

APOGEO SPATIAL

ELEVATING GLOBAL AWARENESS

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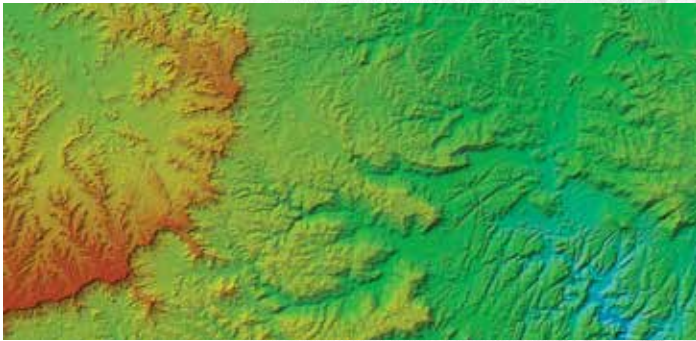
“Security is a state of mind and being. When we talk about hacking, what we’re basically saying, in moving data and manipulating data, ‘Are we confident that I can do what I need to do with my communication, and am I extra certain and confident that it will arrive unencumbered?’ When you’re not, you change the way you live.” – Bill Parker

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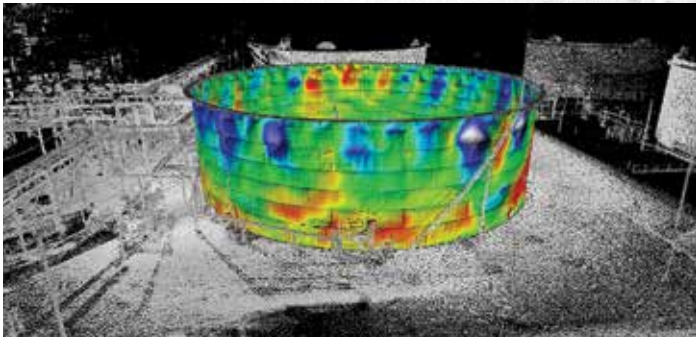
Image of the International Space Station courtesy of NASA.

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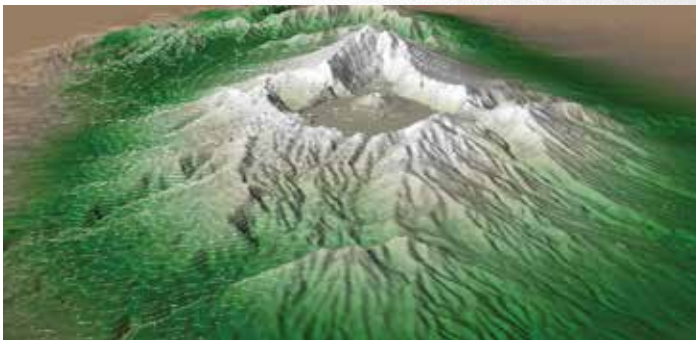
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The International Space Station

AN IMPORTANT REMOTE SENSING RESEARCH PLATFORM

The International Space Station (ISS) was launched and constructed in 1998. In November 2000, the first astronauts went to live onboard, and it's been manned ever since that time.

Included in this issue are three articles about the ISS. On page 18 is our interview with NASA astronaut Nick Hague about his mission to the ISS that failed in October, and his eagerness to get to the ISS in March 2019.

The ISS National Lab does science in space to benefit life on Earth. The ISS was designated as a U.S. National Laboratory in 2005 by Congress, enabling space research and development access to commercial, academic, and government users. The ISS National Laboratory is responsible for managing all non-NASA research, and all investigations require the capacity to utilize microgravity for Earth benefits. With this program, world-class microgravity research is possible for small companies, research institutions, Fortune 500 companies, government agencies, and others interested in tapping into the unique space environment.

The ISS National Lab experts have contributed an article about some experiments that are occurring on the ISS on page 22, and we also have an article on page 28 about the first LiDAR from space that is testing all the way to the ground. Previous LiDARs from the ISS measured clouds and the atmosphere.

The cover image of the ISS is courtesy of NASA.

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The Importance of Diplomacy

THE ISS AS A REMOTE SENSING PLATFORM

Dear Readers,

What a pleasure to speak with the wonderful Bill Parker, career foreign service officer, now international consultant, about his career and the importance of diplomacy and international cooperation. He knows this better than most.

We also discussed the urgent need for “rules of the road” for space, with increasing numbers of satellites and debris; and the need to communicate the message of how “space is for living” – that the assets in orbit are so essential for our daily lives. People still don’t realize the extent to which this is true. Finally, Bill shared with me a very personal highlight of his career, which involved one of those huge old satellite phones and an ultimate evening of diplomacy. Read more on page 8.

In this issue, we dedicate an entire special section and three feature articles to the International Space Station (ISS), that amazing example of international cooperation. The ISS consists of the U.S., Canada, Japan, the Russian Federation, and eleven Member States of the European Space Agency. Russia is essential because of the use of their Soyuz launch vehicle.

Our interview with NASA Astronaut Nick Hague is on page 18. He has been making the rounds on the media, not just *Space News*, but mainstream media as well, such as ABC News, NBC News, and CBS This Morning. We were thrilled to speak with him, too. You all know that he survived a launch failure in October, when the Soyuz rocket had a problem with a booster, and he and his Russian colleague landed safely. Read about the experience in his own words. It was the only time in 35 years that the Soyuz rocket has failed a launch.

Nick also shares his excitement to go to the ISS in March, what he’ll be doing, his passion for service, and the importance of sharing the transformative experience with others. He also happens to be from my hometown, Hoxie, Kansas, and my mother was his high school English teacher. She was an excellent teacher

(retired and a writer now) and Nick shared with me that he’s taking her photo to the Space Station with photos of others who have helped him get where he is today – and where he will be in March – in space!

The ISS is the platform for many scientific experiments, including some for remote sensing. The ISS National Lab shares information on page 22 about several ongoing experiments, including the study of eyewall-cloud altitude of tropical cyclones using 3D images constructed from astronaut photography as part of the CyMISS Project; and information about the MUSES platform, developed and managed by Teledyne Brown Engineering, which is on the exterior of the ISS.

On page 28, read about space-based LiDAR being tested by NASA, which for the first time goes to the ground! The Global Ecosystem Dynamics Investigation (GEDI) instrument is a LiDAR sensor that was launched to the ISS on December 5, 2018 on SpaceX’s 16th resupply mission. GEDI is installed on the Japanese Experimental Module Exposed Facility (JEM-EF).

My colleague from many moons ago (Colorado folks, remember *Front Range TechBiz*?) Todd Neff published a book on LiDAR last fall, *The Laser That’s Changing the World: The Amazing Stories Behind Lidar from 3D Mapping to Self-Driving Cars*. I must say, it’s an engaging, entertaining read, even for a nontechnical person like me.

Finally, I am thrilled to announce that we at *Apogeo Spatial* will be holding the questions about the future of our industry, and we know that you hold the answers. We want your thoughts and views on where we are going on this crazy ride – what is next, after what’s next? You’ll discuss AI, ML, how IOT plays into that, and the future of computing for the space industry. Is a move to Quantum Key Computing inevitable, and if so, by when? Join the discussion on page 17!

Enjoy the issue!

-Myrna James Yoo



Myrna James Yoo

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Myrna James Yoo
Publisher, Apogeo Spatial

Global Engagement Solutions, LLC, is an international management consulting firm that provides a broad spectrum of services for those interested in building public and private sector partnerships abroad. The primary focus area is in finding disruptive technologies and assisting the client in bringing them to market. Bill retired after 31 years of foreign service with the Department of State with the rank of Minister-Counselor, which is the diplomatic equivalent of Major General. He was Foreign Policy Advisor at USSTRATCOM, and at NATO missions worldwide.

WHILE I HAVE KNOWN BILL PARKER FOR MANY YEARS FROM THE GEOINT AND SPACE SYMPOSIUMS, I HAD NOT REALIZED BOTH THE DEPTH AND BREADTH OF HIS EXPERIENCE WITH THE FOREIGN SERVICE, AND HIS DEEP COMMITMENT TO BUILDING BRIDGES ACROSS CULTURES AND AMONG NATIONS. THESE CONCEPTS PROVIDE THE SOLID FOUNDATION FOR HIS WORK, PROJECTS, BOARDS, AND EVERYTHING HE DOES. IT WAS MY PRIVILEGE TO DISCUSS TOPICS FROM THE WORK OF THE FOUNDATIONS IN WHICH HE'S INVOLVED, TO THE IMPORTANCE OF "SPACE FOR LIVING" – HELPING CITIZENS APPRECIATE HOW MUCH OF THEIR DAILY LIVES BENEFIT FROM ASSETS IN SPACE. WE DISCUSSED THE PROUDEST MOMENTS OF HIS CAREER, WHICH TOOK US TO THE BEACHES OF NORMANDY AND WERE DEEPLY PERSONAL. I HOPE YOU ENJOY THE CONVERSATION.

JAMES YOO Bill, thank you so much for agreeing to be interviewed. I'm very excited to be doing this. So, *Apogeo Spatial* partnered with Secure World Foundation for many years. What is your connection there?

PARKER I have attended many of their outstanding workshops and seminars in Washington. At one point, Michael Simpson (former Executive Director) asked me if I wanted to be on their Advisory Committee. I said it would be an honor and a pleasure. They are on the cutting edge of bringing everybody together on some very critical issues in space.

JAMES YOO Yes, they really bring in the absolute experts on everything that they do, whether it's space debris cleanup, or keeping all the assets in space safe; they really bring in the top people worldwide.

PARKER You're absolutely correct, including Pete Martinez, who's their new boss, who came from the U.N., and understands the importance of space touching everyone on Earth and all the issues. They're just very capable, very devoted, and understand the complexities and are able to put it into words and workshops that help the users.

JAMES YOO That's great. It is important work. Our editor, Ray Williamson, was their first Executive Director. He is wonderful. He has been the editor of the magazine providing some guidance on the content since my company has owned it, for 16 years. Now, can you explain what you do, and how the organization works, first of all? I realize that you're global in reach, and doing some important work.

PARKER What I've tried to do is use my foundation in international awareness and being a former foreign service officer. I look at the issues facing the world today. I maintain my network of people from all facets of life in various countries, throughout my career, from various assignments in international organizations and in specific nations, and ended up at U.S. Strategic Command (STRATCOM), where I really just dove into space.

I recognized quite early that space would be advantageous to foreign service officers, and to those

who are not necessarily official representatives but those who do international engagement – if they had a better understanding of the importance of and how to utilize space, and all the capabilities that are now available that weren't available to us when I was a young foreign service officer.

At STRATCOM I took many courses, and learned from some of the best and brightest in the business, both in uniform and in suits. When I was serving overseas, we didn't have smart phones. We had RF for communication. Some people had a satellite phone, and they were far and few between. In the modern era, we are now able to communicate with the speed of thought, and we're moving larger and larger amounts of data to screens that fit in your hand. Therefore, it can change a lot of our decisions and how we do business.

JAMES YOO It's pretty incredible, really, when you think about that.

PARKER Right. It's just moving so rapidly. If you just think a couple years back... You know this better than most. There were, what, six or seven firms that did launch or lift, and now they're just growing exponentially. When you get into smallsats, and satellites, and communication – it's just growing. What I do is, I see people and know people around the world. Some nations don't consider themselves spacefaring. With the Secure World Foundation, there was a great workshop at the last Space Symposium where we talked about, "Are we all on the same page? What does 'spacefaring' mean?" Some people think all nations are spacefaring. So, "Are we agreed on rules of the road?"

What I try to do is discover technologies – those that could be adapted or adopted by various nations or foreign entities, companies, or governments, and how they could utilize them to augment what they already have or to improve their lives as individuals on the Earth.

JAMES YOO Are you involved with some of the nations that do not have access to space, and connecting them to affordable ways for them to get involved? Is that part of it?

PARKER Yes, that is part of it, having friends in various countries, not necessarily officials, but friends who are working in the various communication sectors, such as Indonesia, or countries in Africa. It's very difficult for them. How do they become aware of technologies that would better their condition or give them a larger knowledge base? What I try to do is connect those dots,

bringing folks who can help them either in training, because, what I also realize is that our U.S. technical training is also critical.

JAMES YOO Now, that really has become a very important thing. The space-based data we get on Earth is so important for companies, academia, and government, but it has to be useful. It has to be turned into "actionable information..." All the companies have their own versions of this. I think, for a long time, when the commercial data became available, with IKONOS, really, as the first commercial satellite from Space Imaging in 1999...

PARKER Correct.

JAMES YOO Back then, there was all this incredible data, but it took many years for that to tip over into being affordable, and useful, and really pervasive, and now it is. It's been fun to watch that over the years, right?

PARKER It's interesting you say that. The training center for the U.S. foreign service is in the National Foreign Affairs Training Institute in Northern Virginia. The officers should be made aware of what's available on their desktop, for example, if you're an embassy officer sitting in Bamako, Mali, and you need a map of the countryside, you want to visualize spatial relationships among various features. You can look for quantities. You can map densities. You can ascertain what's inside of certain areas.

This becomes quite helpful for our diplomats, and others in the U.N. and international organizations, in quiet conflicts. Show people that they're not fighting over 10 gallons of water; there's much more water there. There's enough water for people. Using digital elevation models, showing what's underground. How do we help conserve it? How do we explore for more? Whereas, I was old school. You had to get on a plane, or you had to leave the embassy. You had to drive through roads, you had to have exploratory digs. You had to take contractors there. A lot of this can be done and shared with all parties now, Myrna, almost instantaneously.

But, do we recognize the need for this as a basic human need? It needs to be a course that's similar to geography, for example, or English, or science.

JAMES YOO Yes. Another thing that has changed that will make this really possible and immediately impactful is that only in the last several years has it been easy to use. You truly do not have to be a technical GIS expert to go in and get the information you need. That's really very recent that this change has occurred, but that should have huge benefits.

"Space for Living"

PARKER That's what I'm trying to do as an international advisor to the Space Foundation, and being on the Advisory Committee of Secure World Foundation. Both organizations engage internationally and locally. Space is for everyone. It's for living. How do we utilize it? How do we bring the man on the street into this realm — for example, in America, recognizing and being able to use, as you just talked about, GIS data, and seeing it as something as useful as spell check?

JAMES YOO GPS made that transition, right? GPS was created by our military.

PARKER That's right.

JAMES YOO Our federal government's funded the creation of GPS via satellites, and now it is not only pervasive, it's embedded in everyone's cell

phone, and, of course, most people know that, but they don't know that it's also embedded in almost every app that they download. Right?

PARKER Correct.

JAMES YOO It's happening in the background for consumers, but it's free for all these companies to use GPS data and integrate it into their business model. They don't even have to kick anything back to those who created it. There are a lot of technologies like that.

PARKER As I say, I'm trying to call it "Space for Living." People don't necessarily have to know how GPS is related to precise timing. A man or woman on the street will never know all of the intricacies of space, because space is really hard. But, most people don't have a good idea of how self-driving vehicles function. We don't necessarily need to know. What we need to have is confidence. We need to have confidence and awareness that space is for living. How do we utilize it? How do we get it to the lowest common denominator for human beings, which is their phone? How do we get it down to their smartphone and their everyday household necessities?

The ISS Example of International Cooperation

JAMES YOO Right. That's great. One thing that I think can help bridge the gap of awareness and interest with the people, consumers, citizens around the world, is the ISS (International Space Station). It's such an incredible example of international cooperation, as well. I want to ask you about that, because with your contacts around the world, from all of your foreign service experience, you're in a unique position to bring people together, and really create some more international cooperation. I realize with politics and everything, how people feel about the United States certainly ebbs and flows.

But, it's a really important... Maybe your work is more important than ever on that side, and it's really a great thing. It's really unique and rare, I think.

What I love about the Space Station is that it seems like it has always been sort of above politics, in a way, similar to the way it's above the Earth, too, pardon the pun.

PARKER That's correct.

JAMES YOO Can you think of other examples like that?

PARKER You're absolutely correct. It's interesting. The United States could have a certain type of relationship with Country A based on a trade relationship, a diplomatic relationship, education and cultural exchange relationship, and we might say things in the press, or we might say things back and forth over diplomatic lines of communication.

When your diplomat's serving in Country A's capital, you have day to day, hourly contact with the people of that country to include their foreign ministry, and economic ministries, and university presidents. That's where the real work gets done. That's where the real cultural understanding takes place.

When we bring them to this country on a Fulbright program, or on a grant to study at NASA, and they go back and they understand not only who we are culturally, but they understand what we're trying to

do scientifically... You're living with them, you're eating with them, you have people from that nation working in your embassy, you see them every day. You can't escape. You don't want to escape! That's how I view the ISS. ISS is even more important, because you can't just walk away. You can't pick up and leave, nor can the support function people on Earth do so. That's why it's so important to have all those flags and all those cultures working together. Not only do they bring technical skills in supporting that environment, you work with that person for a common purpose. You're working for the general good of mankind on the ISS. You begin to understand and can overcome, possibly, some of those delicate issues or tough issues that are Earthbound, because you're working for a larger, bigger cause.

Does that make any sense?

JAMES YOO Absolutely. I love that. Your work is just so important for those reasons.

PARKER So what happens, now, is COPUOS (the U.N. Committee on the Peaceful Use of Outer Space) and other organizations that are Earthbound necessarily go through a structure, and they have rules and regulations. I think what joint international space projects do, and especially things like ISS, or going to the Moon with an international effort will allow us to have something that we could all take pride in and also have some ownership.

JAMES YOO Absolutely. I'm really thrilled to let you know that we are actually starting a new International Space Station Special Section in the magazine, working directly with NASA and the ISS National Lab. We are featuring the remote sensing projects that are on the Space Station...

PARKER That benefit humankind...

JAMES YOO Yes. Absolutely. We'll also be featuring the astronauts' photos of Earth while they're on the space station, sharing their experiences of the Overview Effect – the change in consciousness to perceiving a "oneness." We're so excited.

PARKER Wonderful. You'd be surprised what kind of cross-cultural communication and deeper understanding comes from two people living together, even in a space that's not so confined. I'd really like to see an interview with astronauts from different cultures and countries. What did they learn about other nations, and their cultures, and their philosophies that they never knew, and would

not have an opportunity to know if they weren't on the ISS, or on the first Moon base, or on Mars together? I'd be more than willing to help volunteer to do some of that questioning.

JAMES YOO I am quite sure those interviews would reveal specific examples of cross-cultural appreciation and fascination. They have to be becoming lifelong friends up there.

PARKER That's correct. They're depending on each other.

JAMES YOO Right? It's a really amazing example of what diplomacy should be.

PARKER Yes, as is what we do. The strongest programs, in my opinion, in the U.S. diplomatic or government arsenal are exchange programs, like the Fulbright program and other programs, where American professors and students go to India or Germany. Those programs have included people like Margaret Thatcher and Valéry Giscard d'Estaing (former President of France). The Fulbright program started with Senator Fulbright from Arkansas, and it is still run by the Department of State. One thing is certain. When you spend two years, three years in a country, you begin to understand who we are and why we do and say some of the things we do and say. You have a deeper understanding.

JAMES YOO Definitely.

PARKER Having said that, I would love to see this "Space for Living." We need to begin to connect space to other curricula. Wouldn't it be great if you had an architect? Wouldn't it be great if you had someone from Caterpillar that could begin to think about the Moon dozers? Wouldn't it be great if you had a female fashion designer who now would start training people in, "What does it take to design a space suit for women that's going to be comfortable, not terribly ugly, that's going to be wearable and usable"?

By doing this new space education that touches on all the familiar disciplines, you do several things. You bring those people into "Space for Living." You have more than just the engineering department, the bio department, the technical department. Everybody has a piece. How do you stay in shape in space? Bring in the coaches, and test some of the new equipment. Bring in the physical education people.

I guess what I'm saying is that, I like to see people be able to interact, to understand that every technology on Earth probably has a benefit or role in the future of space.

JAMES YOO I think you're right.

PARKER Since I've been around the Space Foundation for so long, I've seen their space symposium grow over the past 10 years. I think you've seen it. It's enormous and quite popular now. Most people are blown away by the big-ticket items, and they're absolutely magnificent and wonderful. And when you go out to the other tents and exhibits, there are people that are making things, and they're designing things that I have never thought of, but they come from a ground beginning. A terrestrial beginning. An Earth beginning.

JAMES YOO Absolutely. That's true. That's a really good point.

PARKER Right? They just need somebody to get their arms around it, to bring them into the enterprise, into the dialogue.

It would be great if we had several models, several cylinders of excellence, where you could retire from DOD and with a space background, and be on loan to one of the corporations. Then after a while, go back to DOD to engage and help them – help them even in their acquisition processes. Don't budget and fund for what your platform is; budget and fund for where you want to be in the space enterprise.

Can we have people that take a break from corporate, do more training and speaking at National Security Space Institute, or NASA, and then transition back to government, to another organization, maybe the State Department, and show people what we can do with GIS layers and digital elevation models? Does that make any sense?

JAMES YOO Yes, definitely. I think one thing you're getting at, is utilizing the incredibly gifted and intelligent people within the commercial sector – having them ultimately bring some of that expertise into our government, and vice versa.

PARKER It's improving everybody's understanding and cooperation. The Japanese do it fairly well, because they have a Ministry of Government and Private Sector Cooperation. We still have these cylinders of excellence – silos that keep people separate. "I'm a government person. You're a private sector person. You're an academic person. You're a research person." We seem to forget, sometimes, why we established the RAND Corporation, because it brought all of those people together. But, can they go back? Can they leave RAND for a while and go into a Boeing, and share their expertise? Or, maybe you go into three or four companies, and you share it under one tent, especially when you have a major problem? Yes, it has to be capitalized, and somebody's going to market it. When we were on a war footing in this country, everybody had a role. Make it so that everybody can play a role and engage in the end product.

JAMES YOO Absolutely. I'm so glad I asked you about that. Should we talk about BridgeSat for a minute? I know you sit on their Advisory Board, and they're doing some pretty cool things with optical comms. Do you want to share a little bit about BridgeSat?

PARKER A couple years back, one of my friends at ISRO, the Indian Space Research Organization, said, "Bill, we're going to put maybe 100 or 200 smallsats up in one go." I said, "Yeah, right. I wouldn't even

mention that. I don't believe it." Myrna, you just saw it last year! 104 satellites launched in one shot!

JAMES YOO Yes!

PARKER When I lived in remote islands in the Philippines, I had this big ham transceiver thing that used to glow and get hot in my bedroom. I'd tell my wife, "This is what we're supposed to use to call the embassy when we need help." This thing never did anything except receive a periodic VOA (Voice of America) broadcasts. It was either jammed by a palm tree, or the antenna was downed by a typhoon... Okay? Nobody in the embassy was listening. The one time I got through, the poor Marine guards were like, "Who is this? Who do you want?"

JAMES YOO "Where are you? What?"

PARKER "What's your name? How'd you get on this frequency?" What I'm getting at is, when you got 1000 satellites up, you've got comms everywhere. I can sit in my office, and I have relevant data. I see the local airport. I see planes landing. I see helicopters taking off from across the river. At some point in time, we're going to recognize we have a lot of data to move.

We have a lot of data to move to a lot of places on Earth, and I've never heard anybody say, "I'll take it tomorrow."

JAMES YOO Right. The need's never going to be slower. It's always going to be faster.

PARKER The bidding wars that go on for frequencies and channels, it is so competitive. I think companies like BridgeSat, when they're providing laser communication services for satellites and planes to the ground, will change the paradigm, when they can move 1 or 10 to upwards of 100 gigabits per second of data.

One of the problems we have today, when we're moving data, we say, "Is somebody watching me?" "Is it going to be hacked?" "Will it get through?" We're basically talking about confidence. I think what BridgeSat is doing is building confidence with better security for data transfer. "My laser communication services and high-speed data communications will give you confidence that you are able to move and manipulate data worldwide." Make any sense?

JAMES YOO Definitely. Confidence that it's more secure.

PARKER That's what confidence basically is. We talk about security. I try to break it down into the lowest common denominators. Security is a state of mind and being. Walking down the street, "Am I relatively safe?" By using these new optical communications, and setting up their ground stations, confidence will be very high that the data will arrive safely and unencumbered and immediately.

JAMES YOO Right.

PARKER The point is, for me, when we talk about hacking, what we're basically saying, both in moving data, and manipulating data, and communications with data, "Are we confident that I can do what I need to do with my communication, and am I extra certain and confident that it will arrive unencumbered?" When you're not, you change the way you live. You change the way you do things, if it is no longer trusted.

JAMES YOO I love when you said, "Security is a state of mind." It's so true.

PARKER It's just a state of mind. We begin to think about it as a protection device, with the internet. "Give me some more security. Give me a wall." If I don't believe it's secure, then I will not share. I will not send certain things via certain channels.

JAMES YOO Absolutely. We didn't yet talk about the space rules of the road, similar to the maritime and ITA rules. Do you want to talk about that?

Rules of the Road for Space

PARKER Oh, gosh. I'm going to burn your brain out, because it burns my brain out. In conjunction issues, it used to be this way. When we knew a potential collision or conjunction was likely, at some point in time, the appropriate State Department office was notified so that, especially as telemetry got better, we could notify an embassy to notify the government in that country that they might end up with some unwanted space debris from the possible collision.

JAMES YOO Yes.

PARKER We just talked about 104 smallsats, and things that we may not even be able to track because they're too small, but they're lethal, in space. We're getting to a point where we have to adapt some rules of the road.

I know some people think we do, but I'm thinking more in terms of the airline industry, IATA. They have rules of the road for air traffic that every country, and every pilot, and every airline are aware of. No ifs, ands, or buts. They know exactly what to do when they land in Hong Kong, they know exactly what to do when they're flying over someone's territory that's prohibited. They know what kind of distress calls to put out. They know when a plane is in distress and how to help each other.

It is even more codified in the maritime industry. If you graduated from Kings Point, the Merchant Marine Academy, or Annapolis, or you go to a British maritime academy, when I'm at sea, both ship captains know exactly what to do or say to alert each other. "I'm passing to your port," or "I'm passing to your starboard." As a captain, how do I respond to a distress call from another vessel? What are my responsibilities to vector other ships to that location? It's codified.

Somehow, some way, we have to get to a point where we can help each other with those types of rules and regulations in space.

JAMES YOO It's a little bit like the Wild West up there, isn't it?

PARKER It's even worse than the Wild West. Now, when you make debris, as some countries have, very irresponsibly, you're now looking at the possibility

of that debris existing for a very long time. Again, that's where the joint space operation centers and having other nations sit with us comes in. There has to be some responsible rules of the road.

Regardless of what our diplomatic relationships are with certain nations, it almost comes full circle back to cooperation in space and ISS. We have to work together to ensure that we don't have any major calamities. You know what I'm saying?

JAMES YOO Right. There are lives at risk in that case, up there, on ISS.

PARKER There are many lives at risk in that case, and we don't have the capability to rescue anybody.

JAMES YOO Right. Now I have a different type of question to wrap up. What has been your most gratifying moment of your career?

PARKER I was assigned to U.S. Mission to the North Atlantic Treaty Organization, NATO, from '90 to '94. And I had a large satphone. Somehow, I guess because I spoke French, I was put in charge of the 50th anniversary of the D-Day invasion commemorative event. I had a team of military and civilians from various U.S. embassies and U.S. military commands in Europe. We were preparing for a visit of then-President Clinton.

If you've ever seen one of these things, the Allied nations all assemble on the beaches where they landed. We visited the American cemeteries with them with the President and his gaggle and escorted American veterans to the battlefield where they fought and their friends died. I visited all of the villages on the Normandy coast. Seeing the German soldiers and the American soldiers hug, because they were doing what they were asked to do for their countries.

I was able to call my father on that satphone from a position that he described from when he landed on Utah Beach on D-Day Plus 6, six days after the landing.

JAMES YOO Your father? Really?

PARKER Yep.

JAMES YOO That is amazing. He landed there six days later?

PARKER I found the exact spot. He had told me about it through the years, where he established his first Company HQ.

JAMES YOO You were able to call him from that spot because of that huge satellite phone?

PARKER Yes. He told me where, and I was able to call him from that spot, looking at this village, looking at this place. It had changed. I took pictures and sent them home later. That was tremendous. Just think if he had a satphone and access to the data we find so ubiquitous these days...

JAMES YOO That is an incredible life experience. How incredible that the 50th anniversary fell at a time when you were there, and able to do that with your French, and your father was still around. You could actually talk to him about it.

PARKER Yep. That's right. He was a soldier, retired as a Colonel, but also a civilian working for government. He was the one who took us overseas when I was 13. I've seen the tools of the trade. Just think, in Normandy, we drove back and forth, and we had to have a radio man or woman with us to call the other units when we were setting up for dinners and events

in the villages, where people wanted to thank the various American and Canadian French units that fought for them. We had to station someone there. We didn't have sat imagery; we didn't have GIS; we didn't have smartphones. You can imagine – you know this business well. If I had had a laptop and a smartphone, I could've downloaded everything I needed – maps, GPS, live situational awareness. It would've changed the entire exercise. I think about, what if American soldiers had sat phones when they landed in 1940s?

JAMES YOO Right. It was more similar to then, than it was to now.

PARKER Exactly. I did have a satphone, but not a lot of overlays. Not a lot of GIS. I didn't have optical communication.

JAMES YOO Can you imagine planning military exercises without all of that?

PARKER That's my point. The people who know what it was like pre-'89, and where we are now, realize that this has been a major change.

JAMES YOO That's really amazing.

PARKER It's absolutely amazing.

JAMES YOO The only thing we didn't cover is how an FSO educates himself regarding space and what mechanisms are available?

PARKER That's important. It dovetails with my whole piece about the need to allow movement back and forth from industry to government, to private sector... I served in the foreign service on basically every continent. At the end of my foreign service career, I wanted to serve in some entity that touched all of my areas of interests – a command whose missions involved space, deterrence, cyber security and the need for volumes of data in real time. That's why I chose STRATCOM.

STRATCOM was standing up the first cyber command, standing up intelligence, surveillance, reconnaissance, joint-functional components. They were doing maritime domain awareness through other components. They were responsible for missile defense and needed reliable data and communications.

I'm glad you asked, because this puts it all in context.

That was my boost, where I was able to attend the National Security Space Institute, among other laboratories and think tanks. I got to learn from people who have been space professionals and in bunkers during the Cold War, who were now professional enlisted folks and commanders from all branches of our armed services and most civilian agencies. They educated me. I got to travel with them.

During my time at STRATCOM, I was tasked with finding ways to change and improve how the acquisition system identified and secured innovative solutions to military problem sets. After studying the issue, I realized I needed to engage with entrepreneurial actors from outside traditional contracting sources. If you want to get out-of-the-box thinking you better be prepared to do a little out-of-the-box thinking yourself. Along those lines, I engaged entrepreneurs who were also venture capitalists. Importantly, neither of my new colleagues possessed government contracting experience. As such, they were simply unaware of what was impossible. The command was so impressed with their approach that they were engaged to secure private funding to demonstrate the capability of commercial IP routers on orbit. While the full story of IRIS is worthy of a book, the bottom line is that, compared to informal bids by military contractors, we delivered at 20% of the cost and 2-4 years faster than contractors' best estimates. I remain passionate about being a force for introducing this model more broadly into our military and government acquisitions systems.

“Neither of my new colleagues possessed government contracting experience. As such, they were simply unaware of what was impossible. The command was so impressed with their approach that they were engaged to secure private funding to demonstrate the capability of commercial IP routers on orbit.”

The State Department could never afford a DOD level of training, and we'll never have a large enough training budget to maintain a training cohort. But, somehow, some way, through the private sector, research and academic institutions, we are bringing this intellect and this knowledge together to help create that “Space for Living.”

JAMES YOO That really brings us full circle, doesn't it, how space assets benefit humanity as a whole?

PARKER Being a kid of the Mercury, Gemini, Apollo, Space Shuttle generation, back in the day, when it was so new, we were riveted. We rolled televisions into our classes when I was a kid to make sure we didn't miss a launch. We knew all the astronauts' names. We knew their families. It was live television at its best. If you were lucky enough, you got a trip to Cape Canaveral. We built rocket models. The cars at the time all had rocket names, and were all based on looking sleek like a rocket or a missile. That was my early time. Every launch was like Christopher Columbus.

JAMES YOO Yeah. That's really cool.

PARKER With the advent of the shuttle, and I know now what I didn't know, having served at STRATCOM, is that space is hard. It's a hard business. It's expensive, and it can be unsympathetic, as it was in 1986 and 2003, when two of the Space Shuttles exploded. But most people think it's routine, and it's not.

JAMES YOO It's not at all. That's really a true statement. Space is really hard, and even people like Elon Musk make it look easy in a way, because they move so fast and do new things like reusable rockets.

PARKER Space is hard. The American public doesn't have to know all the technology, the GPS, how it affects their banking, and their timing, and their clocks, and when things start and stop. Somehow, though, we have to help them appreciate the benefits to humanity of having satellites and capabilities on orbit.

JAMES YOO I agree. Sixteen years ago, when I took over the magazine, I was a publisher, not a satellite expert. Over these years, I have gained an incredible appreciation for this industry. I now realize the importance of the assets in space for daily living, which we should not take for granted. Also, there's an underlying theme here of diplomacy, of cooperation, of helping each other.

PARKER It's the foundation.

JAMES YOO It's not just the United States we're talking about. We're talking about global citizens, countries all over the world, and helping each other. I think this

underlying theme is so important, about space being a unifier. I mentioned the Space Station in particular, but I think you're thinking of it even more broadly, about all of space, the activities and benefits, being a unifier, including your work the Space Foundation and Secure World Foundation. Is there anything else that you'd like to share?

PARKER Only the importance of people like yourself, and magazines, and educating people, including the forums that Secure World Foundation and the Space Foundation, and others in the industry provide for people to get to know each other. I'm seeing more and more, through the years, international engagement with symposiums. I think it becomes a true melting pot, and people will learn from each other.

JAMES YOO I agree. I want you to know we take our role very seriously publishing information that people need to know. Thank you so much for that.

PARKER Thank you, Myrna.

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“The space station usually flies above politics.”

XXX
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EXECUTIVE INTERVIEW



Nick Hague
NASA Astronaut



Myrna James Yoo
Publisher, Apogeo Spatial

Tyler N. Hague was selected by NASA as an astronaut in 2013. He earned a BS from the United States Air Force Academy in 1998, and a MS from MIT in 2000. In 2009, Hague was selected for the Air Force Fellows program in Washington, D.C., and was a staff member in the United States Senate. Hague is currently assigned to launch March 2019 and will serve aboard the International Space Station as a flight engineer for Expedition 59 and 60. He is married to Lt. Col. Catie Hague, U.S. Air Force. They have two sons.

ASTRONAUT NICK HAGUE IS SLATED TO FINALLY GO TO THE INTERNATIONAL SPACE STATION IN MARCH. HE HAS BECOME A BIT OF A “MEDIA DARLING” IN RECENT MONTHS, AS THE ONLY NASA ASTRONAUT WHO HAS SURVIVED A ROCKET DISINTEGRATION TWO MINUTES INTO LAUNCH, WHEN HIS RUSSIAN SOYUZ ROCKET BOOSTER MALFUNCTIONED, WHICH IS A VERY RARE OCCURRENCE. HIS COLLEAGUE WAS RUSSIAN COSMONAUT ALEXEY OVCHININ, AND WITHIN A FEW MINUTES OF LAUNCH, THEY CRASH-LANDED IN KAZAKHSTAN, SAFELY AND ACCORDING TO THE PLAN IN PLACE TO RESPOND TO A LAUNCH MALFUNCTION. THE RUSSIANS FOUND THE ROOT CAUSE OF THE PROBLEM, WHICH NICK DISCUSSES HERE. THE FOLLOWING LAUNCH IN THE SOYUZ WAS SUCCESSFUL ON DEC. 3, 2018, TAKING THREE ASTRONAUTS TO THE SPACE STATION, WHICH HAS BEEN CONTINUOUSLY MANNED FOR 18 YEARS, SINCE NOVEMBER 2000.

I SPOKE WITH NICK ON DECEMBER 12, 2018, A FEW DAYS FOLLOWING HIS INTERVIEW ON *CBS THIS MORNING* DECEMBER 7, WHEN HE SAID, “LIFE DOESN’T ALWAYS TURN OUT THE WAY YOU’VE PLANNED. MORE OFTEN THAN NOT, WHAT DEFINES YOU IS HOW YOU BOUNCE BACK FROM THAT.” ALSO IN THAT INTERVIEW, NICK’S WIFE CATIE QUOTED THEIR YOUNG SON, WHO SAID, “WELL, YOU TRIED, IT DIDN’T WORK OUT, SO IT’S TIME TO GET A NEW JOB.” FORTUNATELY, NICK WILL GET TO TRY AGAIN TO GET TO THE ISS.

JAMES YOO Thank you so much for joining me, Nick. You are, I believe, going to space to the International Space Station in March. Is that when you’re scheduled to go now, Nick?

HAGUE Yes. If all goes according to plan, I’ll be blasting off from the Baikonur Cosmodrome in Kazakhstan.

JAMES YOO Great. That is so exciting. I know that a lot of people realize what happened. Do you want to share what happened when you did not make it and had to do an emergency landing a few months ago?

HAGUE So, almost to the day two months ago, October 11th, Alexey Ovchinin, my commander, and I were launching to the space station on the same launch pad we’re going to use at the end of March. And two minutes into the launch during the first-stage separation event, one of the external rocket boosters didn’t separate properly and collided back into the rocket, essentially causing the rocket to disintegrate. As that happened, the abort system detected the problem with the rocket, which activated the emergency escape system and pulled us away safely from the rocket. And then, we essentially performed a standard landing in the Soyuz reentry capsule underneath the parachute, landing in the middle of the Kazakh Steppes (in northern Kazakhstan). We were rescued by SAR (search and rescue) forces, minutes after our capsule touched down.

JAMES YOO That’s really incredible how well it went, considering how dangerous that sounds and that something went wrong. But actually, for something going wrong, it went very well, and no one was injured, right?

HAGUE Absolutely. And that’s a testament to the system, the program that’s in place over in Russia to launch crews on the Soyuz rocket, and the Soyuz spacecraft. They hadn’t exercised a launch-abort in 35 years. When it was needed, it worked flawlessly. When the search and rescue forces needed to respond, they responded flawlessly. They’ve got a really great program over there, and it was impressive to see it in action.

JAMES YOO I know that you’re very excited that you’re going to be able to actually go to the Space Station in March. Is it still planned to be for a six-month period?

HAGUE Yeah. It’s roughly six months. And it’s exciting to get up there. I’ve been down here at NASA since 2013, and have essentially trained continuously. So,

Interview with NASA Astronaut Nick Hague

TRIP TO THE ISS IS OPPORTUNITY TO SERVE



50th Anniversary of the Moon Landing

Nick will be on the ISS on July 20, 2019, for the 50th anniversary of the Apollo 11 landing on the moon. Russia was a fierce competitor then, and now they are one of NASA's most important partners for the space station. This change is a testament to how difficult space really is, that the greatest minds on Earth need to work together to be able to run the ISS.

All over America, many events will celebrate this anniversary, including the National Air and Space Museum in Washington, D.C., the Space Center in Houston, the Kennedy Space Center in Florida, and Denver's Wings Over the Rockies, which is having an Apollopalooza week-long event. Neil Armstrong's hometown of Wapakoneta, Ohio, will be celebrating with a Summer Moon Festival.

you've got five years of training building up to spending six months on the Space Station. So, it's exciting to get the opportunity, especially to have it so soon, to go and try to do this again. It's going to be thrilling to fly around the world for six months.

JAMES YOO That's incredible. Thank you for being willing to let us publish some of your photos from the Space Station. We're looking forward to that. *Apogeo Spatial* is about leveraging data about the Earth from space, ultimately to benefit humanity. We publish photos from satellites on a regular basis, and I'm excited to expand our scope and publish photos from the Space Station as well. I also wanted to share that we have a partnership with the ISS National Lab.

HAGUE Yes. I'm familiar with them.

JAMES YOO Great. I know you'll be doing some experiments. We have their first article about the remote sensing experiments in this issue. Do you have any idea yet what kind of experiments you'll be working on?

HAGUE So, it's one of the surprising things about the program, that with long-duration space flight, being up there for six months, they can't exactly script out what we're going to do. The impact of my launch-abort, and the shuffle of everything that's going to happen up there is just one example of how fluid the program is. So, they train us to have generic skills so that we can apply those to any particular experiment that we're required to support. Two-thirds of the science that I'm going to do up there, I won't see until they ask me to do it on board.

JAMES YOO Oh, wow.

HAGUE So, that's a little daunting. But, it's also a testament to the training team, getting us prepared to be able to do something like that. The things I'm most familiar with are the ones where I'm a human test subject, so I'm the guinea pig, and they're trying to see how I respond to changes in weightlessness without gravity as a vector.

Here is an example. If you think about it, everything you use in terms of internal navigation inside your head about keeping a mental map of where you are in a building, and being able to find your way from point A to point B, is all anchored on this idea that you always know where down is. And so, it's not uncommon up there for astronauts to get lost inside the Space Station even though it's so small, because you don't have any sense of where down is. There are several experiments I'm doing that are looking at how we create those mental maps, and they're looking at the effects of microgravity, or not having that strong down direction – how that changes how our brain works. They will take images of our brains before launch, and then after we land, and see if there are any structural changes – being able to perform virtual reality tasks, our perception of time and time dilation. Is there any impact on that? There are all these different aspects that we're trying to look into.

JAMES YOO That is really fascinating. There are so many different experiments that are happening. It's almost as if you're becoming a scientist, as well, by doing these experiments that are not really related to space!

HAGUE That might be giving me a little too much credit. So, I wouldn't say that I'm turning into a scientist. But they've trained me to be a scientist's eyes, and ears, and hands, and to be able to perform the

experiments. I'm collecting the data, and I'm sending the data down to PhDs on the ground who are making decisions with it.

JAMES YOO Oh, okay. I know there are experiments in life sciences, physical sciences, and technology development, in addition to remote sensing, the latter of which is the specific focus of *Apogeo Spatial*.

HAGUE You name it – we're looking into it.

JAMES YOO What do you think about all the new commercial space companies that are out there these days, with SpaceX, Virgin Galactic, Blue Origin, and so many additional companies now? You're going up on the Soyuz MS-10, which is a very tried-and-true reliable launch vehicle. What do you think about the "NewSpace" companies?

HAGUE I think that the energy in the private sector is awesome. The more people that we can get involved with space, I think the better off we're going to be. The commercial crew program, for instance, testing now with Boeing and SpaceX, which will be able to launch crews from the U.S. – think about the societal impact. Right now, it's very difficult for anybody to go watch somebody launch into space. It's out in the middle of nowhere in Kazakhstan. But as soon as we bring it back to the Florida coast, thousands of people are going to be able to experience watching a crew launch into space firsthand. And think of how many people that's going to inspire.

JAMES YOO Right. We'll have a little more national pride again, perhaps, in that way.

HAGUE Yeah. It's going to be great, and I hope it inspires lots of young boys and girls to get involved with STEM fields, and to want to be a part of the space program. From a program perspective, I think it's a great advancement too, because it gives us a more robust program. My launch abort's a great example. If something happens with the Soyuz, we will still have other ways to get the crew to orbit and continue the mission, which is ultimately what we're trying to do. So, it makes the program more robust.

JAMES YOO Yes. That's great. I'm also hearing a lot about space tourism, about citizens wanting to go to space. Several companies are really making that a reality: Virgin Galactic, Blue Origin... I think that it's really going to be interesting. We're in this timeframe now of space being so exciting again.

One thing I'm really fascinated with is this concept that when people go to space, whether they're astronauts or not, when they look back at the Earth and see the

planet, there's a change in consciousness that happens – a sense of awe, or a sense of oneness. We're really interested in covering that as well.

HAGUE Yeah. I've heard the same thing, termed "The Overview Effect." It puts things in a slightly different perspective. And so, that's one of those things with space flight that I'm looking forward to, experiencing it firsthand and seeing how it affects me will be one of the personal highlights that I'm going to have in the mission.

Sharing that with as many people as possible becomes our responsibility once we get back down on the ground, and trying to help people

"The space program is really about service. What we're doing ultimately is trying to give more to others than we give to ourselves. We're trying to do that for humanity - for the benefit of all the people that are on the ground."

understand that. And so, I think the idea of tourism in space is great, because the more people that can experience it firsthand, the more that we can get the message out there.

JAMES YOO I agree. You know, I love that you said that it's a responsibility. That's how I feel about the magazine, that we have a responsibility to share as much information like this as we can. That's really one of the reasons why I publish and own this magazine. I'm thrilled that we'll be able to take your message and get that out there for you as well.

Nick, I know you're from a small town in Kansas. Do you feel that growing up in a rural area has contributed to your success as an astronaut, and in general in life?

HAGUE Yeah. It's one of those things where, when you're growing up in a small town in rural Kansas, it's natural to focus on all the things that are missing. You know? You're just not part of it. And that's the way I felt growing up, that I'm outside of it all. The world is happening all around me and I'm just not part of it.

Looking back now, though, I realize that the small town environment gave me so many opportunities that I might have missed if I had been in a school district that had thousands of students as opposed to a few hundred students. I was able to really test out my interests and try everything just to try it – play every sport, be in multiple clubs, try band, forensics, debate – go ahead and just really spread your wings and test some things out; that's what growing up in a small town did for me. It gave me all those opportunities, and really gave me the foundation to move forward in life. And so, it was very formative.

In hindsight, there's no better place to grow up. I'm thankful for the experiences I had growing up in northwest Kansas.

JAMES YOO That's great. And I agree with you. It made me also want to go out and do all those things. I moved to Chicago as soon as I could. Nick, is there anything else that you'd like to share with us – any final thoughts?

HAGUE Yes. It kind of builds off the last thing. I appreciate what you're trying to accomplish with your magazine. It's really about service. What we're doing ultimately is trying to give more to others than we give to ourselves. We're trying to be part of something bigger than ourselves. That's what the space program is about. We're trying to conduct that

science. We're trying to explore the unknown. We're trying to discover answers to questions that we don't have the answers for. But, we're trying to do that for humanity – for the benefit of all the people that are on the ground. And that's a vital mission; it's a vital mission that we've been doing for decades continuously. And it's a vital mission that we need to continue to do. I think whatever you can do to spread the awareness, and to reach new demographics, to let

people know that we are doing this, is so important. Spreading that awareness to everyone, whatever you can do, is a positive.

I can't tell you how many people I meet who have never met an astronaut before, and they're surprised to meet me because they didn't know that we were still working in space – that we still have an astronaut program. Because when the shuttle was retired, they thought we shuttered the doors. We didn't. We're continuing. And so, spreading the message is a critical job.

JAMES YOO That really is important. I know that as I've learned more and more about the federal government – NASA, NOAA, USGS – since I took over this magazine 16 years ago, that I have more and more respect for the incredibly important work you are doing, collectively. And I absolutely love that we have a role in continuing to get the word out about all of that. We're not a big consumer publication, as you know, but we really do take that responsibility seriously as well. I appreciate your mentioning that. Thank you so much, Nick, for joining me today. I'm looking forward to publishing your personal photos and thoughts from space, and to staying in touch. Thank you.

HAGUE Absolutely. My pleasure, Myrna. Thank you.

Disclaimer: Publisher Myrna James Yoo is from the same small town that Nick considers his hometown, Hoxie, Kansas. Her mother, Bette James, was Nick's high school English teacher, as well as a key influence in his life. Nick shared that he is taking Mrs. James' photo, among others, to the ISS to recognize those who have contributed to his success.

ISS

The International Space Station is a unique place – a convergence of science, technology and human innovation that demonstrates new technologies and makes research breakthroughs that are not possible on Earth.

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The station facilitates the growth of a robust commercial market in low-Earth orbit, operating as a national laboratory for scientific research and facilitating the development of U.S. commercial cargo and commercial crew space transportation capabilities. More than an acre of solar arrays provide power to the station, and also make it the next brightest object in the night sky after the moon. You don't even need a telescope to see it zoom over your house. And we'll even send you a text message or email alert to let you know when (and where) to look up, spot the station, and wave via apps, such as ISS HD Live.

The space station remains the springboard to NASA's next great leap in exploration, enabling research and technology developments that will benefit human and robotic exploration of destinations beyond low-Earth orbit, including asteroids and Mars. It is the blueprint for global cooperation – one that enables a multinational partnership and advances shared goals in space exploration.

See also <https://www.nasa.gov/feature/the-international-space-station-is-a-unique-place>

<Special Section>

A Focus on Remote Sensing from the International Space Station

A UNIQUE EARTH IMAGING AND OBSERVATION PLATFORM FOR SUSTAINABILITY



Image of the International Space Station courtesy of NASA.

Humans and our ancestors have always gazed up at the night sky with wonder and awe. Only in very recent memory have we been able to gaze back at our planet from that same sky. Today, it is routine to see images taken from space that look back down on our planet. Stunning images of the northern lights, harrowing images of hurricanes, and beautiful nightscapes of whole continents lit up by human-generated light commonly appear on our TV, computer, and phone screens.

Perhaps the scientific power behind these images is not always front of mind as we appreciate their aesthetics. However, the value of imaging capabilities from space significantly affects our daily lives through improved disaster response; analysis of agriculture, water quality, and the atmosphere; advanced maritime tracking; land use studies; and much more.

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ISS

Specifically, the International Space Station (ISS), which orbits at an altitude of approximately 240 miles, provides a valuable vantage point for Earth observation. The unique orbital path of the ISS passes over regions of the Earth containing more than 90% of our planet's population. Additionally, in contrast to other satellites used for Earth observation that are typically sun-synchronous and capture imagery of locations at the same time each day, the ISS passes over locations at varied times of day and year. This provides views under varying lighting conditions and during different seasons—expanding the breadth of data researchers can collect on a given location. ISS-based imaging, which ranges from handheld cameras to advanced multispectral imaging systems, is therefore well poised not only to capture our imagination but also to support the democratization of global remote sensing data, and to advance our efforts to increase sustainability and to improve life on Earth.

Tracking Tropical Cyclones from Space

Tropical cyclones occur year-round, with regional



▲ **FIGURE 1**
MUSES (Multi-User System for Earth Sensing) Platform from Teledyne Brown Engineering.

hurricane and typhoon seasons peaking in certain months of the year. However, the damage done when these storms make landfall lasts far longer and lingers in our minds. Encouragingly, advancements in space-based imaging are improving our ability to predict the path and strength of hurricanes and therefore our ability to save lives.

For example, a multi-year project onboard the ISS U.S. National Laboratory is studying the eyewall-cloud altitude of tropical cyclones using 3D images constructed from astronaut photography. It may seem elementary that photography alone could help combat one of nature's most destructive forces, but images from slightly different angles can be pieced together to estimate distance—and rapid image acquisition from space as the ISS passes over a storm can provide a large enough dataset to create 3D images of cyclones that allow accurate cloud altitude determination above sea level.

Using these data, scientists from Visidyne, Inc., study how eyewall construction relates to storm trajectory and wind speed as part of the Cyclone Intensity Measurements from the ISS (CyMISS) project. The higher-accuracy measurements resulting from the CyMISS project could help lead to improved global forecasting of tropical cyclones, which is vital to helping communities better prepare for these storms, minimizing both fatalities and destruction. See Figures 1-3.



Democratizing Powerful Earth Observation Data

In addition to astronaut photography, advanced imaging systems like the Hyperspectral Imager for the Coastal Ocean (HICO), which operated on the ISS from 2009 until 2014, provide high-resolution multispectral Earth-imaging capabilities. As the first space-based imaging spectrometer designed to examine optically complex coastal regions that require both land and water imaging, HICO collected more than 10,000 images during its five years of operations.

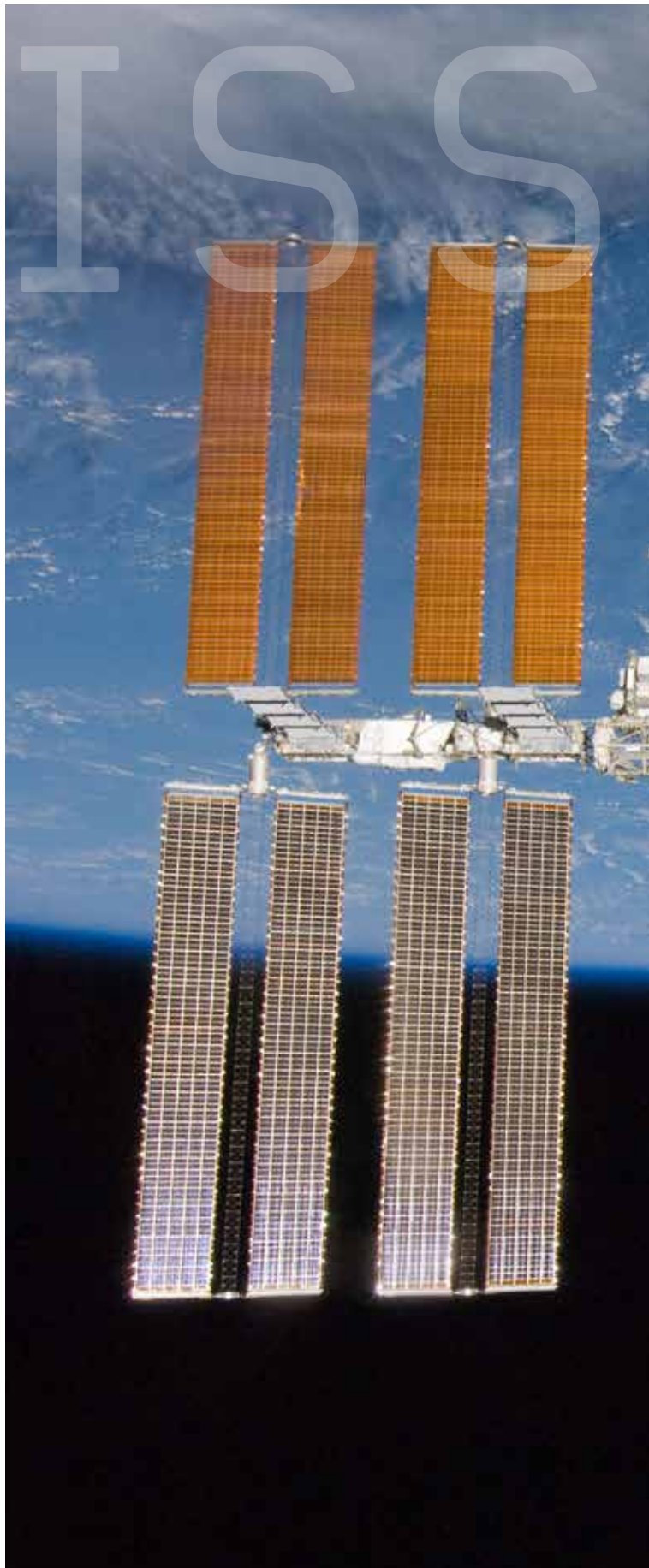
Bringing the power of space-based Earth imaging data—from not only ISS-based imagers but also the rapidly growing constellations of small satellites

orbiting the Earth—into the hands of scientists around the world requires tremendous data processing systems. The highly complex processing algorithms needed to analyze and interpret these “big” data are often out of reach for researchers who do not have the necessary computers, tools, and expertise. To meet this critical need to democratize Earth-imaging data, HySpeed Computing leveraged ISS National Lab funding to develop an online analysis tool, the HICO Image Processing System (IPS). The system combines open-source and commercial software (including ENVI) in an accessible cloud-based interface that allows users to submit requests and receive results on-demand. HICO IPS is serving as a pathfinder in providing the global science community with a means to easily and quickly access and analyze valuable remote sensing data for innumerable applications.

Evaluating Ecosystem Productivity from Orbit

Another ISS National Lab project that uses HICO data demonstrates how Earth imaging data from space can be used to study not only water but also land, with important sustainability implications. From space, you can see our blue planet swirled with the lush green of plants and algae in ecosystems teeming with life, dependent upon the primary producers using sunlight to convert carbon dioxide into biomass.





Understanding daily and seasonal changes in ecosystem productivity (the rate at which biomass is generated in an ecosystem) is crucial to farmers and land managers seeking to improve the health of crops and forests and to optimize the use of resources such as water and fertilizer. Data showing how ecosystem productivity varies on a global level can also provide insight into Earth's changing climate and show how fluctuating levels of carbon dioxide in the atmosphere affect ecosystem stability and agricultural production in the future.

Going to space to study ecosystem productivity on the ground may seem counterintuitive, but land-based sensors that measure gas and energy movement between Earth's surface and the atmosphere are not widely available, though they do provide precise, highly localized information. Space-based sensor data enable these localized data to be used in geospatial models to monitor trends in global ecosystem productivity. By combining HICO imagery with data from ground-based sensors, researchers from the University of Maryland, Baltimore County, were able to develop robust algorithms for measuring ecosystem productivity to improve land use and crop resource management, which could enable scientists to assess variations in ecosystem productivity in areas across the world. See Figure 4.

Driving Commercial Investment

In June 2017, a new commercially operated facility solely dedicated to Earth imaging was launched to the ISS National Lab—the Multi-User System for Earth Sensing (MUSES) platform, developed and managed by Teledyne Brown Engineering. Mounted to the exterior of the ISS, the facility enables a wide variety of remote sensing and Earth observation research and provides a test bed for technology demonstration and maturation of space-based sensors

The MUSES platform offers precision pointing and can simultaneously host up to four Earth-viewing instruments, such as multispectral and hyperspectral imagers, spectrometers, high-resolution cameras, radar, LiDAR (similar to radar but using pulsed laser light), and panchromatic imagers (sensors sensitive to a wide range of light wavelengths), among others. The instruments can be remotely serviced, swapped, or upgraded using the robotic arm on the ISS, making the platform highly flexible. Sensors hosted on MUSES can enable powerful environmental monitoring,



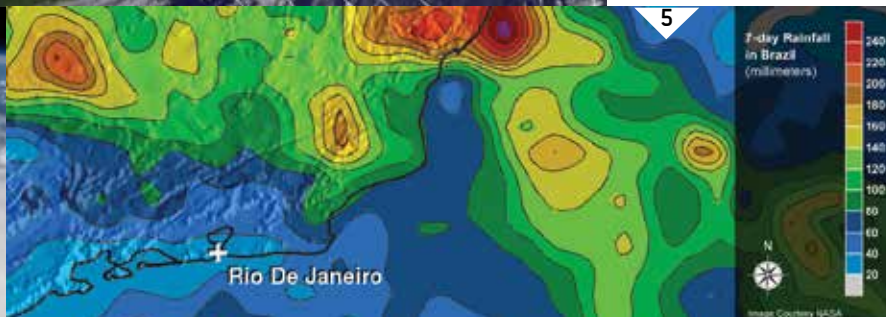
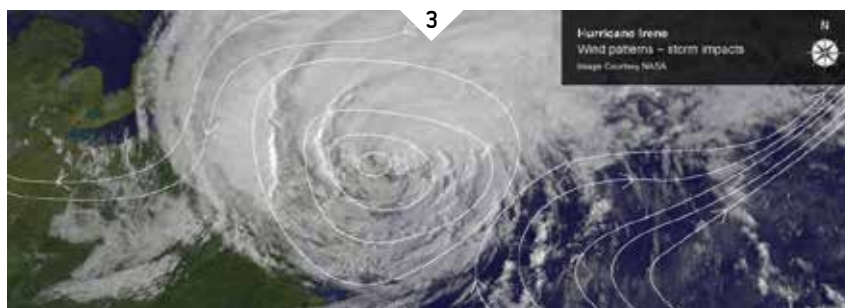
“The MUSES platform offers precision pointing and can simultaneously host up to four Earth-viewing instruments, such as multispectral and hyperspectral imagers, spectrometers, high-resolution cameras, radar, LiDAR (similar to radar but using pulsed laser light), and panchromatic imagers (sensors sensitive to a wide range of light wavelengths), among others.”

detecting phenomena ranging from water pollution and harmful algal blooms in our oceans to coastal erosion, landslides, and flooding. MUSES instruments can also provide valuable information for global maritime tracking, land management, food security monitoring, and air quality assessment. Furthermore, as a permanent, commercially operated, remote-sensing facility on the ISS, MUSES represents a new step toward commercial investment in space-based Earth observation—estimated by Northern Sky Research in 2017 to be a \$52 billion market over the next 10 years. See Figures 5-6.

Sparking Wonder Through Imagery

In the end, of course, the space-based Earth images alone still inspire us. Apple, known for the striking aerial imagery in their AppleTV screensavers, announced a new collaboration with the ISS National Lab at their Worldwide Developers Conference in June, during which Apple previewed a series of new breathtaking aerals of Earth taken by astronauts onboard the ISS. The stunning images capture different parts of the world during day and night, revealing both natural features and signs of human activity—and the images are now available to Apple users following the release of tvOS 12 in September.

Seeing the beauty of our planet from this unique perspective, we are inspired to turn our gaze back up to the stars like so many humans before us and ask what is possible—both from the ISS and beyond.



▲ FIGURE 2-4.
A multi-year project onboard the ISS U.S. National Laboratory is studying the eyewall-cloud altitude of tropical cyclones using 3D images constructed from astronaut photography.

▲ FIGURE 5
Image shows 7-day rainfall in Rio de Janeiro, Brazil in millimeters.

Lidar from Space!

LIDAR REMOTE SENSING ON THE ISS

By Etop Esen, PhD, Commercial Innovation Manager and Remote Sensing Lead,
ISS U.S. National Laboratory, Houston, Texas, www.issnationallab.org

Since the International Space Station (ISS) began operations in November 2000, it has served as a host platform for testing several remote sensing and Earth observation instruments. Traditionally, NASA and the other ISS program partner space agencies have sponsored the development of the majority of these instruments, with the main objective to improve our scientific understanding of Earth's dynamic terrestrial and atmospheric systems.

More recently, the ISS U.S. National Laboratory has facilitated increased access by private companies, such as Urthecast, Visidyne, Teledyne Brown Engineering, and Orbital Sidekick, either for the testing of sophisticated, proprietary imaging sensors hosted on external commercial-use ISS facilities or for the development of new analytical tools to provide targeted data and imagery to end users. This brief article highlights and summarizes the objectives and results of two lidar (light detection and ranging) remote sensing missions—one present and one past—to the ISS and their benefits for both scientific and commercial pursuits.

The Global Ecosystem Dynamics Investigation (GEDI) instrument is a lidar sensor that was launched to the ISS on SpaceX's 16th commercial resupply services mission on December 5, 2018 and installed on the Japanese Experimental Module Exposed Facility (JEM-EF). See Figures 1-2.

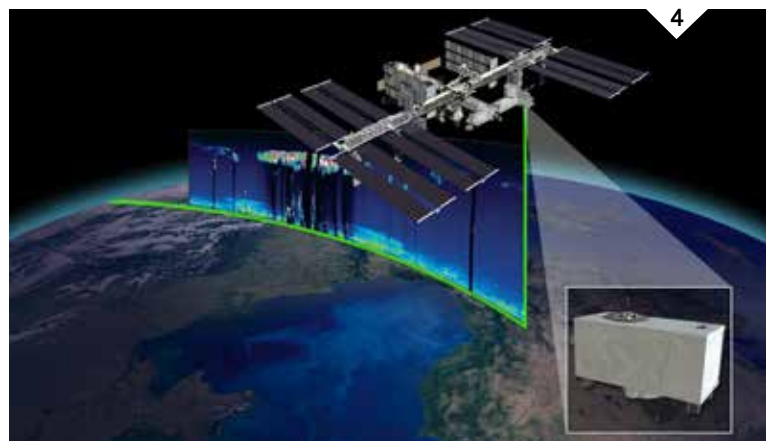
GEDI is a full-waveform lidar system with three lasers that emit 242 pulses per second at 1,064 nm and precisely record the amounts and return timing of reflections from vegetation and other objects at different heights above the ground. The lasers produce a total of four beams and eight ground tracks, covering a 4.2-km (2.6-mile) swath perpendicular to the flight path. GEDI can be rotated on the JEM-EF by up to 6°, which allows the lasers to be pointed 40 km on either side of the ISS ground track.

From the three-dimensional waveform data,

detailed metrics on surface topography, canopy height and cover, and vertical structure will be derived and used to quantify the impacts of deforestation and forest regrowth on the Earth's global carbon balance. GEDI is one of the first lidar sensors from space that is "enabling the translation of forest height and canopy measurements into estimates of above-ground carbon, how it's changing, and how forests may or may not be able to sequester it in the future," according to Todd Neff in his book, *The Laser That's Changing the World*. The dense spatial sampling will also provide new high-resolution data to characterize plant and animal habitats across global ecosystems. GEDI is scheduled to collect data for two years. See Figure 3.

The Cloud-Aerosol Transport System (CATS) mission was launched in January 2015 and ended in October 2018. CATS used a two-laser lidar system operating at three wavelengths to provide vertical profiles of atmospheric aerosols and clouds from the ISS. In its primary multi-beam mode, splitting of the first laser into 532-nm and 1064-nm wavelengths provided information on the layer type (i.e., cloud or aerosol). The secondary CATS mode used the second laser and narrower wavelength intervals to demonstrate the use of high-spectral-resolution lidar, and it also tested a shorter laser wavelength of 355 nm.

Cloud and aerosol location and height were obtained from the CATS information. Additionally, the concentrations, persistence, and types of aerosol particles from different sources such as dust, sea salt, fires, volcanic eruptions, and fossil fuel combustion, were also determined. The results also indicated that detection at 1,064 nm provides a more representative picture of the above-cloud aerosol layer than detection at 532 nm.



▼ **FIGURE 1.** Upper: The ISS and location of the JEM-EF. Lower: Location of GEDI (highlighted in gold)

on the JEM-EF. Image courtesy <https://gedi.umd.edu/instrument/instrument-over-view/>.

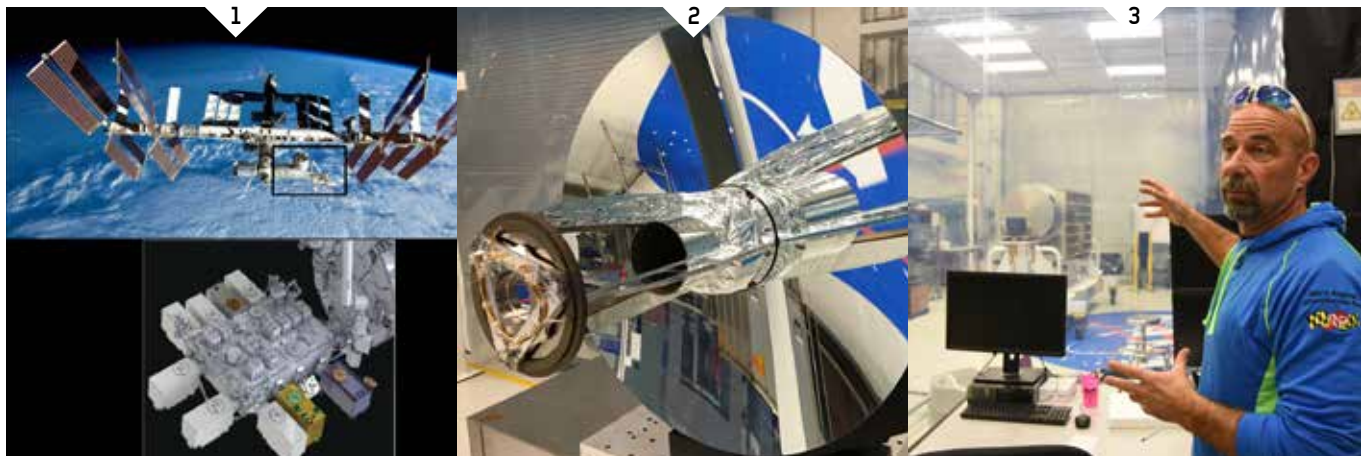
▼ **FIGURE 2.** GEDI's 80-cm telescope for collection of received light, courtesy <https://gedi.umd.edu/instrument/instrument-over-view/>.

<https://gedi.umd.edu/instrument/instrument-over-view/>.

▼ **FIGURE 3.** NASA Goddard GEDI program manager Jim Pontius describes the GEDI

instrument, which is behind him in a clean room, in October 2017 as capable of "decadal science." Photo

courtesy of Todd Neff, author of his new book, *The Laser That's Changing the World*.



The orbital path of the ISS allows for remote sensing over large portions of Earth's atmosphere and surface. At an inclination of 51.6° and average altitude of 400 km, the ISS completes approximately 16 orbits every 24 hours, and every three days, it passes over the same area under varying solar illumination.

CATS' lidar comprehensively covered the primary aerosol transport paths over the tropics and mid-latitudes and collected data at different local times of day for study of the diurnal changes and effects of clouds and aerosols on climate and weather patterns. The CATS instrument was the first space-based lidar to provide near real-time (less than six hours) cloud and aerosol data to users, thereby significantly improving the accuracy of computer models for aerosol forecasting. See Figures 4-5.

For lidar from space, CATS followed CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) spacecraft that studies the role of clouds and aerosols in the Earth's weather. It is part of the A-Train constellation of five satellites studying the climate system, and also measures particles below the ocean surface, including phytoplankton. It is a joint mission with CNES, the French space agency.

The ISS is currently the only existing satellite bus on which multiple hosted remote sensing instruments can simultaneously acquire data. The hyperspectral sensors DLR Earth Sensing Imaging Spectrometer (DESI) and ISS-Hyperspectral Earth Imaging System Trial (HEIST) and the multispectral ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) sensors were launched and deployed in 2018, and the Orbiting Carbon Observatory-3 (OCO-3) sensor is planned for 2019.

When combined with GEDI lidar and remote sensing data from past missions such as CATS and the Hyperspectral Imager for the Coastal Ocean (HICO), these ISS sensors covering Earth's land surface, vegetation, oceans, and atmosphere provide rich and unprecedented opportunities for data fusion, analysis, and modeling by scientists, researchers, and commercial companies all seeking to understand and contribute to the preservation, conservation, and sustainable use of Earth's resources.

“The CATS instrument was the first space-based lidar to provide near real-time (less than six hours) cloud and aerosol data to users, thereby significantly improving the accuracy of computer models for aerosol forecasting.”

◀ **FIGURE 4.** Illustration of CATS lidar acquisition of a vertical atmospheric profile from ISS, courtesy NASA.

▶ **FIGURE 5.** Location of CATS (past) and GEDI (current) lidar sensors on the ISS, courtesy NASA.



Lidar Book Launch

THE LASER THAT'S CHANGING THE WORLD: THE AMAZING STORIES BEHIND LIDAR FROM 3D MAPPING TO SELF-DRIVING CARS

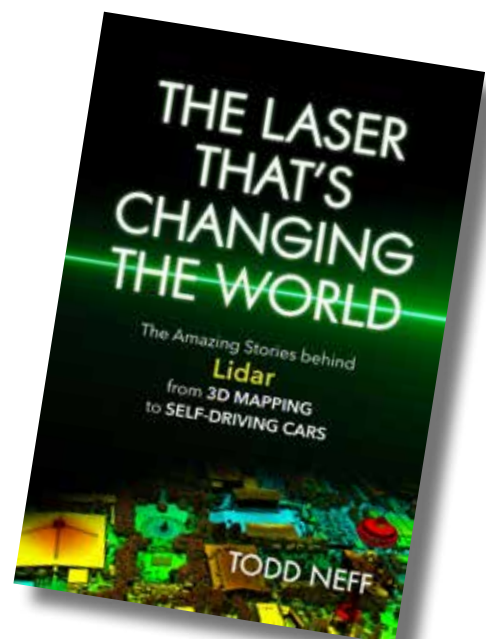
The Laser That's Changing the World is a new comprehensive science and technology book that tells the stories of lidar's origins, the people who propelled it forward, and how tech-transfer has taken lidar from new technology into mainstream commercial applications. Author Todd Neff looks back at the history (providing an excellent additional timeline at www.lidarhistory.com) and looks forward to where lidar will take us.

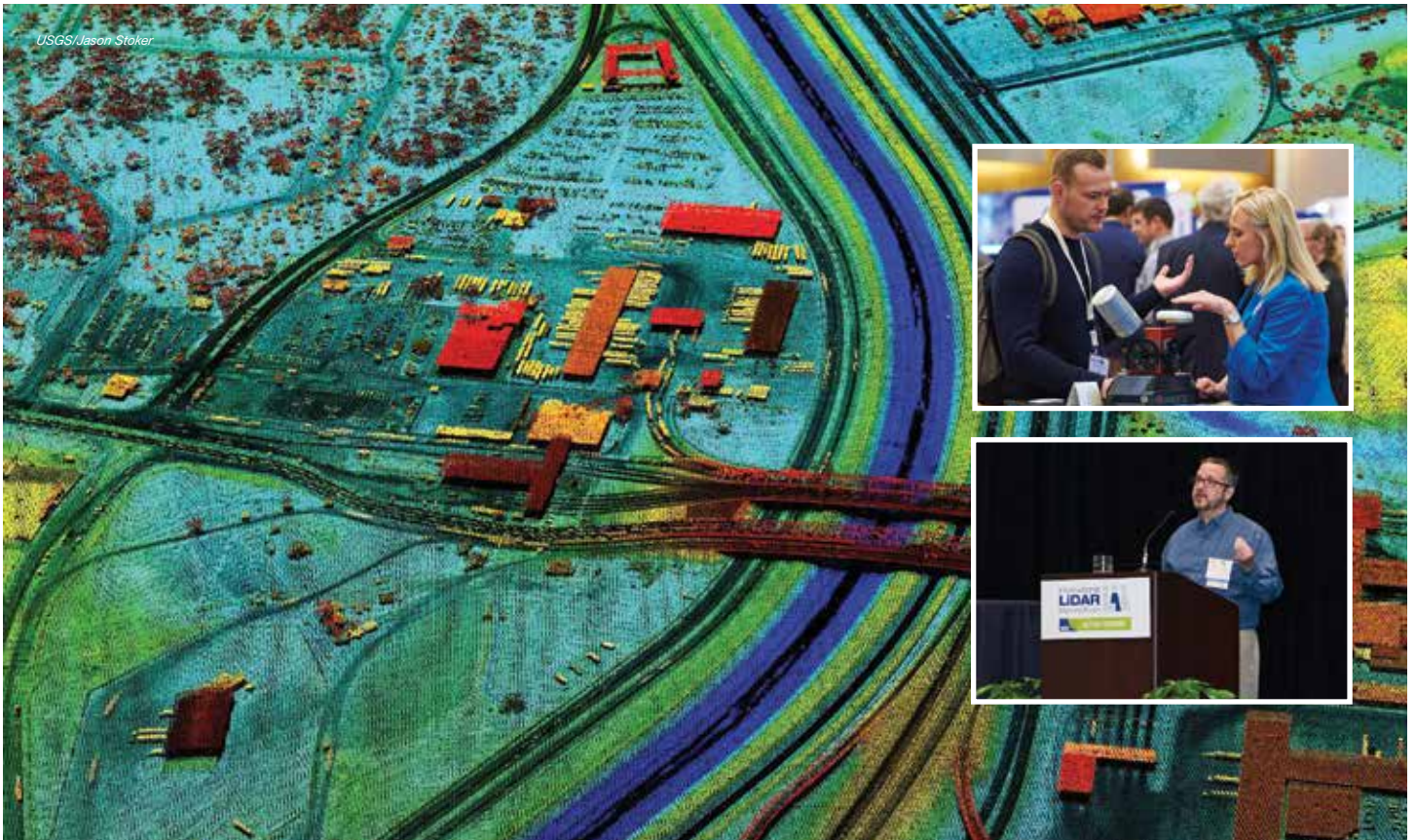
Lidar has quietly radiated from its niche in atmospheric science to water to land and into space. It has helped us better understand the air we breathe, the creep of continents, the paths of intercontinental ballistic missiles, the water in mountain snow packs, the damage done by hurricanes, the impact of climate change on ice caps and much more. Lidar has found lost cities and mapped modern ones, characterized enemy territory from cruising altitude, nabbed speeders, avoided blackouts, and listened to the conversations of stink bugs.

It's now headed to the streets, where lidar will soon go mainstream as a key enabler of self-driving cars, averting thousands of traffic deaths a year, changing how we commute and, over time, reshaping our cities and how we live in them. The book was released Oct. 9, 2018, from Prometheus Books.

"Here is a grand tale of genius, grit, and serendipity—a sweeping history of the unsung invention that is transforming modern life. Just as lidar has revolutionized how we see, comprehend, and navigate our world, this timely book will open your eyes to the fast-changing technological environment that surrounds you."—David Baron, author of *American Eclipse* *"Here is a masterful presentation of the development of optical remote sensing from its very beginning, using searchlights to study the sky. With the advent of the laser, lidar was born, and this book follows the explosive development of the revolutionary impact that lidar continues to have in fields as diverse as meteorology, surveying,*

3-D imaging, virtual reality, and autonomous vehicle guidance. The reader gets to know the key people in each of these fields and effectively joins their team in responding to the complexity of the challenges and the array of advanced technologies involved. A captivating and fast-moving adventure, meticulously researched and documented, this book is essential reading for everyone interested in the expanding impact of science and technology on the modern world."—Allan I. Carswell, CM, FRSC, FCAE, FCASI, PhD, DSc, PEng, Professor Emeritus, York University, and founder of Optech Incorporated and president of the Carswell Family Foundation *"This book provides a rich history of laser scanning and lidar that will fill in many of the missing pieces of the development puzzle of this soon-to-be ubiquitous technology. GPS became mainstream, but lidar will be more important."*—Gene V. Roe, PhD, founder of Lidar News





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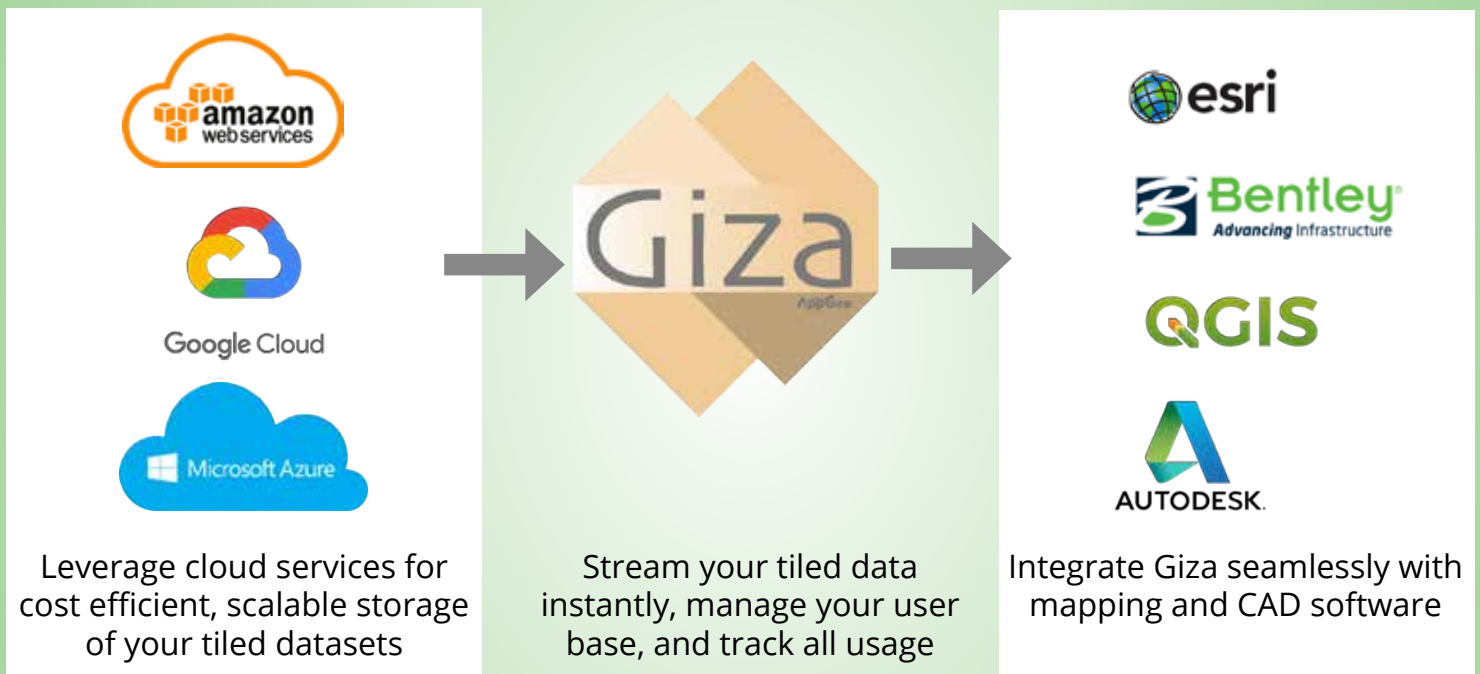
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