat parts (see <http://www.cubesat.org/index.php/collaborate/suppliers>). According to Thomas Flatley (Branch Head, Science Data Processing Branch), “CubeSats are ideal for smaller companies. Right now there isn’t enough money in the CubeSat business for a large company to be interested in it and justify a large development effort. But there



▶ *CubeSat components developed at NASA Goddard could have far-reaching commercial applications.*

—PHOTO BY NASA

are niche markets that could appeal to small and medium size companies.”

Mr. Flatley is currently working on an initiative designed to extend CubeSat projects for use in deep space and for long-duration and “beyond Leo” Earth orbits. To do this, NASA Goddard CubeSats are made from highly reliable components from select vendors, universities, and other government agencies (NRL, AFRL), combined with high-reliability components developed in-house. The success of a scalable, high performance bus could in turn create a new market for CubeSat component suppliers. In addition to the Department of Defense and other government agencies, there is a burgeoning interest in CubeSats for commercial applications such as imaging and communications. Google, for instance, is investing significant resources into companies developing technologies and capabilities that will rely on the CubeSat/ SmallSat platform.

The development of highly reliable CubeSat technologies is already sparking the creation of new startup businesses. For instance, several major universities are actively developing high-performing CubeSat components. A number of professors involved in this research have created spinoff companies specifically dedicated to doing CubeSat business.

## Wallops Flight Facility Launch Support

Wallops Flight Facility has a long history with sounding rocket and balloon programs, expertise that is ideally suited for supporting CubeSat projects – in fact, in 2006 Wallops launched GeneSat-1, the first CubeSat put into space from the United States.

This experience prompted the National Science Foundation in 2008 to select Wallops Flight Facility to collaborate with their recurring CubeSat program for space weather research. Since then, Wallops has supported a variety of CubeSat projects, providing value-added services essential for enabling innovative science, technology, and hands-on CubeSat missions.

Wallops Flight Facility supports CubeSat projects by offering:

- Ground station support for transmitting high data rates over a government frequency band
- Engineering assistance for reviews and for resolving issues
- Testing of CubeSats
- Advanced mission planning, deployment, and communication technologies

For example, Wallops Flight Facility includes a radar system that serves as a UHF satellite telemetry ground station for CubeSat missions. This ground station addresses the growing need for high data rate transmissions over a government licensed frequency. Historically CubeSat projects have used amateur radio frequencies, which in the case of government-funded projects may violate the intent of the amateur radio service.

Other services delivered by Wallops Flight Center in support of past CubeSat missions have included:

- Providing primary and spare hardware components for the launch
- Coordinating safety documentation
- Performing re-entry casualty analysis
- Presenting pre-ship review

These and other services provided by Wallops Flight Facility helps ensure the ongoing success of future CubeSat missions developed by academia, other government agencies, and private companies.

## CubeSat related technologies developed at NASA Goddard

NASA Goddard has developed a number of technologies designed to increase CubeSat functionality and make it a more suitable platform for deep space missions. For example, Mr. Flatley is working on SpaceCube Mini,

a miniaturized version of the SpaceCube 2.0 high-performance data processor small enough to be used on CubeSat projects. SpaceCube is designed to increase the data processing power of a CubeSat mission by one or two orders of magnitude. In addition, SpaceCube could be useful for other high-data systems, providing both data reduction and onboard awareness. SpaceCube allows for autonomous operations, which could be valuable in applications where instruments collaborate with each other, such as a sensor web.

Other technologies in development address the “3 Ps” – propulsion, positioning, and power – whose availability would significantly strengthen CubeSat as a robust, versatile platform. For example, Maryland Aerospace is developing a CubeSat pointing system, partially funded through the NASA SBIR program.

To address the limitations of CubeSat onboard power, NASA Goddard is developing the “CubeSat Power System with Automatic High-Powered Payload Cycling” (**GSC-16679-1**). In general, CubeSats are very low power systems that have difficulty with high-powered payloads. This new CubeSat power system will automatically turn a high-powered payload on/off based on the battery state-of-charge. This will enable a new class of CubeSat payloads and allow for more advanced research to be conducted from a CubeSat satellite.

Another technology, “Micro-Resistojet for Small Satellites and Various Propellants Especially Methanol” (**GSC-15053-1**), provides CubeSat with a novel micro-resistojet for use with various propellants. The micro-resistojet is especially suited for “green” methanol.

The “SmallSat Constraint and Deployment System” (**GSC-16305-1**) offers a more secure constraint interface during CubeSat launch and an efficient guided ejection, while permitting a less restrictive inner volume.

These technologies will not only help make CubeSat projects more commercially promising, they may also offer the potential to be adapted for other terrestrial markets.

## CubeSat commercial applications

CubeSat missions themselves may eventually provide significant commercial potential. CubeSat applications under consideration include satellite servicing, vehicle examination, space station inspection, and removal of space debris. The last is an interesting possibility – a CubeSat device could be designed to track and attach itself to an unwanted satellite that has fulfilled its useful life, and propel the satellite back into the atmosphere to be destroyed.

NASA Goddard is actively developing technologies designed to help CubeSats transition from functionally limited academic tools to a robust deep-space platform. Much of this work is being conducted in collaboration with other entities, including universities and commercial interests. A portion of this collaboration is funded through NASA Goddard's SBIR/STTR program.

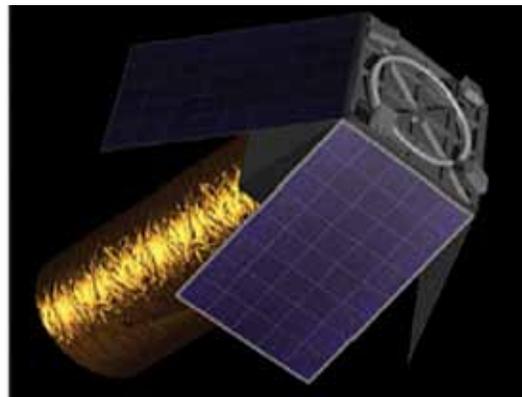
In this article, we review several examples of how SBIR/STTR grants are helping the development and advancement of CubeSat-related technologies.

### **Integrated Attitude Determination and Control System (ADACS) for CubeSats (Maryland Aerospace Incorporated) (GSC-16724-1)**

One limitation of the CubeSat platform has been a lack of sophisticated positioning

capability. To address this, NASA awarded an SBIR to Maryland Aerospace, Inc. to develop a high performance ADACS (Attitude Determination and Control System) for CubeSats. This program builds upon Maryland Aerospace's existing MAI-400 ADACS for small satellites by developing and integrating two Star cameras into the MAI-400. The resulting product will be called the MAI-400SS Space Sextant, and it will enable the precision attitude control (better than 0.05 degrees) necessary to perform space weather, cosmology, and Earth imaging experiments from a CubeSat.

The system is designed to be completely autonomous, and features "Lost In Space" star identification in which observed stars are associated with corresponding catalog stars. This technology allows CubeSats to perform high resolution imaging and other missions requiring precision fine pointing and dynamic retargeting. The MAI-400SS will facilitate rapid development of low-cost CubeSats by providing a turnkey system for spacecraft attitude control.



► Maryland Aerospace's ADACS units, shown (left) standalone and (right) installed in an artist's rendition of a typical CubeSat.

—PHOTO BY NASA

## Miniaturizable, High Performance, Fiber-Optic Gyroscopes for Small Satellites (Intelligent Fiber Optic Systems Corporation)

To further advance positioning functionality for CubeSats, NASA awarded an SBIR grant to Intelligent Fiber Optic Systems (IFOS) Corporation to develop “miniaturizable” high performance fiber-optic gyroscopes (FOGs). This approach will provide a robust attitude control sensor that can maintain long-term alignment despite being subjected to shock and vibration.

These components are essential to support navigation and attitude control systems for advanced NASA satellite missions. The IFOS FOGs will have significantly reduced size and weight, with ruggedized components designed to meet stringent dynamic and thermal specifications. A robust, high performance cost-effective gyroscope suitable for space-based operations will also be useful for NASA applications that require spacecraft stabilized instrumentation platforms for long-term space applications.

This technology can also benefit the commercial aviation industry, as well as sensor arrays for medical applications and homeland security.

## Magnetic Bearings for Small Satellite Control Moment Gyros and Other Miniature Spacecraft Mechanisms (Honeybee Robotics Spacecraft Mechanisms Corporation)

Honeybee is developing a miniature passive magnetic bearing (PMB) for small satellite attitude control system components such as control moment gyros and reaction wheels. The mini-PMB is a cross-cutting technology that can also be applied to any small mechanism that might benefit from low parasitic torque, low induced vibration, and long life. Extending mission lifetime to 15 years or more (instead of the currently typical 1 to 3 years) will likely change the way mission planners think about CubeSat capabilities.

## Multi-functional Optical Subsystem Enabling Laser Communication on Small Satellites (Arkyd Astronautics)

Arkyd is currently developing technology for implementing small satellite optical communication. This device is a novel multi-functional optical subsystem used for attitude determination, stability control, scientific observation, and high-precision optical communication on small satellites. The technology will potentially provide small satellite attitude control and communication performance improvements several orders of magnitude over the current state-of-the-art.

This technology will increase the capabilities of CubeSats in low-Earth orbit, significantly reducing the cost required to conduct space-based Earth science, solar science, astronomy, and commercial research. The technology will also enable CubeSats to perform the initial robotic exploration required to gather intelligence, as part of an integrated architecture to support follow-on human exploration missions. This system will better enable CubeSats to perform high-bandwidth tasks from low-Earth orbit, including:

- Satellite crosslink communications
- High-definition video from orbit
- Low cost Earth observation constellations
- Real-time disaster monitoring
- Data-rich scientific payloads

For more information about NASA’s SBIR/STTR program, including how to submit a proposal in response to a solicitation, see <http://sbir.gsfc.nasa.gov/SBIR/SBIR.html>.



► Honeybee’s miniaturized passive magnetic bearing (mini-PMB) installed in a CubeSat.

—PHOTO BY NASA

As we've noted in this issue of *Tech Transfer News* SmallSat research involves adhering to size and weight specifications, while innovating based on both new and existing technology. CubeSat-compliant spacecraft are generally built from commercially available off-the-shelf components, and many of the projects involve collaboration between multiple entities. With many different interests, levels of expertise, and specializations coming together in a single mission, protecting Intellectual Property (IP) is a particularly challenging enterprise. Navigating the efforts of academia, industry, and NASA Goddard in a way that advances the art of SmallSats without compromising mission objectives is no small task.

We spoke with Bryan Geurts (Chief Patent Counsel for NASA Goddard's Office of Patent Counsel) to learn his views on protecting IP resulting from the development of CubeSats and similar projects.

**Q. Has there been NASA Goddard IP generated through CubeSat-related research?**

The short answer is yes. The NASA CubeSat program has generated, and continues to generate, a lot of new technologies. And while participants come from all over - private industry, universities, not-for-profits, and government - some of the key CubeSat projects originate at and are led by NASA Goddard.

Moreover, we've done a lot of work with sounding rockets out of Wallops Flight Facility, work that is similar to CubeSats in that it involves working with very small payloads, often for short-duration flights of



**Bryan Geurts**  
CHIEF PATENT  
COUNSEL

*Code:* 140.1

*Years with NASA:* 12

several minutes or so. The ultimate goal is to be able to do more with less. It's amazing what can be done with these small payloads. One example of a NASA Goddard CubeSat is the Compact Relativistic Electron and Proton Telescope, or CREPT. This small solid-state telescope will measure energetic electrons and protons in the Van Allen Belts, which are large doughnuts of radiation surrounding Earth. CREPT measurements will give us a better understanding of the physics of how the radiation belts lose electrons through electron microbursts.

The interesting trend emerging in the SmallSat world over the last year is that most participants are more often universities filled with their own teams of scientists. The whole notion of IP is not really thriving, because these university scientists are not looking to gain recognition through IP; they are just looking to get their SmallSats out and working. With most SmallSat projects, budgets are so small that a stated intention is to use off-the-shelf, standardized, and commercially available components as much as possible. As the scientists see it, they don't want IP mucking things up; so the SmallSat field is not as friendly toward IP as I'd like it to be.

**Q** *CubeSats generally use available, off-the-shelf components. Is it possible to create protectable IP from components available to anyone?*

It depends on how you arrange the parts. To be patentable, an invention has to be new, not obvious, and useful. It's not particularly difficult to arrange components in a novel way, meaning that no one else has done exactly the same thing. And since everything we build is for a specific purpose, the "useful" criterion is usually not an issue.

The challenge is to meet the "not obvious" criterion. This is particularly problematic when you're using standard components; sometimes it is difficult to demonstrate that the way you've assembled these parts is more than just a design preference and would not be obvious to others. If you can't meet the nonobviousness standard, then there is no patent to be had.

For example, some years ago we tried to patent a technology we called Flight Modem, which is basically a modem and a GPS receiver (both commercially available products) configured in a way to keep track of sounding rockets. The Patent Office claimed that an existing, much more complicated system used on commercial airplanes could be considered Prior Art, even though what we were doing was not closely related. We appealed, but were denied based on the Patent's Office's judgment that we had not met the "not obvious" rule. So this criterion can be very difficult to meet, although it can be done.

**Q** *CubeSat projects often involve numerous collaborators, including academia, private industry, and other government agencies. Is it difficult to sort out who owns what IP when multiple people are involved in the research?*

CubeSats provide an open environment that fosters collaboration. And as we discussed earlier, the CubeSat standard is based on existing components. Therefore any IP generated from CubeSat research usually involves the experiments

themselves, rather than the base flight hardware. When these experiments involve NASA Goddard working with one or more outside parties, IP ownership is usually defined up-front via Space Act Agreement, CRADA, contract, or similar legal instrument.

**Q** *Should NASA Goddard innovators create NTRs for their CubeSat projects?*

Absolutely! If for no other purpose, we need to be able to defend ourselves. We need to officially document every invention; otherwise an aggressive competitor might try to prevent us from using our own technology. This is especially true under the new AIA [America Invents Act] regime. We need to ensure all our inventions are properly documented and protected, which may mean broadly publishing a technology to show the world we thought of it first.

**Q** *Do you foresee more NASA Goddard IP coming out of CubeSat research in the future?*

Given the ongoing environment of tight budgets, I think it is inevitable that we'll be doing more and more CubeSat work. I believe the CubeSat idea will continue to catch on; and we'll be doing more CubeSat projects in collaboration with industry, other government agencies, and academia.

Assuming this happens, I can see CubeSat-related IP going in two different directions. One possibility is that the CubeSat standard will continue to remain open, in which case IP will likely not become a major issue. Another possibility is that as CubeSats really catch on, industry starts building businesses around them. In this scenario, these businesses will probably want to leverage IP to protect their bottom lines. This could change the open nature of CubeSats because when industry starts protecting its IP, the government and academia usually follows suit.

**W**e followed up with Bryan Geurts, Chief Patent Counsel, to see what's new at NASA Goddard related to CubeSat/ SmallSat IP since the last issue featuring the CubeSat platform. You will read of the challenges still ahead, but also what can help NASA Goddard continue to emerge as a leader in this arena.

**Q. What are the IP challenges specific to working with university and industry partners?**

We're seeing the same thing from industry as well as the universities, and that is a lack of interest in inventing a process or apparatus to be protected by patents. Industry is willing to play the game dictated by the universities, which is the model of walking up and down the shelves like in a supermarket when they want to send up a satellite. The vendors are going along with that model. As a consequence, there is not much activity in processes pertaining to SmallSat innovation. If there is an individual satellite that is looking at specific things and may have a novel idea, there is still the desire to build it with what is commercially available. Innovation becomes tempered by ease of process, opposite to what we're used to in more traditional missions, where there would be several discrete technologies developed to make the satellite operate, and we can protect those technologies through patents. That is better for creating value in IP, and not just relying on commercially available parts. If many scientists had their own way, the culture would shift from the old model of protecting IP to this new SmallSat model of using what is easy and cheap to acquire, even if it is not what's best for current and future missions.

**Q. What can NASA Goddard innovators do to protect their research without limiting the potential for outside collaboration?**

At the very top of my wish list is for scientists to consult our office early, early, early—the earlier the better—so we can sit with them to strategize about how best to get technology out there. Sometimes it does mean giving it away freely, but other times it is important to start the patent process. And there are

also times when it should be held very tightly to the vest. The point is that we can help craft a strategy early on; if we don't, things may happen by default and it may be too late to go back and protect the technology.

**Q. How does your office work with NASA Goddard personnel to help facilitate tech transfer opportunities?**

Our mantra for a long time has been for innovators, engineers, project managers, whoever, to come to us early so we can craft something to everyone's advantage. If given the chance, we can generally craft something to make everyone happy. Goddard is quickly coming up to speed in the SmallSat arena to become a recognized leader, which will present new IP opportunities as long as we can help encourage the SmallSat culture to see innovation as valuable not just for a specific project, but for advancing the field and future missions through proprietary technologies.

**Q. Is there a SmallSat area you think is particularly exciting from an IP perspective?**

As SmallSats move further toward that commercial supermarket model, it can be hard to identify really groundbreaking technologies. I think it is analogous to architectural building; yes, the building has to be functional, but it also should be aesthetically pleasing. By strategically placing technology through IP, it becomes advantageous to others, and not just a single mission. It can be functional but also pleasing to those who will be closest to the field, and perhaps set a precedent for what is still yet to come. We want to maximize the potential for a new technology, just as an architect or engineer wants to maximize space. We always want to maximize an innovation, but unfortunately, strategic IP thinking is not happening as much as we would like in the arena of SmallSats. But that certainly doesn't mean things can't change; and we hope to be responsible for more positive results as Goddard continues to lead the way with next generation satellites.

# In the News

## NASA Has Made Contact with Firefly Cubesat

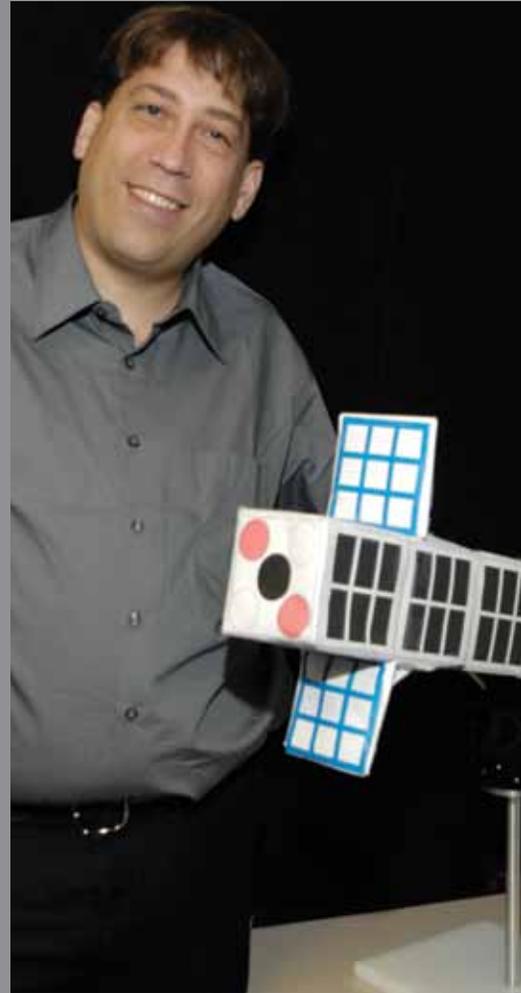
[JANUARY 8, 2014]

A NASA team made first contact with the National Science Foundation-funded Firefly spacecraft at 7:33 p.m. EST on Jan. 6, 2014. On the first pass, the team – based out of NASA's Wallops Flight Facility, Wallops Island, Va. – received enough data to show that the spacecraft was healthy and transmitting a strong signal.

The data volumes on the spacecraft had been filled, as expected, given that the spacecraft had been downloading data since launch on Nov 19, 2013. When the team downlinked the first installment of the data, they found that the spacecraft power system is healthy and the computer processing unit temperature is within a good range, at about 50 F.

The team will soon begin work to download the rest of the data, assess Firefly's status, and then move the spacecraft into science mode. Firefly is led by a joint team of scientists from NASA's Goddard Space Flight Center in Greenbelt, Md., and Siena College in Loudonville, N.Y.

—Karen C. Fox  
NASA Goddard Space Flight Center



► Doug Rowland, the principal investigator for Firefly at NASA's Goddard Space Flight Center in Greenbelt, Md.

—PHOTO BY NASA

## SmallSat Poster Session

[MAY 16, 2014, GREENBELT, MD]

The NASA Goddard Astrophysics Science Division (Code 660) hosted a poster session on CubeSats and

SmallSats on Friday, May 16, 2014. The purpose of the poster session was to share ideas and stimulate discussion. Presenters showcased their concepts using posters to display new ideas and collaborations.



▶ NASA Goddard SmallSat Poster Session.

—PHOTO BY NASA

## NASA Goddard's "IceCube" Selected for 2014 Science Mission Directorate

[JUNE 18, 2014]

Beginning in October 2013, the NASA Science Mission Directorate, or SMD, started a new CubeSat Initiative -- a cross divisional project to develop scientific CubeSats for all four science divisions within SMD. CubeSats offer a low-cost option for enabling scientific discovery related to astrophysics, heliophysics, Earth and planetary sciences, addressing space technology and exploration systems development needs, and extending important hands-on experience to undergraduate and graduate students.

Through effective internal and external partnerships, combined with existing SMD suborbital investments, NASA leverages CubeSats for exploratory and potentially systematic science observations at minimal cost. With missions that can be less than \$2 million to \$4 million per satellite and with a rapid development cycle, along with the advent of routine access to space provided by NASA and the U.S. Department of Defense launch vehicles, and evolving nanosat launch systems, CubeSats are now a viable frequent flight opportunity for rapid innovation in science and technology.

SMD CubeSats are offered as part of the annual ROSES -- for Research Opportunities in Space and Earth Sciences -- solicitation. "IceCube," under the direction of Donna Wu, Principle Investigator at NASA's Goddard Space Flight Center, has been selected for the 2014 fiscal year. IceCube is a sub-millimeter wave radiometer to advance understanding of ice clouds and their roles in climate change.

--Jenny Rumburg  
NASA Headquarters, Washington

## CubeSat mission selected by NASA to study solar particles and space weather

[JUNE 18, 2014]

The website Physics.org reports that NASA has selected CuSPP, a CubeSat collaboration between the Southwest Research Institute (SwRI), NASA Goddard Space Flight Center, and the NASA Wallops Flight Facility. The CuSPP CubeSat will carry a "novel miniaturized Suprathermal Ion Sensor (SIS) developed at SwRI." It will also be used "to support space weather research by measuring particles that escape ahead of powerful shock waves in the solar wind."

Read more at: <http://phys.org/news/2014-06-cubesat-mission-nasa-solar-particles.html#jCp>

[ RELATED *Technologies*

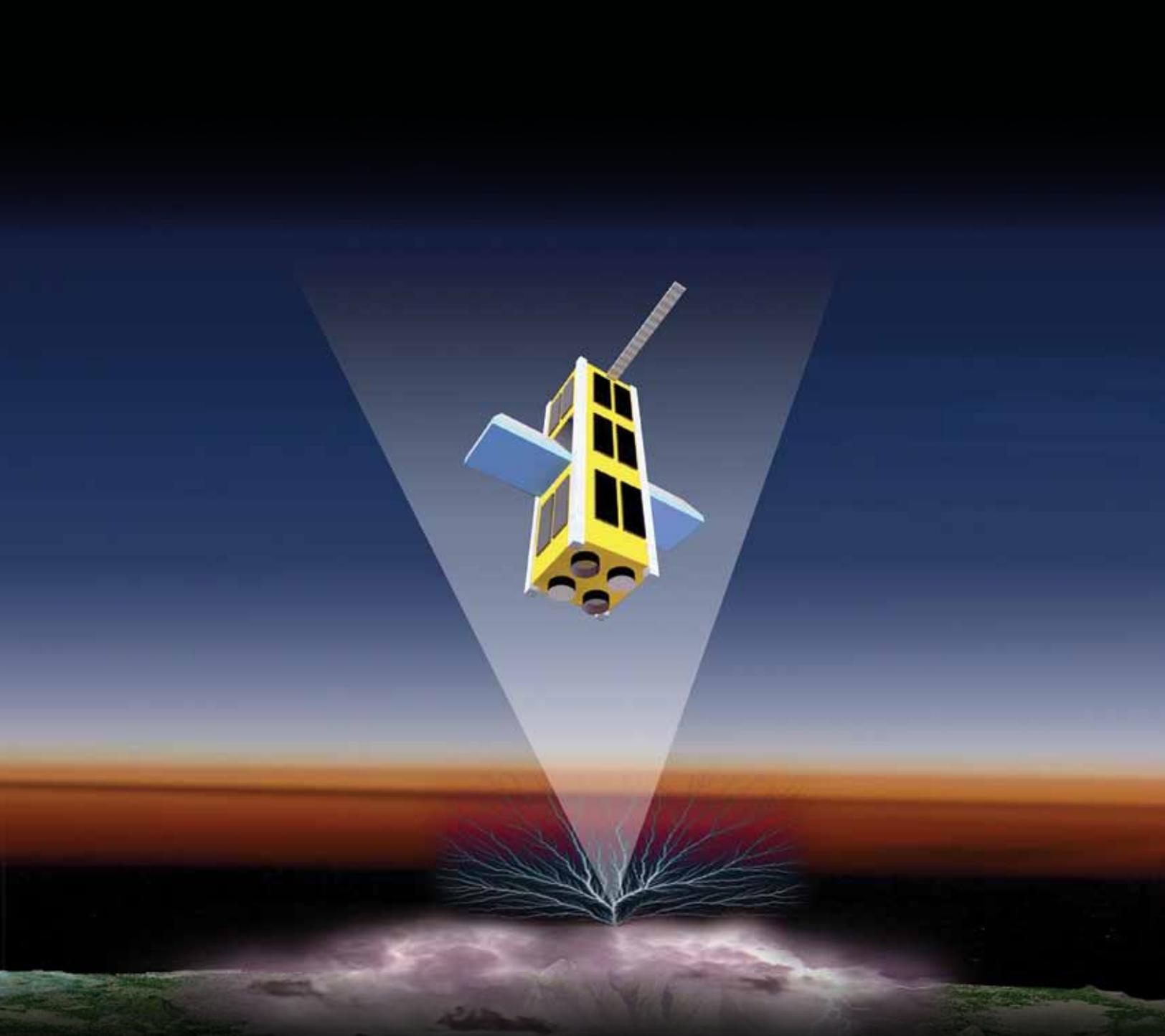
Related Technologies

CASE NO.	TECHNOLOGY	TECHNOLOGY DESCRIPTION
GSC-17197-1	<i>Tool for CubeSat/SmallSat Design Semiconductor Part Selection With Regard to Radiation Effects</i>	<i>A tool that provides tailorable guidelines for part selection based on mission architecture and existing data that helps increase the life of the spacecraft.</i>
GSC-17113-1	<i>Cubesat Compatible High Resolution Thermal Infrared Imager</i>	<i>A small, adaptable, and stable thermal imaging system that can be flown on an aircraft, deployed on the International Space Station as an attached payload, launched on a ride-share as an entirely self-contained 3U CubeSat, flown on a small satellite, or be a co-manifested satellite instrument.</i>
GSC-17112-1	<i>Pi-Sat: A Low Cost Distributed Spacecraft Mission Test Bed</i>	<i>The Pi-Sat project provides a preconfigured flight software development system for Distributed Spacecraft Mission and Smallsat/ Cubesat research and development.</i>
GSC-17034-1	<i>CubeSat Form Factor Thermal Control Louvers</i>	<i>A thermal control louver assembly based on the CubeSat form factor designed for small spacecraft missions. The key outcomes for this design are passive thermal control and improvement in internal thermal stability for small spacecraft. Using the CubeSat standard will mean that the thermal louvers can be applied to any small satellite application.</i>
GSC-17018-1	<i>3D Plus Programmable Read Only Memory (PROM) Emulator Board</i>	<i>The 3D-Plus PROM that is used on The SpaceCube v2.0 is a one-time programmable non-volatile device that stores Xilinx FPGA configuration files and can also program a Xilinx FPGA. The PROM Emulator is a stand-in device that can be reprogrammed as many times as desired, but is still capable of configuring the Xilinx FPGAs.</i>
GSC-16991-1	<i>Neutron Spectrometer for Inner Radiation Belt</i>	<i>A novel, neutral-particle instrument for CubeSat platforms to address several critical science goals of solar and heliospheric physics as well as the radiation environment in low Earth orbit.</i>

CASE NO.	TECHNOLOGY	TECHNOLOGY DESCRIPTION
GSC-16969-1	High-Energy Instrumentation for Small Satellite Platforms	An instrument prototype that measures gamma-rays, neutrons, and energetic particles for Small Satellite platforms. A key asset of the instrument design is the ability to measure a broad range of radiation, which in concert can address several critical science goals of solar and heliospheric physics as well as the radiation environment in low Earth orbit.
GSC-16967-1	Science-Defined Software Radio	A digital receiver electronics board that is miniaturized, deployable on CubeSat platforms and usable on aircraft platforms. The goal of this effort is to deliver a rapidly reconfigurable instrument signal processing platform and supporting digital processing modules to the cross-cutting line of business.
GSC-16966-1	LHR-CUBE: A limb-viewing CubeSat instrument for atmospheric measurements of methane and carbon dioxide - FY13 IRAD	The LHR-CUBE (Laser Heterodyne Radiometer-CubeSat) concept will measure atmospheric methane (CH <sub>4</sub> ) and carbon dioxide (CO <sub>2</sub> ) from within a 6U CubeSat spacecraft. LHR-CUBE will provide a small, lightweight, low cost, fast turn-around platform for limb measurements that will help constrain the vertical distributions of CH <sub>4</sub> and CO <sub>2</sub> by providing measurements with differing vertical sensitivity.
GSC-16900-1	Miniature Release Mechanism or Diminutive Assembly for Nanosatellite deployables (DANY)	The DANY mechanism provides a secure method to constrain deployables without using any internal space due to its minimized thickness. DANY is fastened to the chassis and it provides a preloaded threaded interface to attach the deployable. After actuation, the threaded block is released, allowing the deployment to happen.
GSC-16867-1	Intelligent Payload Module	The Intelligent Payload Module (IPM) is a box that is targeted for use on satellite and airborne platforms. The purpose of the IPM is to be capable of performing onboard science processing on high speed sensor data with data rates as high as 1 Gbps.
GSC-16863-1	SpaceCube Communication Interface Box	The SpaceCube CIB serves as the on-orbit avionics for attached payloads providing command and telemetry data across 1553, 10BASE-T Ethernet, RS-422 and LVDS interfaces.
GSC-16856-1	Flight Processor Virtualization for Size, Weight, and Power Reduction	Cost saving and fault tolerant benefits of virtualization technology as demonstrated by consolidating multiple flight processors into a single virtualized system.
GSC-16849-1	Layout techniques for dual sided Printed Circuit Board (PCB) incorporating Fine Pitch Column Grid Array Devices to meet IPC Class 3/A manufacturing specifications	Layout techniques for dual sided Printed Circuit Board (PCB) incorporating Fine Pitch Column Grid Array Devices to meet IPC Class 3/A manufacturing specifications

CASE NO.	TECHNOLOGY	TECHNOLOGY DESCRIPTION
GSC-16839-1	<i>Back-to-Back High Density Connector on a Circuit Board to Increase Interconnect Density</i>	<i>The Airborn Nano series of connectors is used in this innovation. The idea is to place two of the connectors in a back-to-back fashion on a circuit card assembly to increase the amount of interconnect available. This was not possible with these series of connector prior to this innovation.</i>
GSC-16808-1	<i>SpaceCube v. 2.0 Flight Power Card</i>	<i>The SpaceCube v2.0 flight system leverages six years of heritage SpaceCube designs while advancing the technology one more step. The power board provides secondary voltages to a backplane, 3.3V, 5.0V, and +/- 12V which is converted from a 28 +/- 8V input. The card is designed specifically for the extended 3U SpaceCube system. The power design includes active current limiting, EMI filtering, input protection, and is capable of being ganged together to increase the maximum power capability. The design also includes a custom mechanical and thermal packaging solution.</i>
GSC-16807-1	<i>3D Plus Programmable Read Only Memory (PROM) Programming Procedure</i>	<i>The technology was developed for the SpaceCube v2.0 Engineering Model Processor Card, the PROM contains the configuration file of the main Xilinx Virtex-5 FPGA. Without the correct PROM program, the board will not operate after power up</i>
GSC-16805-1	<i>SpaceCube v2.0 Micro</i>	<i>The SpaceCube Micro is a subset of the SpaceCube v2.0 Engineering Model, Mini, and Engineering Test Unit designs. It is a Single Board Computer (SBC) intended for systems requiring a low power, yet very powerful data processor.</i>
GSC-16700-1	<i>SpaceCube v2.0 Flight Processor Card</i>	<i>The SpaceCube v2.0 Flight processor card leverages six years of heritage SpaceCube designs while advancing the technology one more step. This version of the processor architecture is better suited to handle radiation upsets than its predecessorss, and is being built for a longer life cycle. This version of the card will take either the radiation hardened device, or the commercial device that contains dual PowerPC440 processors.</i>
GSC-16679-1	<i>CubeSat Power System with Automatic High-Powered Payload Cycling</i>	<i>CubeSat power system that will automatically turn a highpowered payload on/off based on the battery state-of-charge. This will enable a new class of CubeSat payloads and allow more advanced research to be conducted.</i>
GSC-16551-1	<i>CRUQS A Miniature Fine Sun Sensor for Nanosatellites</i>	<i>A new miniature fine sun sensor has been developed. The sun sensor uses a quadrant photodiode and housing to determine the sun vector. Its size, mass and power make it especially suited to small satellite applications, especially nanosatellites. We are seeking an accuracy on the order of 2 or 3 arcminutes and will enable new science in the are of nanosatellites.</i>

CASE NO.	TECHNOLOGY	TECHNOLOGY DESCRIPTION
GSC-16287-1	<i>Miniaturized High-Speed Modulated X-Ray Source</i>	<i>First small, low-cost option for high-speed modulation of x-ray intensity. Smaller and more energy efficient than current SOTA x-ray tech. Modulation over time allows for x-ray communication</i>
GSC-15953-1	<i>SpaceCube Demonstration Platform</i>	<i>The HST SM4 RNS flight spare SpaceCube unit was modified to create an experiment called the SpaceCube Demonstration Platform (SC DP) for use on the MISSE7 Space Station payload (in collaboration with NRL).</i>
GSC-15936-1	<i>SpaceCube Version 1.5</i>	<i>The SpaceCube 1.5 is a high performance and low power system in a compact form factor. The SpaceCube 1.5 is a hybrid processing system consisting of CPU, FPGA, and DSP processing elements. The primary processing engine is the Virtex-5 FX100T FPGA which has embedded processors. The SpaceCube 1.5 System is a bridge to the SpaceCube 2.0 processing system.</i>
GSC-15782-1	<i>Ultra-low Power (&lt; 100mW), 64-Channel Pulse Data Collection System (PCDS)</i>	<i>This innovation offers a simple design concept that seamlessly captures 64 separate high-speed pulses of widths that are equal or greater than 4ns; yet this is accomplished with less than 100mW power consumption.</i>
GSC-15760-1	<i>SpaceCube 2.0 an Advanced Hybrid On-Board Data Processor</i>	<i>The SpaceCube 2.0 is a compact, high performance, low power on-board processing system that takes advantage of cutting-edge hybrid (CPU/FPGA/DSP) processing elements. The SpaceCube 2.0 design includes two radiation-hardened by design Virtex-5 FPGA parts and possesses exceptional size, weight and power characteristics.</i>
GSC-15753-1	<i>WATS: Wind and Temperature Spectrometry of the Upper Atmosphere in Low-Earth-Orbit</i>	<i>WATS is a new approach to determining the three components of the wind or ion-drift by measuring the full wind vector, the temperature, and the relative densities of major neutral species in the Earth's thermosphere.</i>



▶ *CubeSats orbiting the moon.* —PHOTO BY NASA

## NASA Goddard Tech Transfer News [ <http://itpo.gsfc.nasa.gov> ]

NASA Goddard *Tech Transfer News* is the quarterly magazine of the Innovative Technology Partnerships Office (Code 504) at NASA's Goddard Space Flight Center. Also available online at: <http://itpo.gsfc.nasa.gov>. Send suggestions to [Robert.S.Leonardi@nasa.gov](mailto:Robert.S.Leonardi@nasa.gov).