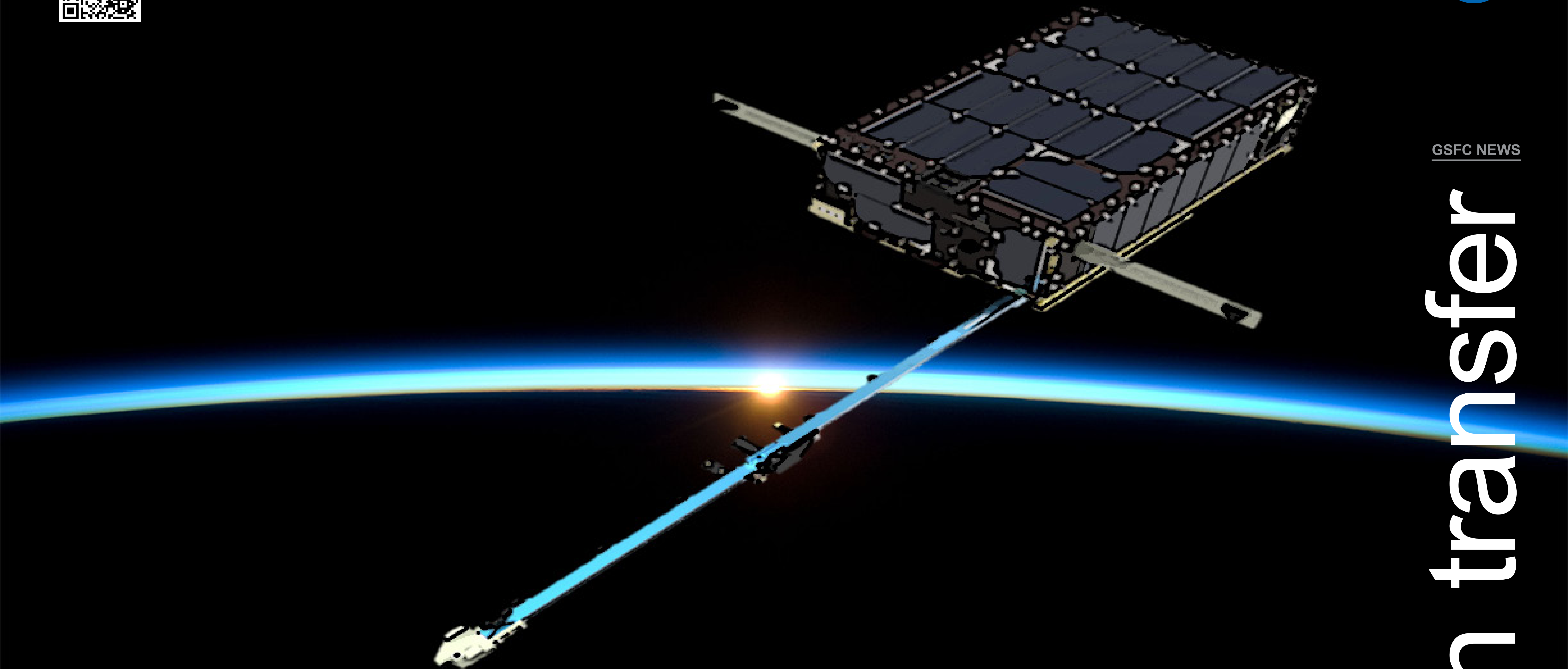
National Aeronautics and Space Administration

GSFC NEWS

# tech transfer



## 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

**– COVER IMAGE BY NASA**

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

SmallSat/Cubesat

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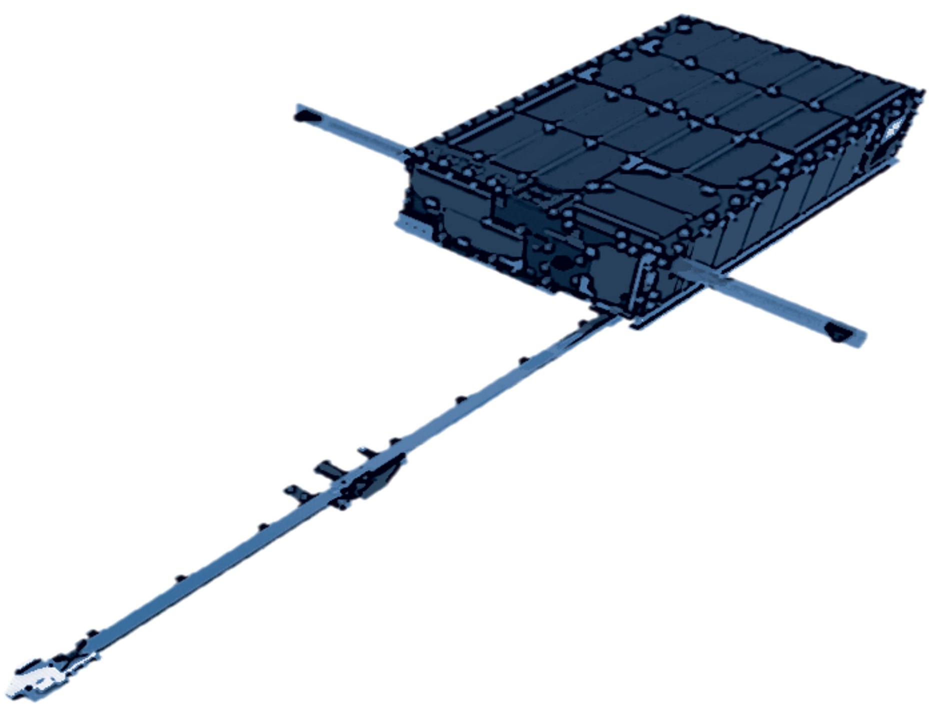


volume 13, number 3 | summer 2015

SmallSat/
CubeSat

# [ FROM THE *Chief*

From the Chief

Last summer, our "SmallSat/CubeSat" issue (Volume 12, Number 3, Summer 2014) acknowledged and outlined the substantial opportunities made possible by emerging miniaturized satellites. On the cover of this issue NASA Goddard Space Flight Center's (GSFC) Dellingr CubeSat is featured. Dellingr is a new 6U CubeSat designed and built by NASA GSFC to demonstrate the capabilities for addressing space research science project needs. The initial science focus of Dellingr will be applied to heliophysics research studies.

For the research science community Dellingr is poised to prove out smaller, more efficient, and a less costly option for accommodating NASA space science mission needs.

Dellingr demonstrates innovation in technology components, sub-systems, as well as a new compact satellite platform for executing inexpensive science missions. As a result, these new technologies have been reported to the NASA GSFC office responsible for managing technology transfer program activities. The technology transfer program ensures these technologies are properly vetted for further sharing for use in broader research science communities and the widening interests in building SmallSats/ CubeSats to address commercial needs.

In this issue, you will also learn more about NASA GSFC's approach and interest that enabled in-house and out-of-house design, development, application, and managing overall expectations of SmallSats/CubeSats capabilities.

Some of the technology transfer opportunities resulting from SmallSats/CubeSats are:

1. GSC-15936-1 SpaceCube 1.5
2. GSC-15953-1 SpaceCube 1.0
3. GSC-16223-1 SpaceCube Mini
4. GSC-16700-1 SpaceCube 2.0
5. GSC-16795-1 Advanced CubeSat Ejector (ACE)
6. GSC-16900-1 DANY Mechanism
7. GSC-17034-1 Thermal Control Louvers
8. GSC 17152-1 Dellingr
9. GSC-17197-1 Tool for CubeSat/SmallSat Part Selection

**NONA CHEEKS**
*Chief, Innovative Technology Partnerships Office (Code 504)*
*NASA Goddard Space Flight Center*

CubeSat Development

## Dellingr: The Dawn of a New CubeSat

**FEATURE:** Tech Transfer Magazine
***Byline:*** Ashley Morrow

One small team at NASA's Goddard Space Flight Center in Greenbelt, Maryland, is working to develop an even smaller satellite that could revolutionize the mission-building process.

About the size of a shoebox, the Dellingr CubeSat looks tiny in comparison to many of Goddard's spacecraft. Because of their size, these miniaturized satellites provide relatively quick and cost-effective access to space compared to larger missions, which may take five to six years and millions of dollars to build.

"The ultimate goal is to turn this into a platform where scientists can do relevant science and precursor missions to prove early instrument concepts," Dellingr Project Manager Chuck Clagett at Goddard said.

Up until now, CubeSats haven't exactly been popular for Goddard science applications. Previously, CubeSats served primarily as educational tools at the university level to teach students design and system engineering work. Most of them carry a science instrument of some kind, but if the instrument does not work the mission is not necessarily deemed a failure.

Clagett and his Deputy, Luis Santos at NASA Goddard Space Flight Center, Wallops Flight Facility in Wallops Island, Virginia, said they think Goddard hasn't often used these vehicles for science applications due to their size. Most CubeSats are in the 1U to 3U range, where a U is roughly a 4-inch cube. Assuming core functioning subsystems, like the power supply and processors, take up 2U of the satellite, that doesn't leave much room for science test instruments, Clagett said. The Dellingr team is pioneering a larger concept for NASA use, doubling the CubeSat's size to 6U.

"The core subsystems don't double just because the satellite is twice the size," Clagett said. "They take up about the same amount of room. It frees up a lot more space for instruments."

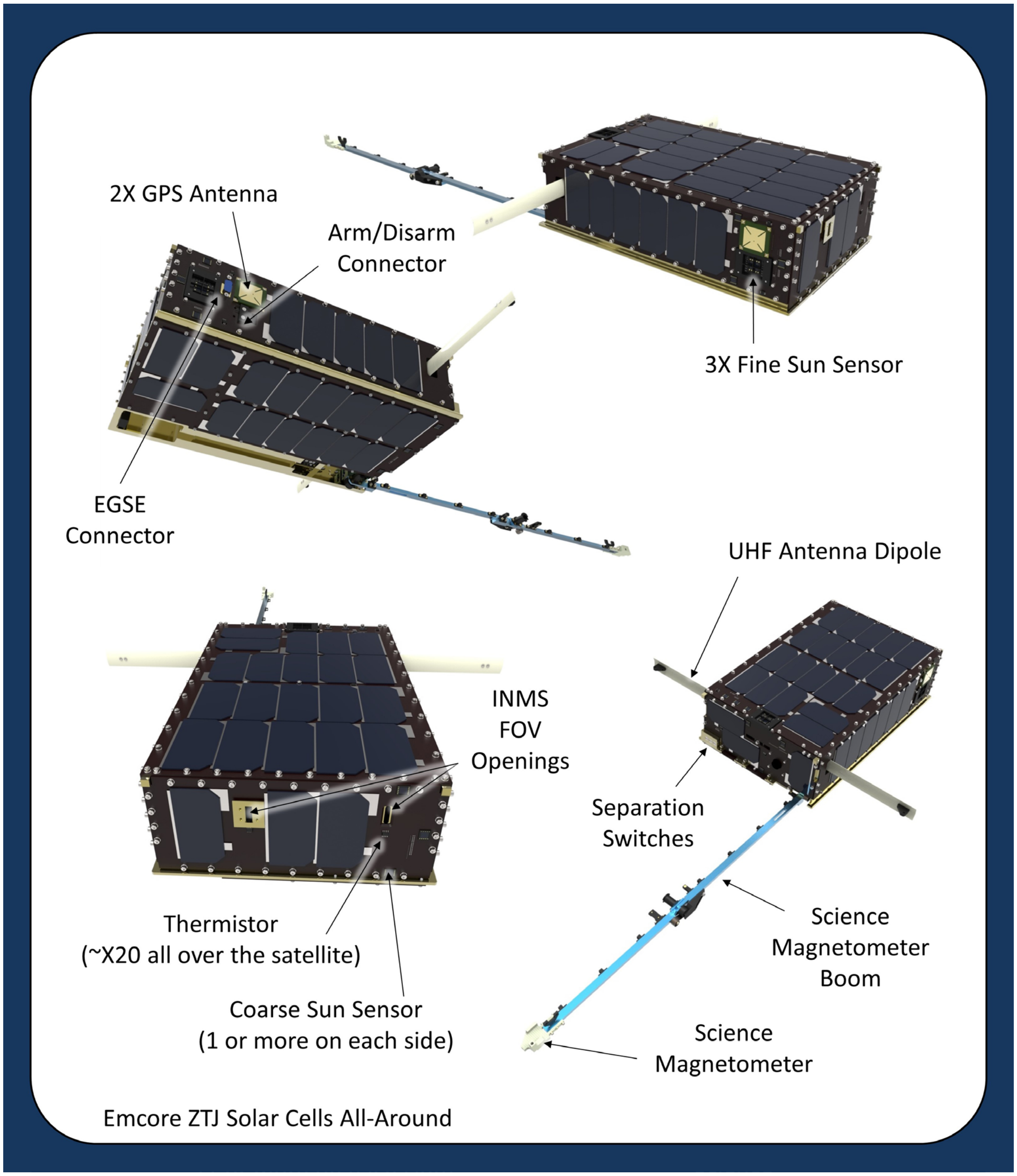
Dellingr will carry two test instruments that will study the atmospheric elements composition and Earth's magnetic field measurements using newly developed algorithms.

The low cost of a CubeSat mission, in combination with the new model's larger volume for hardware, makes the 6U CubeSat a great tool for testing new technology. Clagett said CubeSats can serve as effective, low-cost platforms for testing new instrument concepts and engineering technologies. In fact, it could be more effective than a development effort on the ground to prove the concept is reliable because they allow instruments to be tested in an actual space environment. It may also be less costly than extensive ground-based testing. “If it weren’t for the limited budget and schedule on CubeSats, we could develop almost whatever we need,” Santos said about some of the challenges associated with CubeSats, such as challenging scientific requirements. “But it would defeat the purpose of making a CubeSat.”

The team often repurposed leftover materials from other missions to keep costs low.

“We were given leftover solar cells for free from one of the big missions, so we decided to build the solar panels ourselves,” Clagett said. “That ended up being a bigger challenge than we thought, but now we have the process down, so it can be used in other CubeSats. It’s become a real benefit.”

Currently, Clagett, Santos and their team are integrating the satellite. They expect to finish and prepare for environmental testing late in the fall. Once Dellingr is delivered for flight, the team will be able to secure its ride into space on a rocket as soon as late summer 2016.



# SMALLSAT/CUBESAT *Interviews*



**Michael Johnson**
**Chief Technologist, Applied Engineering and Technology Directorate**

***Code:*** 500

***Years at NASA:*** 24

***Education:*** EE, Electrical Engineering and Computer Science, MIT

**Q. *How did you get into spacecraft engineering?***

**Michael Johnson:** I began my career at MIT Lincoln Lab, designing and developing ground-based and space-based systems. I was there for about 10 years as a Staff Electrical Engineer, responsible for both hardware and software elements of these systems. Then I came to Goddard and joined a small science/engineering team in the Laboratory for Extraterrestrial Physics first as a contractor, then as a civil servant about a year later. My responsibilities were similar to those I had at Lincoln Lab, but with a science instrument focus. I enjoyed hand-on design and development, but there came a point where I kept asking "what if we could…." My desire to answer that question eventually led me away from the lab to technology management, intent on "expanding the possible" and reducing the number of things we can't do.

**Q. *What's unique about Dellingr?***

**Michael Johnson:** It's one of the first 6U CubeSat missions targeting compelling science and a Goddard pathfinder for developing "lean" systems and processes for small satellite development.

**Q. *Was there any "secret sauce" to getting the job done so quickly?***

**Michael Johnson:** We set a very aggressive goal of building and delivering the spacecraft in one year from a standing start, and we'll almost make it. We buy what we can, build what we have to, and attempt to apply the spacecraft development lessons we've learned over the years in streamlining our processes while minimally impacting risk. Our philosophy is if you truncate a process, you're probably increasing risk. But if you intelligently redesign the process, risk may not have to increase.

**Q. *Any thoughts for potential commercial partners?***

**Michael Johnson:** There are smart people here at Goddard, but there is a wealth of talent outside our gates. So it makes sense we partner to mature key capabilities that can yield systems that were previously unfeasible. Miniaturization and integration are two of these capabilities that can enable new mission architectures and reduce mission cost.

Barriers to space are being lowered dramatically – This "final frontier" used to be open only to government and large industry. But now even high school students can have a satellite in orbit. But at NASA we choose to focus primarily on challenges other people cannot surmount. So if the partnership can help us address these challenges, we're interested.

**Steve Fujikawa**

**President, Maryland Aerospace, Inc.**

## Q. *What is the nature of your SmallSats/ CubeSats partnership with Goddard?*

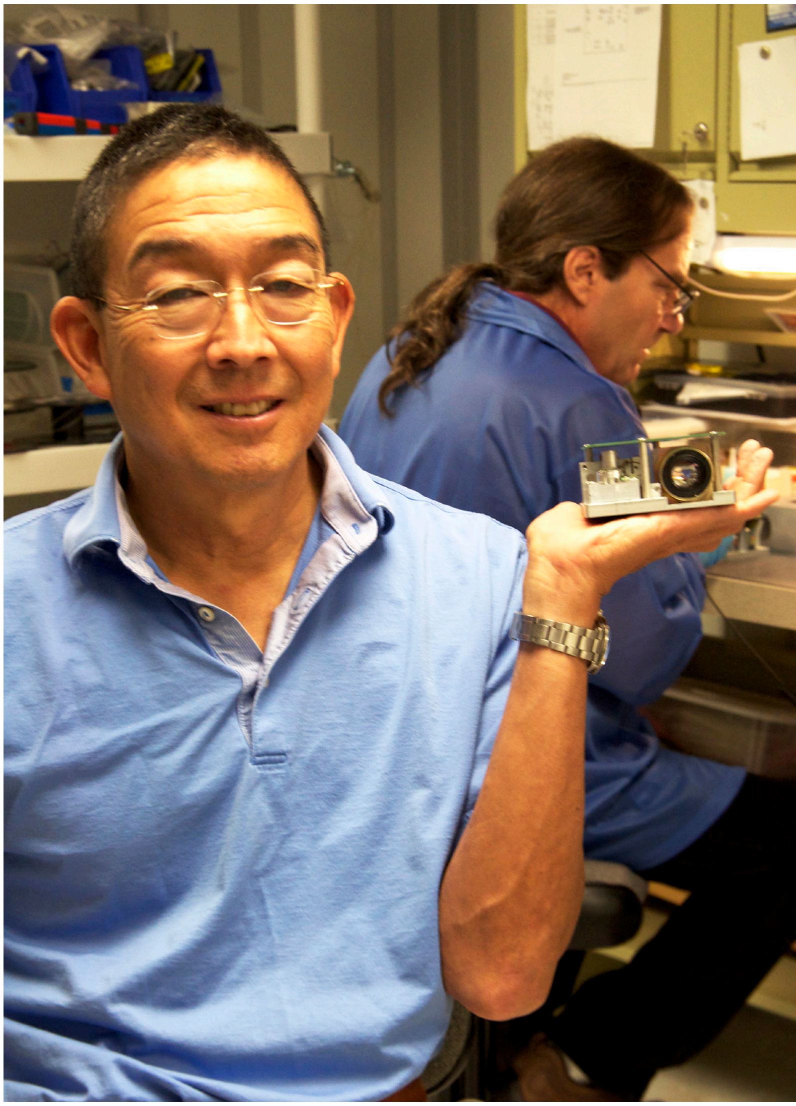
**Steve Fujikawa:** We currently have a Small Business Innovation Research (SBIR) Phase II sponsored by Dr. Alice Liu to develop and incorporate a miniature low cost Star Tracker into our MAI-400 attitude determination and control system (ADACS). The MAI-400 is the 3rd generation of our turnkey ADACS systems incorporating reaction wheels, torque rods, and a flight computer into a 1/2U package. In the past we have supplied MAI-400s and the first generation MAI-100s to Goddard Space Flight Center (GSFC). The current Star Tracker program will give the system 0.05 deg pointing, and is the last key piece to making the system truly high performance.

## Q. *How did Maryland Aerospace, Inc become involved with SmallSats/CubeSats?*

**Steve Fujikawa:** About 15 years ago Maryland Aerospace, Inc. (MAI) saw the enormous potential of CubeSats to take on missions previously reserved for larger spacecraft and saw this as a market niche which wasn't already dominated by the big aerospace primes. In the beginning it was mostly pioneered by academia seeking to build low cost student satellites. NASA and the DoD soon saw the potential as well and introduced new initiatives toward rapid development of smaller and cheaper missions. Our core competency has always been Guidance, Navigation and Control (GN&C) and we looked for ways to take advantage of this to position ourselves in front of the coming wave. In 2004, funded by a DARPA SBIR, we developed the MAI-100 which was the first 3 axis CubeSat reaction wheel system. This was followed by the improved versions of the MAI-200 and MAI-400. Since then, the business has really snowballed and we have delivered about 90 ADACS systems to date as well as other Cubesat enabling technology products

## Q. *What type of SmallSats/CubeSats projects is your company involved in*

**Steve Fujikawa:** Besides ADACS we build most other spacecraft subsystems and even complete satellites, always with an eye toward miniaturizing to the CubeSat form factor. Currently we're building the Kestrel Eye nanoimaging satellite for the U.S. Army Space and Missile Defense Command. Kestrel Eye is being built at very low cost based on CubeSat technology. We also maintain partnerships with industry partners and academia and have participated in many other CubeSat and SmallSat missions through them.



*Steve Fujikawa is President, Maryland Aerospace, Inc., located in Crofton, Maryland, approximately 10 miles east of NASA Goddard Space Flight Center.*

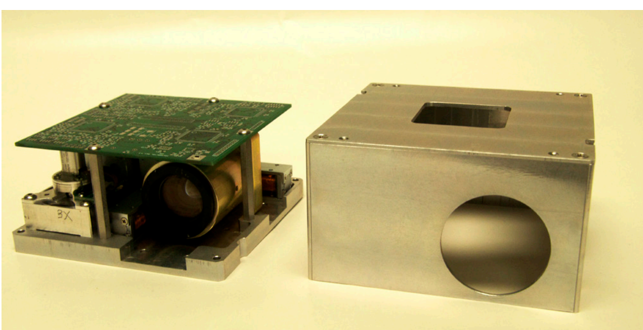
**Q. *What are the primary limitations of SmallSats/CubeSats?***

**Steve Fujikawa:** Before miniature ADACS, CubeSats were limited to simple missions that could be performed from a tumbling attitude. When ADACS enabled CubeSats to be 3 axis stabilized, they could take on more sophisticated missions such as mass spectrometry and space weather. Now we are on the verge of making CubeSats truly high performance and commercially viable, taking on missions like earth observation and maritime traffic monitoring.

An ADACS with a Star Tracker is the first step toward realizing these. Other technologies that will enable this are 6U satellites with increased payload volume and power, along with improved reliability with fault tolerant components and radiation hardened electronics.

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

**Steve Fujikawa:** Our GN&C SBIR partnership with GSFC has proven to be of immense value in enabling the development of our new Star Tracker. We anticipate that the first flight units will be delivered toward the beginning of 2016. Our continuing partnership will improve reliability and performance through further development and testing, radiation testing in particular.



*The third generation MAI-400 attitude determination and control system (ADACS) unit incorporates reaction wheels, torque rods, and a flight computer. The current Star Tracker program will give the system 0.05 deg pointing capability*

**Aprille Ericsson**
**GSFC SBIR/STTR Technology Infusion Manager/Program Manager SmallSats and CubeSats**

***Code:*** 504

***Years at NASA:*** 23

***Education:*** Mechanical Engineering, Ph.D, Howard University; Aeronautical/Astronautical Engineering, M.I.T

**Q. *What is your involvement with SmallSats and CubeSats at Goddard?***

**Aprille Ericsson:** My involvement with CubeSats and SmallSats has been at different levels. Initially, I was a NASA reviewer for both NSF CubeSat proposal evaluations and for University CubeSat design reviews. I also led the Cubesat Tiger Team funded by the GSFC IRAD program. I was involved in the selection of the Dellingr project managers. I've continued to work with the Dellingr team as a project manager and systems engineering consultant. I have tried to grease the skids to avoid potential programmatic issues that could stall the development of the CubeSats here at Goddard. My expertise is in space program/project management, so I am very aware that our center predominantly does large space missions. With that mindset a changing of culture is required. That change includes the science community having a better understanding of this small space platform's potential. Questions that needed to be posed were: How do we get there technically, fiscally, and successfully? How do we get the community to take on risk? We're risk-averse here, because we always want to be successful. It requires the buy-in of management and upper-level, technically-competent people to really understand how we do that.

**Q. *How do you make that culture shift?***

**Aprille Ericsson:** There were a couple of things that we did, starting with creating teams to study the systems and programmatic processes. We identified what matters most from a technologies perspective and how that could change or shift the capabilities of the CubeSats or SmallSats. We worked on finding out the capabilities in pointing, thermal control systems, power, propulsion, radiation hardened components, MBSE, etc., and future needs. That team was able to develop concepts and give them to some of the newer teams as they were coming on, trying to help them with some information or knowledge of what was available. Our intent was to help the planning and development of any future missions. We also pulled together a document, much like a “lessons learned,” catalogue, on what we’d learned in the last year or two. After a couple of revisions, I think we may actually see a class developed to help people at Goddard as they take on developing these small Class D missions.

**Q. *How did Goddard become involved with SmallSats and CubeSats?***

**Aprille Ericsson:** The National Science Foundation has a call that they put out periodically for CubeSat development. The first CubeSat that was developed at Goddard, Firefly, was actually developed with partial funding from NSF. In parallel the Wallops Flight Facility assumed a partnership with NSF, where they offered our ground communication capabilities with our receivers and the WFF Integration and Testing Facilities for selected NSF missions. The culture shift has been having people take these small spacecraft seriously. They aren’t just for college students.

In reality, we’ve been doing SmallSats here for more than 20 years; they were called Small Explorers. Small Explorers projects were of that same SmallSats mindset of accelerated schedule and a compact spacecraft, “cheaper, better, faster”. Then we moved away from Small Explorers and started doing much bigger satellites, so this new mindset is coming back to these smaller missions. We see a nice fit transitioning from a suborbital platform or balloon-developed instrument to be adapted onto a CubeSat or a SmallSat.

**Q. *What are some of the projects that are currently being considered for Goddard’s SmallSats or CubeSats?***

**Aprille Ericsson:** We actually have projects that that are being developed. We have IceCube studying ice clouds; we have Dellingr, carrying two heliophysics instruments and a few technology demonstrations, (it’s in integration and testing phase); and we have CeRES, which studies radiation in Earth’s atmosphere. There are a couple of other technology developments under the SBIR/STTR– program with direct applications for a CubeSat. We’ve got some innovative miniaturized propulsion devices, star trackers, and an attitude determination and control system that could create a stabilization platform. We also have the opportunity to use our in-house core flight systems, which have been developed under a Raspberry Pi (commercially available) platform.

**Q. *What are some of the primary limitations of working with SmallSats or CubeSats?***

**Aprille Ericsson:** There’s not a large pot of money identified for these missions. It’s growing, but we still have a lot of folks trying to tap into a small amount of funding. I think we’re fortunate that we can leverage some of our other capabilities and interests, like some of the projects we develop out at Wallops. For instance, GSFC works on the balloon and aircraft and suborbital flight projects. Since these platforms tend to be small, their miniature technologies can be applied to small missions like a SmallSat or CubeSat. We’re fortunate in that it helps us mature technology and keep its cost lower for future large missions. The costs do range, depending on the type of technology. I think some other companies can drive down costs when they make multiples of the same spacecraft, but at Goddard it’s a little bit more challenging because our spacecraft are often not the same. There’s always room for improvement, we’re always pushing the envelope, so you’re usually not going to find the exact same spacecraft can fit your needs. The cost will continue to vary; based on the science requirements and technology required, as well as, the robustness of the electronics for these platforms. However even with these limitations, anything can happen with CubeSats and SmallSat.

**Q. *What are some things Goddard can or is doing to overcome some of those limitations?***

**Aprille Ericsson:** We’re just trying to be smarter. We’re trying to leverage the various programs and the portfolios of money. The GSFC Internal Research and Development Program is one way we’ve begun to identify and develop using internal funding. We’re also trying to make sure that we’re aware of calls from NASA headquarters, SBIR/STTR or elsewhere. We’ve also become much more engaged in discussions with other government agencies and looking for partnerships throughout industry. Our chief technologists are also looking across disciplines for ways to partner. So we're really looking at opening up our doors to pull off these cool and unique missions. I see progress and a growing snowball of enthusiastic scientists and engineers. GSFC scientists are engaged with the idea of being able to get a flight opportunity in a much shorter timeline, if they've got technology or the instrument to fit on board. CubeSats and SmallSats can offer a much shorter timeline for getting missions in space.

**Q. *Is there anything else you want to mention?***

**Aprille Ericsson:** I think when people look at what NASA does and try to compare it to industry or universities, they must realize that the total mission cost is different. That's not just because the workforce is different, but also because we have to be very cognizant of our success and so we are very selective with our choice of components. We carry radiation-hardened components, we must be much more mindful of contamination issues, items like this could drive up the cost. Additionally there are best practices we use to fly these small spacecraft that may not necessarily be required in a university-like environment. Therefore, ours mission costs more because we want them to be successful and do cutting-edge science.

**Ramsey Smith**
**GSFC SBIR/STTR Technology Infusion Manager/Deputy Program Manager**

***Code:*** 504

***Years at NASA:*** 6

***Education:*** Physical Chemistry/Atmospheric Chemistry, Ph.D, Howard University; Chemistry, Morehouse College

**Q. *What is your role with SmallSats/ CubeSats at Goddard?***

**Ramsey Smith:** I work in the Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) at the Goddard Space Flight Center. Our role is to find technologies that are being developed through our program that can enable CubeSat technology development at Goddard and throughout the agency. I listen to the needs of the technologists and scientists at the Center and we try to match those needs with the expertise that's available to our technical small business community.

We try to address the needs of Code 500, which is our engineering directorate, and Code 600, our science mission directorate. The needs we're seeing right now are miniaturized components and instrumentation, guidance, navigation and control for SmallSats/CubeSats. We also try to look at radiation hardening and radiation protection for those space platforms. Other needs include developing lightweight materials and instrumentation, how to keep power consumption low, and trying to optimize communication from the satellites to the ground stations or other satellites.

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

**Ramsey Smith:** I've been at Goddard for six years, and since I've been here we've had some type of involvement with SmallSats/CubeSats on various levels. Whether it's a science research group, or a group in engineering that's interacting with a partner developing technology for a CubeSat or being part of a mission that launches its own CubeSat, they've been involved in this for quite some time.

Goddard's expertise is not just developing and testing the technology but the science that drives the need for these types of instruments. We can do front-end building and technology development. More important capabilities that we bring to the table are ithe planning of science missions around CubeSat launches and collecting data that can be used by the science community that's not readily available on a larger platform. Our science experience coupled with our heritage of managing and building quality spacecraft and instrumentation is one of Goddard's greatest contributions to the CubeSat community.

**Q. *What are the primary limitations of SmallSats/CubeSats?***

**Ramsey Smith:** One of the primary limitations is rideshare opportunities or launch share opportunities. Funding is always a challenge along with meeting our technology needs. That's why SBIR and STTR programs are very important because they enable us to fund projects that close gaps that we cannot fill internally.

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

**Ramsey Smith:** Funding – that part is somewhat out of our control. For the funding and technology gap, those that can be coupled together we can take advantage of programs like the Internal Research and Development (IRAD) program and use technologies developed through IRAD and SBIR/STTR programs to fill out gaps and needs for enabling CubeSat missions and miniaturized instrumentation.

**Tom Johnson**
**Wallops, Launch and flight Operations**
***Code:*** 800
***Years at NASA:*** 6
***Education:*** Mechanical Engineering, University of Maryland

**Q. *What is your role with SmallSats and CubeSats at Goddard?***

**Tom Johnson:** I'm Goddard's small satellite manager at Wallops Flight Facility. Basically I'm responsible for overseeing management for all the missions that Goddard is currently supporting for small satellites and CubeSats. For example, I'm the project manager for IceCube, which is a technology development project for Earth science that will be studying cloud ice properties.

**Q. *How did you get involved with SmallSats/CubeSats?***

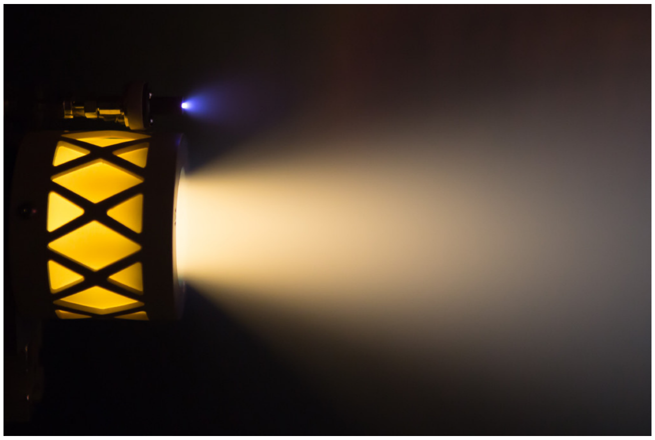
**Tom Johnson:** I started working at Wallops fairly recently. I started working in Greenbelt in 1988, and then last year I moved to Wallops to lead the small satellite program. I was very interested in small satellites and CubeSats. They're an up and coming means of performing space science. One of the great things about them is that you can get them to space very quickly and cheaply.

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

**Tom Johnson:** Goddard is working on numerous small sats, and basically all the science mission divisions are actively pursuing new work and working on CubeSats missions. I mentioned IceCube, and there's another mission called CeREs, which is a heliophysics mission studying radiation belts. There's another IceCube mission that's called Lunar IceCube, which is going to be looking for ice on the moon Goddard is also partnering with Southwest Research Institute on a 6U CubeSat called CuSPP+, which will study the sources of solar and interplanetary particles. There is also Dellingr, which is a Goddard developed 6U cubesat that has 2 science instruments on board.

**Q. *What are some of the advantages of working with SmallSats/CubeSats?***

**Tom Johnson:** One is cost and another one is time. Those are two of the bigger ones. You can do something quickly and you can do it cheaply. You have very fast access to space. We have missions being developed that cost anywhere between one million dollars to eight million dollars, depending on the complexity, the size and where it's going. On the average you're probably looking at around 3 or 4 million dollars. That's for everything: spacecraft bus,



*The Busek Company is developing Lunar IceCube's low-thrust electric propulsion system, the RF Ion BIT-3 thruster.*
*Credits: Busek Company*

science instrument, operations – the whole works, including the launch.

Also, one of the big areas of interest for SmallSats both at Goddard and in industry is doing constellations of satellites. That's putting up multiple satellites that would do similar things, working together to meet their overall science goals. Goddard is actively pursuing satellite constellations. There are also a lot of commercial companies out there that are looking at putting thousands of satellites up in the air for one specific concept.

**Q. *What are some of the disadvantages of working with SmallSats/CubeSats?***

**Tom Johnson:** Probably the biggest disadvantage of CubeSats is that they have to fit inside a specified volume. There is a benefit to this in that you can put CubeSats on any launch vehicle. But what comes along with that is now you're stuck in a standard volume. It's vey challenging to fit everything into that volume, and obviously some missions can't do what's required in that volume. For example, you are not going to do James Webb Space Telescope science with CubeSats—it just simply can't be done.

Another disadvantage is the level of funding. You can do these things very inexpensively, but it's still a challenge. You're basically building an entire satellite putting science instruments and launching it. So you have all the systems that the traditional satellite would have, but you have to do everything for a much smaller amount of money and in less time.

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

**Tom Johnson:** NASA GSFC has been a little slow (or slower than some organizations) getting involved with small satellites. There's been some questions concerning whether science can be performed in such small platforms so a task group has been formed by the National Academies to address this question. One other thing that Goddard has been doing for over seven years now is to support the National Science Foundation's CubeSat program. We provide a combination of engineering, technology, consultation and project management support for the NSF.

I think it's developing the technologies and concepts into which we can get small science instruments. Certainly there is a lot of work going on in that area across Goddard. We're trying to develop a core team that would support all Goddard small satellites. The core team would have mechanical, electrical, thermal, navigational, software, and project support. We would support missions from concept, to proposal, design, integration, and through launch. That way you have a team that's very knowledgeable and experienced, and that's able to provide efficient and effective support to the science community.

*Morehead State University and Goddard are partnering to create the Lunar IceCube mission shown in this artist's rendition.*
*Credits: Morehead State University*