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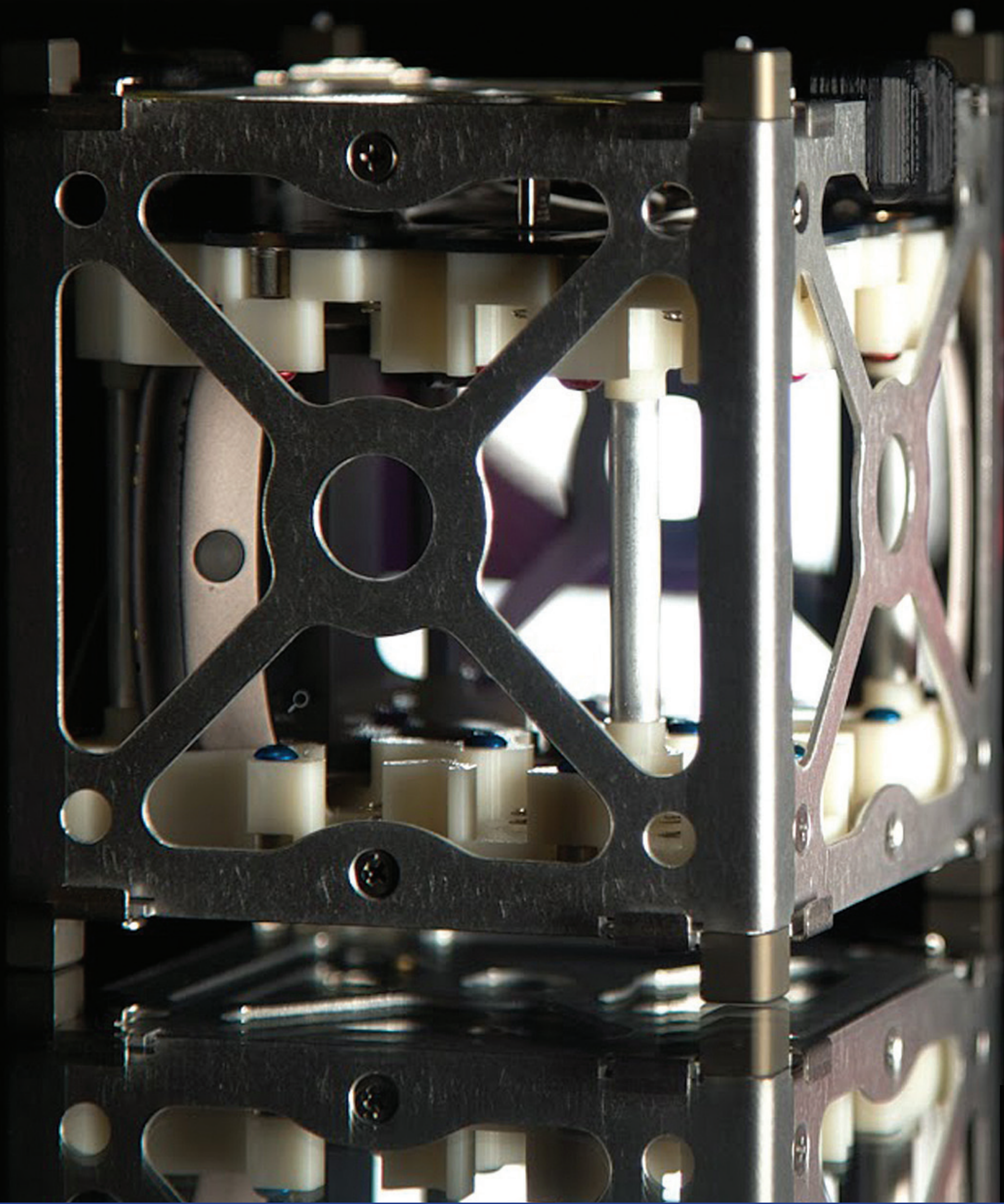

—PHOTO BY NASA

CubeSat

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Nona Cheeks

[FROM THE *Chief*

From the Chief

Doing more with less – in these days of tight budgets and limited funding, that philosophy has become a way of life. At NASA Goddard, this means constantly looking for new ways to be creative and innovative, while taking advantage of every opportunity to reduce development time and costs. This is the driving spirit behind NASA Goddard's increasing interest in the CubeSat platform. CubeSats are very small satellites, originally limited in size to a cube 10 centimeters per side and launched as secondary payloads on other satellite missions. Initially developed primarily as an academic tool designed to provide students with hands-on experience working with real satellites, CubeSats are now being considered for real-world missions to advance our scientific knowledge. An example of this is the upcoming Firefly mission, a collaboration between NASA Goddard and the National Science Foundation to study the link between lightning and terrestrial gamma-ray flashes.

Historically, CubeSats have been generally considered too functionally limited to meet the demands of high-end science research. More recently, the CubeSat standard is being enhanced with the goal of eventually extending this platform into deep space. NASA Goddard is at the forefront of this effort, helping to develop propulsion systems, power sources, and positioning capabilities necessary for these instruments to deliver advanced space science. For example, NASA Goddard's TechCube project is designed to significantly enhance the reliability of CubeSats, which up to now have experienced a high on-orbit failure rate. In addition, Wallops Flight Facility has been supporting the National Science Foundation's CubeSat activities since 2008.

Once their limitations have been addressed, CubeSats may become essential components of NASA Goddard's strategy, providing an entry point into space at a cost that is orders of magnitude lower than other satellite platforms.

In this issue of Tech Transfer News, we speak with several NASA Goddard innovators involved in various CubeSat-related projects and technologies. We also look at how NASA Goddard is using and advancing the CubeSat platform, and also potential commercial opportunities offered by CubeSats. One consistent theme throughout this issue is how CubeSat involves collaboration between government, academia, and private enterprise, working within an established standard and using off-the-shelf components. This environment raises a number of Intellectual Property (IP) related issues, which we discuss with our regular legal contributor Bryan Geurts, Chief Patent Counsel for NASA Goddard's Office of Patent Counsel.

One final note: you may notice a small but important change in the name of our group, formerly called the Innovative Partnerships Program Office. Our new name is the **Innovative Technology Partnerships (ITP) Office,** to reflect the critical technology transfer component of our mission.

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

CUBESAT DEVELOPMENT *at NASA Goddard*

CubeSat Development

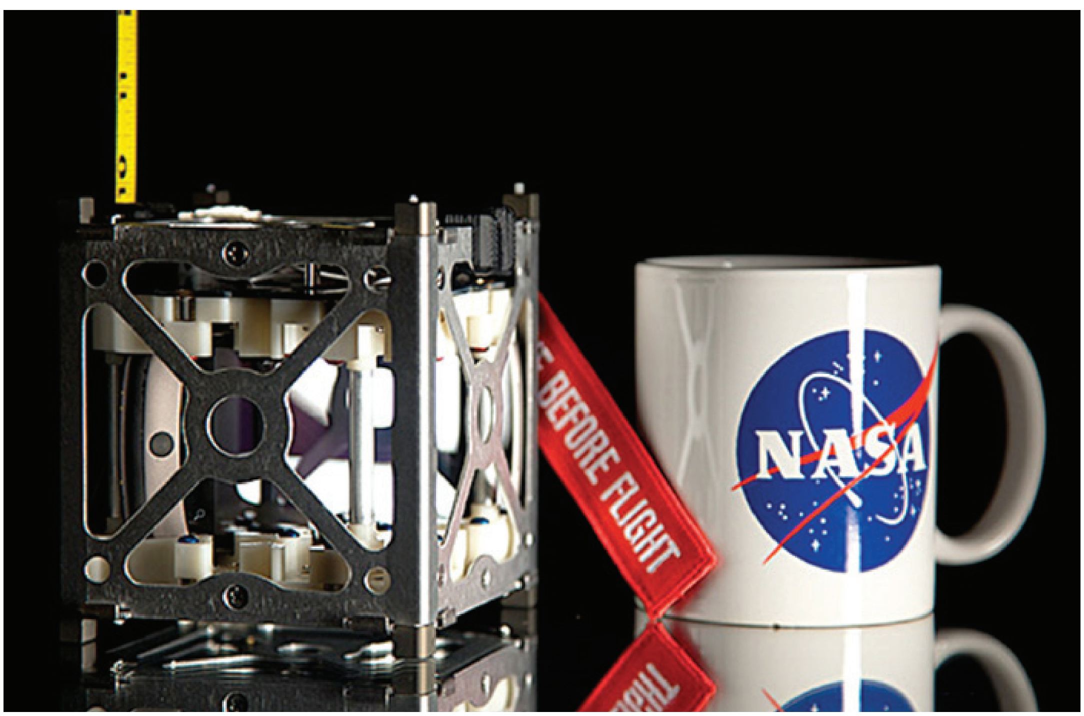
Although the CubeSat standard was originally developed primarily for academic purposes, there has been growing interest in adapting CubeSat instruments to perform important scientific observations and commercial applications. Researchers are actively working on making CubeSats more robust and versatile, 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

The CubeSat standard was initially conceived in 1999, through collaboration between California Polytechnic State University and Stanford University. 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. 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.



▶ *A 1U CubeSat.*

—PHOTO BY NASA

To further reduce cost, CubeSat projects have up to 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 (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 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.

▶ *Antares lifts off from Wallops Flight Facility, with 3 CubeSats onboard.*

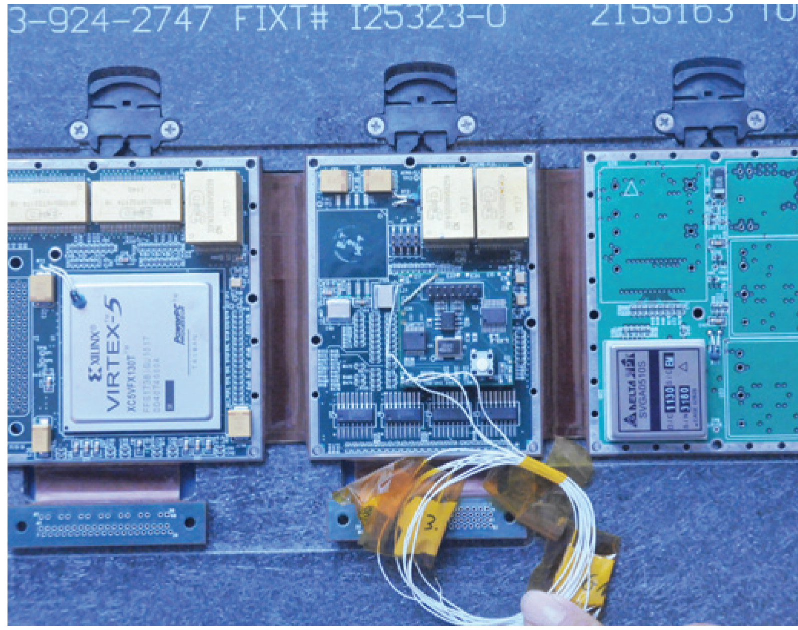
—PHOTO BY NASA

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.”

Other potential propulsion methods include launching CubeSat devices from an airplane platform, or even via a cannon-type device to shoot CubeSats into orbit. “Wallops currently holds a record for the longest cannon-based launch of a particular diameter projectile without any propulsion on the projectile,” says Mr. Schaire. “Wallops has looked at hosting a railgun which uses electromagnetic force to propel the payload. I don’t see this technology being used to launch CubeSats into Earth orbit; but it could possibly be used on the moon to launch payloads from the moon into deep 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 the reliability of the CubeSat platform through the development of a scalable, high reliability bus known as TechCube,” states Thomas Flatley (Branch Head, Science Data Processing Branch). “TechCube’s 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 that can be used on TechCube. 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 the TechCube bus. Both deep space projects and long duration Earth orbiting missions (LEO, polar, MEO, GTO/GEO) would require TechCube.”



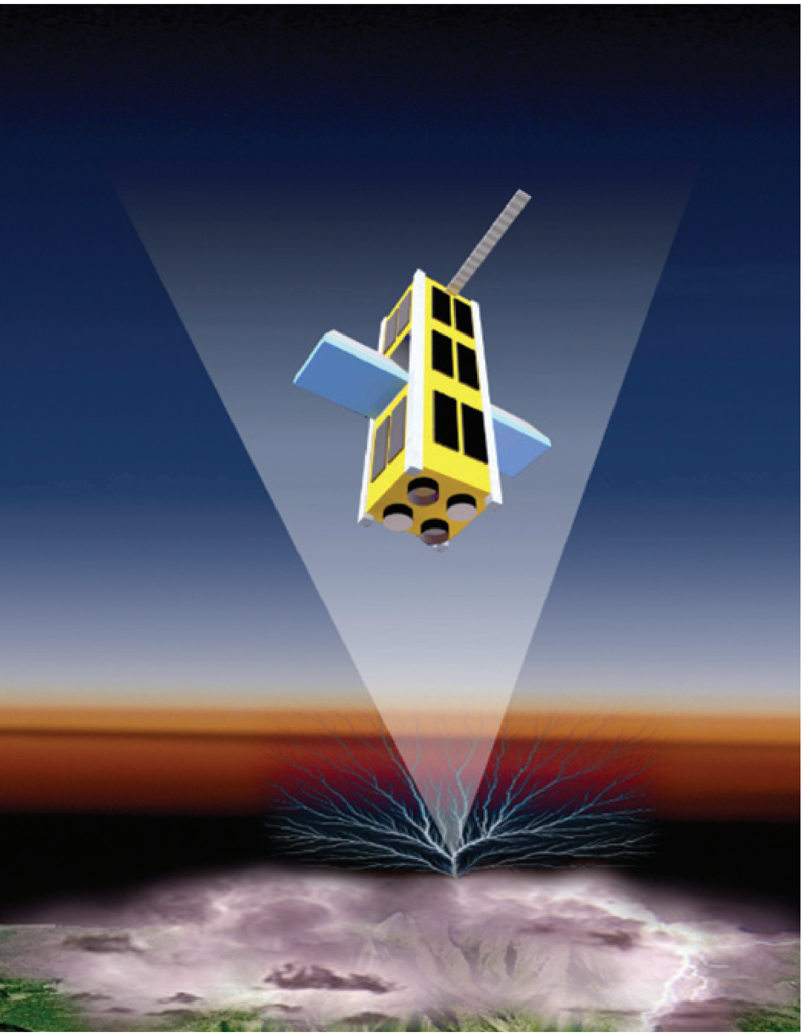
▶ *SpaceCube Mini.*

—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.



▶ *Artist's Conception of Firefly.*

—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, scheduled to be launched later this year. Firefly will explore the relationship between lightning and so-called Terrestrial Gamma Ray Flashes (TGFs), a phenomenon first discovered in the 1990s.

Firefly will investigate 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 primary radiation belt energization, as well as loss electron spectra and microbursts. It will also observe solar electron spectra from > 5 keV.

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. Other NASA Goddard technology initiatives, such as TechCube and SpaceCube, are 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 Firefly and CeREs.

[CUBESAT *Interview*

Interview

Many 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.

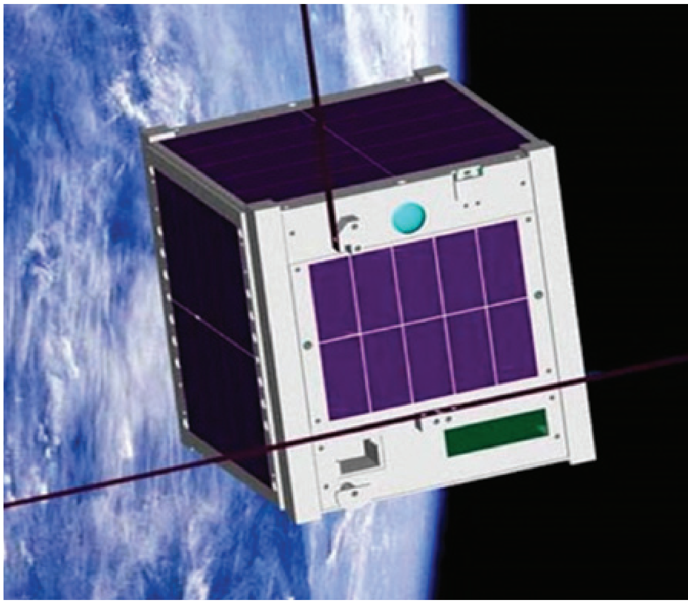
In this interview, several NASA Goddard innovators discuss their ongoing work with CubeSat projects, and how this platform may be of significant interest and value to the future exploration of space.

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

Pamela Clark (Scientist, Sciences and Exploration Directorate): 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.

Carl Adams (Assistant Chief for Technology, Mission Engineering and Systems Analysis Division): Historically, most CubeSat related work has been going on outside NASA. Up to now CubeSats have been seen as primarily an academic tool, designed to help students learn the basics of satellite technologies. NASA Goddard grew more interested in CubeSats as these students started working for us, and brought their CubeSat knowledge with them. They understood that CubeSats can be used to perform useful scientific measurements.

Scott Schaire (Small Satellite Projects Manager, GSFC Wallops Flight Facility, Suborbital and Special Orbital Projects Directorate Staff): 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.



Artist rendition of a CubeSat in orbit.

—PHOTO BY NASA

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.

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

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.

Carl Adams: Budgetary pressure is definitely driving interest in CubeSats. Flagship missions may come about once a decade. In the interim, we need to look at ways to do real science relatively inexpensively.

Carl Adams

ASSISTANT CHIEF FOR TECHNOLOGY, APPLIED ENGINEERING AND TECHNOLOGY DIRECTORATE

Code: 590

Years with NASA: 19

Education: Ph.D. Aerospace Engineering

Engineers are now just beginning to understand the potential for CubeSats to do this. It does require something of a culture shift, however. We're used to working on large programs devoted to major high-profile missions. Instead, we now might have a small group of perhaps five or ten people working on a CubeSat project.

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?*

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.

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.]

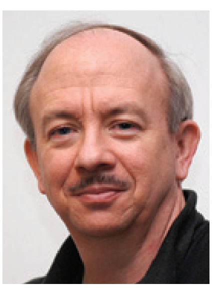
Scott Schaire

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

Robert MacDowall (Chief, Planetary Magnetospheres Laboratory): 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.



Robert MacDowall

CHIEF, PLANETARY MAGNETOSPHERES LABORATORY

Code: 695

Years with NASA: 22

Education: PhD in Astronomy, University of Maryland, College Park

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.

Thomas Flatley (Branch Head, Science Data Processing Branch): 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.

Ben Cervantes (Wallops Mission Planning Lab Lead): 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 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.

Thomas Flatley

BRANCH HEAD, SCIENCE DATA PROCESSING BRANCH

Code: 587

Years with NASA: 27

Education:
BS Engineering, Loyola College, 1985

Carl Adams: Major technological challenges for CubeSats involve what we call the "three P's" – power, propulsion, and pointing.

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.

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

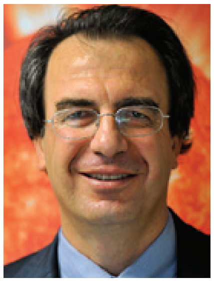
Nick Paschalidis: At this point, CubeSats really aren't ready yet for deep space missions. However, it is ideal for low earth orbit projects designed to advance the science of heliophysics. CubeSat standards are mature enough to perform remote sensing of the sun, and to perform in situ observations of 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 can NASA Goddard provide to overcome these limitations?***

Carl Adams: NASA can help the CubeSat platform become more reliable. As we've noted, historically CubeSats have been notoriously unreliable, with half the missions failing. It's a challenge for a university to develop more reliable components for CubeSats. NASA has the resources and expertise to help do this. Areas in which NASA can provide special value include electronics miniaturization and environmental testing. NASA has large and diverse technology development resources devoted to these areas.

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.

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.



Nick Paschalidis

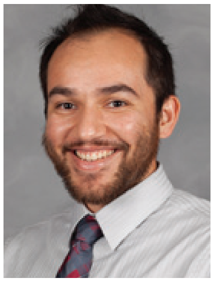
SENIOR PROJECT SCIENTIST FOR TECHNOLOGY ADVANCEMENT, HELIOPHYSICS SCIENCE DIVISION

Code: 670

Years with NASA: 2

Education: PhD in Space Science and Technology

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.



Ben Cervantes

MISSION PLANNING LAB LEAD

Code: 589

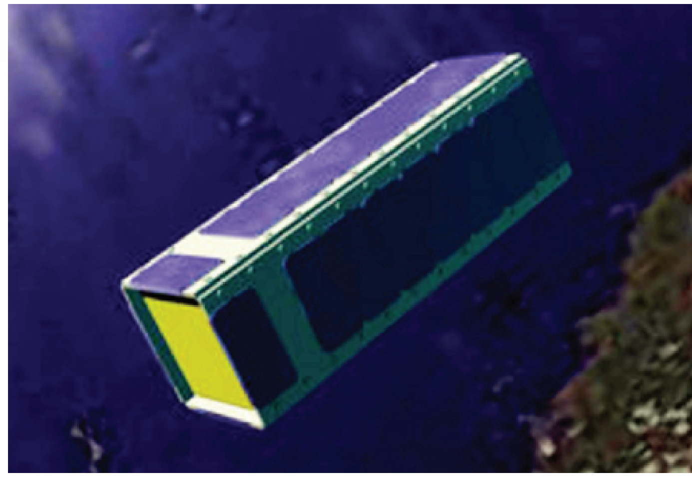
Years with NASA: 8

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

CUBESAT *Commercialization Opportunities*

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.



Artist's rendition of GeneSat-1, a CubeSat mission launched from Wallops Flight Facility.

—PHOTO BY NASA

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

Mr. Flatley is currently working on TechCube, an initiative designed to extend CubeSat projects for use in deep space and for long-duration and "beyond LEO" Earth orbits. To do this, TechCube satellites are made from highly reliable components from select vendors/universities, other government agencies (NRL, AFRL), and high-reliability components developed internally at NASA Goddard. The success of TechCube could in turn create a new market for the suppliers of TechCube components. The Department of Defense has an interest in TechCube, as do other agencies that have a need for highly reliable CubeSat projects.

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 supports CubeSat projects

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.

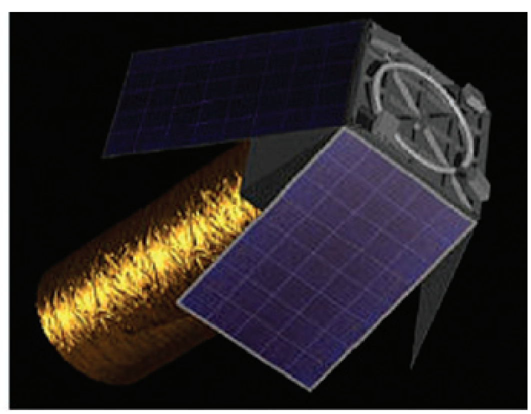
NASA Goddard is actively developing technologies designed to help CubeSats transition from functionally limited academic tools to a robust deep-space platform. Much of this work is being conducted in collaboration with other entities, including universities and commercial interests. A portion of this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

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 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.

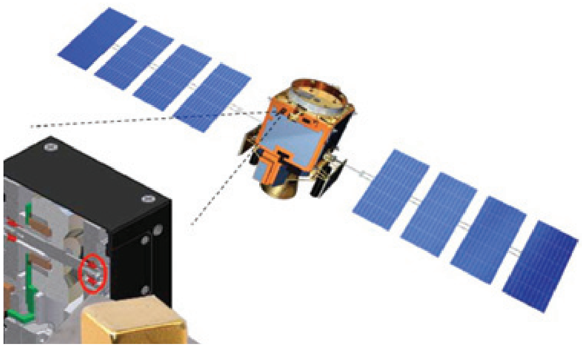
Multi-functional Optical Subsystem Enabling Laser Communication on Small Satellites (Arkyd Astronautics)

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

CubeSat

[PROTECTING *CubeSat Intellectual Property*

Patenting Perspectives

As we've noted in this issue of Tech Transfer News, CubeSat research involves adhering to established standards and specifications, including the requirement that CubeSat-compliant satellites be built from readily available components and technology. In addition, CubeSat missions are often the result of collaboration between multiple entities, including academia and private industry. Such an environment raises a number of interesting Intellectual Property (IP) protection issues.

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?*

Bryan Geurts

Bryan: 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 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 3.3 pound 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.

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

Bryan: 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?*

Bryan: 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?*

Bryan: 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?*

Bryan: 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.

Bryan Geurts

CHIEF PATENT COUNSEL

Code: 140.1

Years with NASA: 11

Education:
B.S.Civil Engineering, B.A. German from University of Utah

Juris Doctor Degree from Brigham Young University

Networking and Outreach

6th Annual Sciences & Exploration Directorate New Year's Poster Party

(JANUARY 30, 2013, GREENBELT MD)

NASA Goddard's Innovative Technology Partnerships (ITP) Office participated in the 6th Annual Sciences & Exploration Directorate (SED) New Year's Poster Party. This event brings together Earth and space scientists, along with invited presenters from the Applied Engineering and Technology Directorate (AETD), to display their posters from 2012 meetings. ITP staff members spoke with attendees about partnerships, licensing, and New Technology Reporting (NTR) benefits.

Innovative Technology Partnerships Office staff member Brady Spenrath speaks with an attendee at the 6th Annual Science & Exploration Directorate New Year's Poster Party..

—PHOTO BY NASA

2013 Annual Aerospace@Annapolis Day

(FEBRUARY 1, 2013, ANNAPOLIS, MD)

The Innovative Technology Partnerships Office participated in Aerospace@Annapolis Day at the Miller Senate Office Building

Guests visit the Innovative Technology Partnerships Office exhibit during the 2013 Annual Aerospace@ Annapolis Day.

—PHOTO BY NASA

in Annapolis, Maryland, on February 1, 2013. Maryland companies and NASA Goddard Partners Northrop Grumman, Emergent Space Technologies Inc., DesignAmerica Inc., and the University of Baltimore, shared table space demonstrating their technologies and speaking on their partnerships and experiences working with NASA Goddard. Over 400 attendees, including senators, delegates, and the general public, visited the event. This provided NASA Goddard an excellent opportunity to inform Maryland lawmakers and residents about NASA Goddard's impact within the state and the U.S., as well as its dedication to forming partnerships that make positive contributions to NASA's research & development and technology innovations.

ARPA-E Energy Innovation Summit

(FEBRUARY 26-27, 2013, NATIONAL HARBOR, MD)

NASA participated in the ARPA-E Energy Innovation Summit at the Gaylord National Hotel and Convention Center in National

Harbor, MD on February 26 and 27, 2013. The Innovative Technology Partnerships Office represented NASA Goddard along with a representative from NASA Glenn Research Center. The ARPA-E Energy Innovation Summit is an event dedicated to transformative energy solutions, bringing together thought leaders from academia, business, and government to discuss cutting-edge energy issues and facilitate relationships to help move technologies into the marketplace. There were approximately 2,700 summit attendees (including students) who provided a steady stream of showcase attendees. NASA received several inquiries in specific areas such as electronics, solar energy, biofuel, CPV technology, batteries, and the TechPort system, to name a few.

▶ *Innovative Technology Partnerships Office staff member Eric McGill speaks with a visitor at the 2013 ARPA-E Energy Innovation Summit..*

—PHOTO BY NASA

2013 Association of University Technology Manager (AUTM)

(FEBRUARY 27 – MARCH 2, 2013, SAN ANTONIO, TX)

Innovative Technology Partnerships Office Chief Nona Cheeks was invited to speak at the 2013 Association of University Technology Managers (AUTM) Annual Meeting, held in San Antonio, Texas. Ms. Cheeks spoke as part of a panel, sharing her knowledge of technology transfer and commercialization. During the meeting, the ITP Office forged business relationships with fellow technology managers from academia and industry; and listened to various experts about the changing climate of technology transfer, influenced by recent economic issues, shifts in social media, and the effects the America Invents Act has had on U.S. patent policy.

Mid-Atlantic Advanced SBIR Strategies Workshop

(MARCH 13, 2013, HERNDON, VA)

The Innovative Technology Partnerships Office hosted a booth at the 2013 Mid-Atlantic Advanced SBIR Strategies Workshop on Wednesday, March 13, 2013, in Herndon, Virginia. This workshop offered attendees the opportunity to network with businesses and government agencies and gather information on Small Business Innovative Research (SBIR) opportunities. ITP Office SBIR/STTR Program Manager and Technology Infusion Manager Cynthia Firman spoke about NASA Goddard's SBIR Program, and conducted a presentation on SBIR strategies and the writing of competitive SBIR Phase II proposals.

▶ *Innovative Technology Partnerships Office SBIR/STTR Program Manager and Technology Infusion Manager Cynthia Firman talks with attendees about SBIR opportunities.*

—PHOTO BY NASA

In the News

Antares awaits launch at Wallops Flight Facility.

—PHOTO BY NASA

The following is a brief review of a few recent news stories prominently featuring NASA Goddard's ongoing work with the CubeSat platform.

Antares launch from Wallops Flight Facility carries CubeSats into space

On April 21 2013, Orbital Sciences Corporation's Antares rocket made its maiden flight from Wallops Flight Facility. The launch is the first of three planned for this year, with the goal of demonstrating Orbital Sciences' ability to conduct resupply missions to the International Space Station. Antares' primary payload was the Cygnus Mass Simulator, an inert vehicle designed to simulate the mass of a Cygnus spacecraft.

In addition, Antares carried four CubeSats into orbit. Three of these were NASA-built PhoneSats: "Alexander," "Graham," and "Bell." Graham and Bell are PhoneSat 1.0 devices, while Alexander is a PhoneSat 2.0b.

PhoneSats are technology demonstration 1U CubeSats designed to test the feasibility of building satellite onboard systems around off-the-shelf mobile telephone technology. These satellites are among the least expensive ever constructed, with a budget of $3,500 per PhoneSat 1.0 unit and $8,000 for PhoneSat-2.0s.

For more information about the Antares launch at Wallops Flight Facility, see http://www.nasa.gov/centers/wallops/news/antares-launches.html.

For more information about the PhoneSats launched by Antares, see http://www.nasa.gov/directorates/spacetech/small_spacecraft/phonesat.html.

NASA announces fourth round of CubeSat Launch Initiative selections

On February 26 2013, NASA announced its selections of 24 CubeSats that will be launched as secondary payloads onboard missions planned for 2014 through 2016. These selections are part of NASA's ongoing CubeSat Launch Initiative (CSLI) program that provides opportunities for CubeSats to fly on rockets planned for upcoming launches.

Among the successful proposals are projects from universities, non-profit organizations, NASA Centers, and a Florida high school. Three of these CubeSat missions are being developed at NASA Goddard Flight Center. For a complete listing of the successful CSLI mission selection, see http://www.nasa.gov/directorates/heo/home/CSLI_selections.html.

For more information about the CubeSat Launch Initiative program, see http://www.nasa.gov/directorates/heo/home/CubeSats_initiative.html.

Technology Disclosures

Disclosures

- **JLAB TRACKING TOOL (JTRAK)**
  Arlene Bigel

- **ADVANCED P-BAND SPACEBORNE RADAR SYSTEM**
  Rafael Rincon

- **GODDARD MISSION SERVICES EVOLUTION CENTER (GMSEC) CRITERIA ACTION TABLE (CAT) VERSION 5.4.1**
  Michael Yang

- **SPACECUBE V2.0 MICRO**
  David Petrick, Alessandro Geist, Michael Lin, Gary Crum

- **ELECTROMAGNETIC META-MATERIAL WITH WIDE-ANGULAR AND BROADBAND-SPECTRAL ABSORPTION**
  Edward Wollack, Kongpop U-yen

- **TDRS SIMULATOR (TSIM)**
  Markland Benson

- **LENS MOUNTS FOR CRYOGENIC OPTICAL INSTRUMENTS**
  Andrew Monson, Michael Pierce

- **A COMPACT TWO-STEP LASER DESORPTION/ IONIZATION TIME-OF-FLIGHT MASS SPECTROMETER FOR IN SITU PLANETARY EXPLORATION**
  Stephanie Getty, William Brinckerhoff, Timothy Cornish

- **GREAT (GODDARD MISSION SERVICES EVOLUTION CENTER (GMSEC) REUSABLE EVENTS ANALYSIS TOOLKIT) VERSION 2.3**
  Daniel Hunke

- **MICROMACHINED THERMOPILE ARRAYS WITH NOVEL THERMOELECTRIC MATERIALS**
  Emily Barrentine, Shahid Aslam, Ari Brown

- **BUNDLE PROTOCOL SOFTWARE LIBRARY VERSION 1.0**
  Timothy Ray

- **CFE/CFS EVOLUTION FOR MULTI-CORE PLATFORMS**
  DwaineMolock, Alan Cudmore, David Edell, Christopher Monaco

- **GRAVITE UPLOAD TOOL**
  Peyush Jain

- **CONSULTATIVE COMMITTEE FOR SPACE DATA SYSTEMS (CCSDS) FILE DELIVERY PROTOCOL (CFDP) DUMP UTILITY VERSION 1.0**
  Timothy Ray

- **SHAPED BEAM HIGH GAIN ANTENNA ON SINGLE AXIS TURNTABLE FOR NASAS KA-BAND COMMUNICATION APPLICATIONS**
  Cornelis Du Toit, Victor Marrero-Fontanez

- **ULTRA-LOW NOISE PREAMPLIFIER FOR WIDE BAND GAP DETECTORS**
  Duncan Kahle, Augustyn Waczynski, Shahid Aslam, Federico Herrero

- **FRONT END DATA SYSTEM (FEDS) VERSION 10.0**
  Ryan Detter, Edwin Fung, Peter Gorog, Daniel Grogan, Larry Alexander, Charles Englehart, George Wofford, Thomas Green, Jeffrey Condron, James Dowling

- **GRAVITE INCINERATOR**
  Peyush Jain

- **INFORMATION-BASED AUTOMATIC GAIN CONTROL WITH HARDWARE ACCELERATION**
  Bo Naasz, Will Clement

- **MIRRORLET ARRAY BASED INTEGRAL FIELD SPECTROMETER (IFS) FOR AGRICULTURE STUDY**
  Qian Gong

- **LAB QUALITY MANAGEMENT SYSTEM (LQMS) APPLICATION**
  Gregory Wood
- **DEVELOPMENT OF A METALLIC BILAYER LIFTOFF MASK**
  Ari Brown
- **LOW EXCESS NOISE, HIGH GAIN AVALANCHE PHOTODIODES**
  Rengarajan Sudharsanan, Xiaogang Bai, PingYuan
- **SOLAR PUMPED FIBER LASER FOR SOAR SAIL PROPULSION, SPACECRAFT REMOTE POWER TRANSFER APPLICATIONS FOR EARTH AND PLANETARY MISSION**
  Donald Coyle, Paul Stysley, Demetrios Poulios
- **DISTRIBUTED INTEGRATED MODULAR AVIONICS (DIMA) HARDWARE AND SOFTWARE REFERENCE ARCHITECTURE**
  Jonathan Wilmot, Glenn Rakow
- **SPACECUBE V. 2.0 FLIGHT POWER CARD**
  David Petrick, Pietro Sparacino, Milton Davis,
- **FOCUSING ROLLER NUT**
  Michael Williams
- **LABNOTES: A MOBILE APP FOR INSTRUMENT CONTROL AND DATA COLLECTION**
  Troy Ames, Emily Steel, Carl Hostetter
- **SMAP RADIOMETER L1A PACKET DATA PROCESSING, USING ALGORITHMS PREVIOUSLY DEVELOPED IN MATLAB BY OTHERS, IS CONVERTED TO ANSI C CODE**
  Elisabeth Brinker
- **SMAP RADIOMETER CCSDS DATA PACKET INPUT PROCESSOR IN ANSI C.**
  Elisabeth Brinker
- **OBS4MIPS.PY**
  Denis Nadeau
- **3-DIMENSIONAL PHOTOVOLTAICS ARRAY FOR LASER BASED POWER TRANSFER**
  Donald Coyle
- **ROBOTIC GRIPPER FOR AUTONOMOUS RENDEZVOUS AND CAPTURE OF SATELLITES**
  Matthew Ardmore
- **FLIGHT PROCESSOR VIRTUALIZATION FOR SIZE, WEIGHT, AND POWER REDUCTION (FY13 IRAD)**
  Alan Cudmore, Justin Rice
- **GMSEC REMOTE APPLICATION SERVICE PROVIDER (GRASP) 2.0**
  Matthew Handy, Thomas Grubb
- **INVESTIGATION OF WAVE-PARTICLE INTERACTIONS IN SOLAR WIND ACCELERATION REGION**
  Nojan Omidi
- **ELECTRONICS MINIATURIZATION WITH A SYSTEMONACHIP FOR POWER SYSTEMS**
  Amri Hernandez-Pellerano, Jeffrey DuMonthier, Robyn King
- **EVOLUTIONARY MISSION TRAJECTORY GENERATOR (EMTG)**
  Jacob Englander
- **INTERCALIBRATION OF MEASUREMENTS FROM MICROWAVE SENSORS FOR TRMM AND GPM USING A WELL VALIDATED RADIATIVE TRANSFER CODE**
  Jean-Luc Moncet
- **THE JPSS DPE BINARY LUT/ FILE READER AND EDITOR**
  Sergei Gusev, William Ardanuy, Alice Issacman, Adam Hollidge
- **THE MICRORADIOMETER AS AN INTELLIGENT (I.E., PROGRAMMABLE OR SMART) PHOTODETECTOR**
  Stanford Hooker, Charles Booth, Randall Lind, John Morrow
- **HAZARDS ANALYSIS MANAGEMENT TOOL**
  Chad Schaeffer, John Schmidt
- **TASS-ENHANCED NEAR EARTH NAVIGATION EXPERIMENT**
  Peter MacDoran, Kenn Gold, Michael Matthews, Michael Davies
- **CROSS SUPPORT TRANSFER SERVICE FRAMEWORK SOFTWARE LIBRARY VERSION 1.0**
  Timothy Ray
- **METHOD FOR PROTECTING THIN FILM LAYERS FROM DAMAGE DURING DEVICE PROCESSING**
  Kevin Denis, George Manos, Erik Crowe
- **EEPROM FILE SYSTEM**
  Alan Cudmore, Steven Slegel
- **GRAVITE DISTRIBUTION**
  Peyush Jain

- **BACK-TO-BACK HIGH DENSITY CONNECTOR ON A CIRCUIT BOARD TO INCREASE INTERCONNECT DENSITY**

  David Petrick

- **LAYOUT TECHNIQUES FOR DUAL SIDED PRINTED CIRCUIT BOARD (PCB) INCORPORATING FINE PITCH COLUMN GRID ARRAY DEVICES TO MEET IPC CLASS 3/A MANUFACTURING SPECIFICATIONS**

  David Petrick, Luan Vo, Dennis Albaijes

- **WEB MONITORING OF EVENTS REMOTELY (WEBMERE) 1.0**

  Thomas Grubb, Matthew Handy

- **GRAVITE PLANNER**

  Peyush Jain

- **GRAVITE DATABASE**

  Peyush Jain

- **A METHOD OF LIVE-CELL IMAGING AND FLUID EXCHANGE FOR A LAB-ON-CHIP CLINOROTATION SYSTEM**

  Alvin Yew, Javier Atencia-Fernandez

- **3D PLUS PROGRAMMABLE READ ONLY MEMORY (PROM) PROGRAMMING PROCEDURE**

  Jonathan Boblitt, David Petrick, Alessandro Geist

- **SPACE NETWORK ACCESS SYSTEM (SNAS)**

  Keiji Tasaki, Rosemarna (Rose) Pajerski, Helaleh Mag hsoudiou

Patents Issued

- **PHASE RETRIEVAL FOR RADIO TELESCOPE AND ANTENNA CONTROL**

  Bruce Dean

- **ADR SALT PILL DESIGN AND CRYSTAL GROWTH PROCESS FOR HYDRATED MAGNETIC SALTS**

  Edgar Canavan, Peter Shirron, Michael DiPirro

- **PROGRESSIVE BAND SELECTION FOR HYPERSPECTRAL IMAGES**

  Kevin Fisher

- **AUTOMATIC EXTRACTION OF PLANETARY IMAGE FEATURES**

  Jacqueline Le Moigne, Giulia Troglio, Jon Benediktsson, Sebastiano Serpico, Gabriele Moser

- **NOVEL SUPERCONDUCTING TRANSITION EDGE SENSOR DESIGN**

  John Sadleir

Provisional Patents Filed

- **MASKLESS CREATION OF SMALL STRUCTURE WITH SELECTIVE DEPOSITION OF GOLD NANO-PARTICLES (GOLD BLACK)**

  Rainer Fettig, Brook Lakew, John Brasunas

- **SPACECUBE V2.0 PROCESSOR CARD, ENGINEERING MODEL**

  David Petrick, Dennis Albaijes

- **ASYMPTOTIC DIET ALGORITHM WITH PSYCHOLOGICAL AND TEMPORAL STABILITY (ADAPTS)**

  Steven Curtis

- **WALLOPS FLIGHT FACILITY 6U ADVANCED CUBESAT EJECTOR (ACE)**

  Luis Santos, John Hudeck

- **COMPACT KA BAND ANTENNA FEED WITH DOUBLE CIRCULARLY POLARIZED CAPABILITY FOR NASA'S KA BAND COMMUNICATION APPLICATIONS**

  Cornelis Du Toit, Kenneth Hersey

- **SPACE PLASMA ALLEVIATION OF REGOLITH CONCENTRATIONS IN LUNAR ENVIRONMENTS BY DISCHARGE (SPARCLED)**

  Steven Curtis

Patent Applications Filed

- **WALLOPS FLIGHT FACILITY 6U ADVANCED CUBESAT EJECTOR (ACE)**

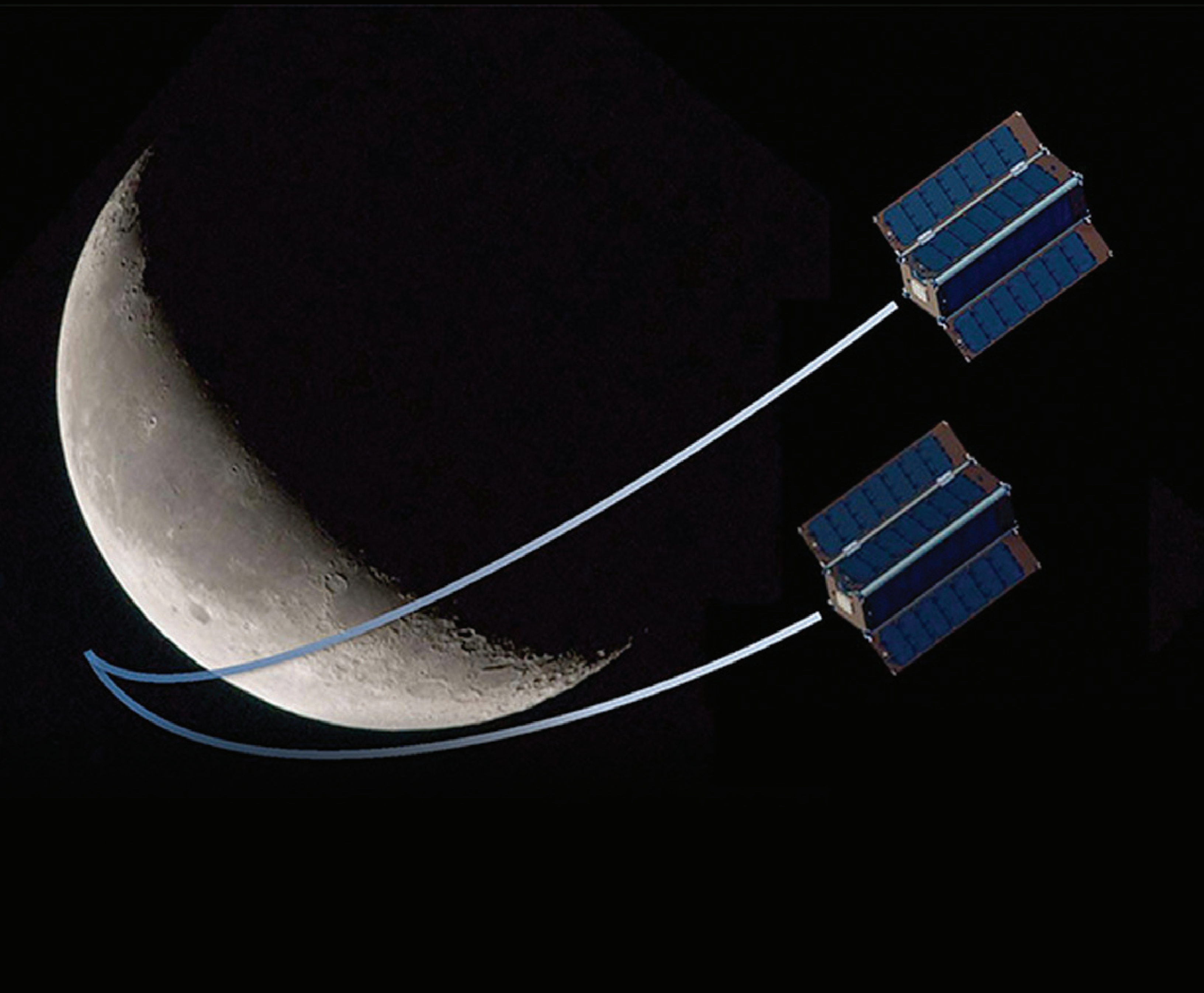
  Luis Santos, John Hudeck

- **IMPEDANCE MATCHED TO VACUUM, INVISIBLE-EDGE DIFFRACTION SUPPRESSED MIRROR**

  Shahram Shiri, John Hagopian, Patrick Roman, Edward Wollack

Space Act Agreements

COMPANY	AGREEMENT TYPE	NOTES
University of Minnesota IRMOS	*Non-reimbursable Space Act Agreement (SAA)*	*JWST loan of astronomy research instrument*
Boeing Co.	*Reimbursable SAA*	*CARA – On-orbit collision avoidance*
Hollywood Black Film Festival (HBFF)	*Non-Reimbursable SAA*	*Inspired sci-fi film screenplays pertinent to the current and future work of NASA. Also to produce films that would stir more interest in the space program and inspire careers in science, technology, engineering and mathematics (STEM)*
Space Dynamics Laboratory/ Utah State University Research Foundation	*Reimbursable SAA*	*Development of a high-resolution cryogenic rotary encoder*
Rocket21.com	*Umbrella Non-Reimb. SAA*	*EPO & OPTIMUS PRIME Spinoff Award*
Wisdom Tools	*Non-Reimbursable SAA*	*Aerodynamically Stabilized Instrument Platform for Kites and Tethered Blimps ("AeroPod"), NASA Case No. GSC-15856-1*



▶ *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.

www.nasa.gov

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