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DEPARTMENTS

3 QUICK TAKES

24 COMMENTARY
Donald F. Robertson
Weapons into lunar and asteroid mining colonies

27 COMMENTARY
Nicholas Nelson
DoD needs to demystify hypersonic weapons technology

30 ON NATIONAL SECURITY
Space insecurity: Concerns grow about combustible mix of space congestion and militarization

32 FOUST FORWARD
How to succeed in spaceports without really launching

Celebrating 30 Years of Covering the Business & Politics of Space
SPACENEWS 30 YEARS

NEXT ISSUES
Our final issue of 2019 comes out Dec. 23. Our first issue of 2020 comes out Jan. 20.

IN DEPTH Q&As

5 **Lunar logistics, terrestrial tactics** NASA Deputy Administrator Jim Morhard is new to space, but his deep knowledge of Capitol Hill might just be what the U.S. space agency needs to get Artemis off the ground.

8 **Pitch Day** At its first space-focused pitch day, the U.S. Air Force rolled out the red carpet — and swiped its credit card — in an effort to enlist the help of innovative small businesses.

ON THE COVER: A Rocket Lab Electron rocket lifts off Oct. 16 from New Zealand carrying a single cubesat for Astro Digital. Credit: Sam Toms for Rocket Lab. ABOVE: SpaceNews iillustration

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CHAIRMAN
Felix H. Magowan
fmagowan@spacenews.com
Tel: +1-303-443-4360

CEO
Greg Thomas
gthomas@spacenews.com
Tel: +1-571-356-9957

ACCOUNTING SPECIALIST
Pam Washburn
pwashburn@spacenews.com
Tel: +1-502-553-0728

EDITORIAL

EDITOR-IN-CHIEF
Brian Berger
bberger@spacenews.com
+1-571-356-9624

SENIOR STAFF WRITER
Jeff Foust
jfoust@spacenews.com
Tel: +1-571-385-1483

STAFF WRITERS
Sandra Erwin
serwin@spacenews.com
Tel: +1-571-356-9022

Caleb Henry
chenry@spacenews.com
Tel: +1-571-356-9531

ART DIRECTION
Robin McDowall
mcdowalldesign.com

CORRESPONDENTS

SILICON VALLEY
Debra Werner
werner.debra@gmail.com

HELSINKI
Andrew Jones
jones.andrew.w@gmail.com

MOSCOW
Matthew Bodner
bodnermm@gmail.com

WARSAW
Jarosław Adamowski
ajaroslaw@gmail.com

CONTACT US
1414 Prince Street, Suite 204
Alexandria, VA 22314-2853 U.S.A.
Tel: +1-571-421-2300

ADVERTISING

BUSINESS DEVELOPMENT DIRECTOR
Paige McCullough
pmccullough@spacenews.com
Tel: +1-571-278-4090

BUSINESS DEVELOPMENT MANAGERS
Kamal Flucker
kflucker@spacenews.com
Tel: +1-571-402-5706

OUTSIDE NORTH AMERICA SALES
Tony Kingham
tony.kingham@knmmedia.com
Tel: +44 (0) 20 8144 5934

Emmanuel Archambeaud
Fabio Lancellotti
earchambeaud@defcommunication.com
Tel: +33 (0) 1 4730 718

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spacenews@cambeywest.com

AUDIENCE DEVELOPMENT
Heather Arnold
harnold@pocketoutdoormedia.com

Go to **spacenewsmediakit.com** for more information

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SIGNIFICANT DIGITS

$199M

How much Globalstar borrowed with help from its largest shareholder, Thermo, and fleet operator EchoStar. Globalstar says the funds should stabilize its finances through 2025.

$50M

How much telecom satellite operator Intelsat is loaning BlackSky for its geospatial data system. BlackSky said the Intelsat funding will finance its infrastructure and product development.

$3.3B

The potential value of a 10-year IDIQ contract Lockheed Martin received to provide operations and support services for the U.S. Air Force's Advanced Extremely High Frequency, Milstar and Defense Satellite Communications System 3 constellations.

4

The number of Ariane 5 launches Arianespace conducted in 2019. Arianespace has 11 Ariane 5 missions remaining before the rocket is retired and replaced by the Ariane 6.

$250M

The size of the insurance claim China Satcom filed for the loss of ChinaSat-18. The company said the satellite, built by the China Academy of Space Technology, suffered a complete power failure shortly after its August launch.

LEOSAT CLOSES SHOP

Broadband satellite constellation startup LeoSat has suspended operations. Mark Rigolle, CEO of LeoSat, said the company laid off its 13 employees after earlier investors Hispasat and Sky Perfect Jsat declined to put more money into the company in order to complete a $50 million Series A funding round. LeoSat still exists as a legal entity, Rigolle said, and its founders continue to look for new funding, but otherwise the company has effectively ceased operations. LeoSat proposed a constellation of 78 to 108 satellites to provide broadband services and had commitments from potential customers worth up to $2 billion, but could not convince investors to fund the $3 billion constellation.

LONG MARCH BOOSTER CRASHES BACK HOME

A booster from a Chinese launch Nov. 22 hit a rural settlement downrange from the launch site. The Long March 3B lifted off from China's inland Xichang Satellite Launch Center, and placed two Beidou navigation satellites into medium Earth orbits. Video and images on Chinese social media showed a rural building destroyed by the booster, which was venting toxic propellants after falling back to Earth. There were no reports of injuries, and locations in the hazard zone for launches are routinely evacuated ahead of launches. China has been investigating technologies, like grid fins, to pinpoint locations where stages come down in order to minimize damage.

ROCKET LAB LAUNCHES TENTH ELECTRON

Rocket Lab successfully launched several smallsats Dec. 6 on a mission that also tested the ability to recover the Electron's first stage. The Electron lifted off from the company's New Zealand launch site and placed seven smallsats into low Earth orbit. Those satellites include one from a Japanese company intended to create artificial meteor showers and six "PocketQube" satellites for a variety of technology demonstrations. The Electron's first stage was upgraded for this mission with technologies to enable it to make a guided re-entry, and the company said initial results of that test looked promising as the company plans to eventually recover and reuse the stage. The launch was the sixth and final Electron mission of 2019, and tenth overall.

LEOSAT/SAM TOMS-ROCKET LAB

STARSHIP POPS

The first prototype of SpaceX Starship vehicle was damaged during testing Nov. 20. The Starship Mark 1 tanks were being pressurized for a test at SpaceX's Boca Chica, Texas, site when a bulkhead ruptured, causing a plume of material to erupt from the top of the vehicle and tossing part of it into the air. The company said there were no injuries during the incident, and claimed it was "not a serious setback." Company CEO Elon Musk unveiled the Starship Mark 1 at Sept. 28 event, saying that the vehicle would fly to 20 kilometers in the next one or two months. In a statement after the anomaly, SpaceX said the company had already decided not to fly the Mark 1 vehicle, a decision it had not previously disclosed. SpaceX will instead turn its attention to a Mark 3 version under construction.

SATELLITE OPERATORS LOSE BATTLE OVER C-BAND

The chairman of the FCC said Nov. 18 he now backs a public auction of satellite C-band spectrum, a decision that could deprive satellite operators of billions of dollars. In a letter to members of Congress, Ajit Pai said he will seek a public auction of 280 megahertz of C-band spectrum for 5G applications, rather than the private auction that satellite operators, under the C-Band Alliance industry group, had proposed. Some members of Congress had opposed the private auction plan that could net satellite companies up to $60 billion, arguing the money should go to the public. The C-Band Alliance had proposed contributing as much as $24 billion to the U.S. treasury if it was allowed to run a private auction. The C-Band Alliance criticized the FCC's move in a statement, but said it would "continue to work cooperatively with the FCC to develop an effective alternative plan." Eutelsat, a former alliance member, said it is OK with a public auction so long as satellite operator costs are covered when moving out of the spectrum.

THALES ALENIA SPACE TO BUILD NILESAT-301

Thales Alenia Space announced Dec. 4 it will build the Nilesat-301 geostationary communications satellite for Egyptian operator Nilesat for launch in the first quarter of 2022. The four-ton satellite will operate at 7 degrees west in GEO, working with the existing Nilesat-201 satellite to provide Ku-band services for the Middle East and North Africa. NileSat-301 brings to 15 the number of GEO and GEO-type satellites ordered this year when counting commercial orders, WGS-11, Italy's Ital-GovSatCom and dual-purpose satellite orders from Space Norway and Hisdesat.

BLUE ORIGIN'S PARTIAL VICTORY

The U.S. Air Force will soon release a revised launch services procurement that addresses issues raised by the Government Accountability Office. Col. Robert Bongiovi, director of the Air Force Space and Missile Systems Center's launch enterprise, said an amendment to the National Security Space Launch Phase 2 request for proposals will be released soon, but didn't give a specific date. Companies that previously submitted bids will get to revise their proposals, and the Air Force still plans to award contracts sometime between April and June. The changes to the RFP stem from a GAO ruling last month on a protest by Blue Origin, who objected to the evaluation criteria laid out in the request for proposals. The GAO upheld that part of Blue Origin's protest, but disagreed with the company's argument that the Air Force should be required to select more than two launch providers.

BLUE ORIGIN/SPACENEWS-CALEB HENRY/THALES ALENIA SPACE/@SPACEPADREISLE

NASA Deputy Administrator Jim Morhard, center, is seen with Rep. Ed Perlmutter (D-Colo.), left, and Rep. Haley Stevens (D-Mich.), as they watch the start of the first all-woman spacewalk Oct. 18 from NASA Headquarters.

NASA/JOEL KOWSKY

Lunar logistics, terrestrial tactics

NASA's path to the moon leads through Congress. Good thing NASA's No. 2 knows his way around Capitol Hill.

Jim Morhard may be a newcomer to space, but not to astronauts. The NASA deputy administrator often tells the story of how, as a six-year-old in Arlington, Virginia, he and his older brother knocked on the door of a famous neighbor. "He let us pet his cat, gave us a drink of water, and my brother got his autograph," he recalled in a recent speech. "That was the first time that I met John Glenn."

It's been a little more than a year since Morhard, a longtime Senate appropriations staffer, was sworn in as the agency's 14th deputy administrator. In recent months, he's taken on a bigger public profile, with more speeches and presentations and even a Twitter account, highlighting NASA's Artemis program to return humans to the moon as a precursor for even more ambitious exploration efforts.

"The primary goal of Artemis is a Mars concept of operations," he said in a Dec. 3 speech at the U.S. Chamber of Commerce's "Launch: The Space Economy" conference in Washington, tying the agency's push to return to the moon with long-term ambitions for human missions to Mars. "We need to safely land humans on the moon, land hardware there, establish a presence and then keep going. It could be the moon will be the jumping off point for much more than Mars."

Immediately after that speech, Morhard sat down with *SpaceNews* Senior Staff Writer Jeff Foust to talk about exploration, NASA's prospects for getting funding to enable those exploration plans, and his first year on the job at NASA.

One thing that was clear from your speech is tying in the moon as a step toward Mars. How has your thinking evolved on this, since earlier this year the emphasis was much more on the moon alone?

What we're doing is really a great preparation to go to Mars and beyond. The moon is critical for anywhere we go beyond. I was on the defense appropriations committee years ago, right after the first Iraq War. Norman Schwarzkopf came to us and he said, "You know, I wasn't worried about the warfighter. I >

< > was worried about the logistics tail. Could I get power, electricity, food, trucks, everything I needed to the warfighter?" It's this logistics tail that's going to be the great challenge, and we're going to have to focus on that as much as the technology.

How does that fit into the sprint to the moon by 2024 that the White House has directed?

That's part of the logistics tail to do that. We've got, using CLPS [Commercial Lunar Payload Services], the hope of having unmanned missions that provide that logistics tail up to the moon. So we should have everything in place to get there by 2024.

We're excited about Doug Loverro coming on board yesterday. Doug comes in wearing a pin, and it's got how many days are left before Dec. 31, 2024. It's to remind people we are focused on 2024 along with safety, cost and schedule.

How do you balance that urgency, that countdown that Loverro is literally wearing on his lapel, with safety concerns about going too fast?

Safety is paramount. I think it helps when you've got as administrator a fighter pilot that did hundreds of carrier landings and you've got a deputy who was in a plane crash. I think that gives a different view of how important safety is. We both have our own experiences with it. We had a meeting a few weeks ago down at Kennedy, and I said, "Look guys, if any of you have any issues on safety, come to me."

Another factor in all this, leveraging your experience in appropriations, is getting sufficient funding this year and beyond. What's your take as we approach the end of the current continuing resolution Dec. 20 and the prospects for getting a final appropriations bill?

Morhard, a former Senate staffer, survived the 2010 plane crash that killed Sen. Ted Stevens of Alaska and four others. Former NASA administrator Sean O'Keefe, another former Stevens' staffer, was also on board.

Anybody who says they know how it's going to end doesn't. I remember going into leadership meetings with Sen. Ted Stevens, when Bill Frist was the majority leader, and each week he'd say, "We've got a plan." Well, it was a different plan from the week before. I'm not saying that's happening today, only that it can be so fluid.

We could have another CR [continuing resolution]. We could have a deal by Dec. 20. Yes, we could have a shutdown. There's no way we can predict, so our job is to be prepared for every eventuality. Jim [Bridenstine] and I got firsthand knowledge of what a shutdown is like. That's the last thing that we want to have happen, but it's up to us to be prepared for it. But we're also preparing for a short-term CR, a yearlong CR and a full appropriation.

Do you get any sense of the momentum, one way or another, regarding how the $1.6 billion in additional funding for Artemis is faring in Congress?

There's no way they're going to show us anything right now, because that leads to further lobbying. I can't read the tea leaves, but I'm confident they'll make the right decisions. We've got to make sure that we continue to fund the science programs in a way that is satisfactory to the constituencies that are out there, as well as our charge for human exploration. And we're going to keep doing that.

You've been on the job at NASA for a little more than a year now. It's a big change from the world of appropriations. How has the experience been like?

It was a big change. I really tried to keep my mouth shut for the first four to six months. There's an organizational structure and then there's an unwritten organizational structure and I needed to learn both. This is about relationships, and I've done everything I can to try to forge those relationships. They are, as you know, just great people at NASA. So, it's been enjoyable, and it's just gets better and better each day.

Yes, we are always going to have challenges. But working together with people that really are at a level that they are is my honor. SN

NASA/JOEL KOWSKY

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Air Force rolls out red carpet, credit card to attract small business

Many small companies are wary of government work. Executives have heard stories of red tape and slow payments. David Shahady, who directs the Air Force Small Business Innovation Research (SBIR) and Small Business Technology Transfer programs, is intent on changing those perceptions.

Since Shahady moved into his job in late 2015, he has been looking for ways to make it easier for innovative small companies to work with the U.S. Air Force. That effort got a shot in the arm in 2018 when Will Roper became Air Force assistant secretary for acquisition, technology and logistics. Roper, who says he wants to turn the Air Force into "a 21st century tech investor," is working with Shahady to revamp the SBIR program.

The two men were in San Francisco in November for Air Force Space Pitch Day where 30 companies received a total of $22.5 million in SBIR funding. At the event, Lt. Gen. John "JT" Thompson, Air Force Space and Missile Systems Center (SMC) commander, Roper and Shahady repeatedly emphasized the Air Force's efforts to knock down legal, contracting and financial barriers to working with innovative small businesses.

Shahady spoke with *SpaceNews* about Air Force Space Pitch Day and about the Air Force's SBIR program.

DEBRA WERNER

How much money does the Air Force have for SBIR?

Every government program has a research, development, test and evaluation line. A portion of that is set aside by law as part of this SBIR program. For the Air Force, it is almost $800 million in 2019. Organization with venture capital budgets of over $500 million are in the top tier of venture capital. I don't think people look at the Air Force as a venture capital entity. I want to see us break that barrier where the industry sees us as a true innovation and venture partner.

Most venture partners claim a share of a company's equity.

We're a tremendous deal. We are a wonderful organization to work with because we don't want equity. Our mission is to build the U.S. economy's industrial base to support the military.

What is different about SBIR phase one, two and three?

It's relatively simple. Phase one is a small amount of money, anywhere from $50,000 up to $150,000. It's about developing a concept or idea. In some cases, we pay companies to do customer discovery.

A lot of companies at Space Pitch Day said they got $50,000 phase one SBIR awards for customer discovery.

That's a model that we're looking at. Do I want the companies to spend their own dollars figuring out if it's good to do business with the Air Force? I can upfront that cost and have that company go around and talk to customers and find the right

U.S. AIR FORCE PHOTO BY SENIOR AIRMAN CHRISTIAN CONRAD

LEFT: Lt. Gen. John "JT" Thompson, Space and Missile System Center commander, speaks Nov. 5 at U.S. Air Force Space Pitch Day in San Francisco. ABOVE: Air Force Assistant Secretary Will Roper, right, and Capt. Ashley Feldman process a $750,000 credit card payment to a grant recipient during Pitch Day.

U.S. AIR FORCE PHOTO BY SENIOR AIRMAN CHRISTIAN CONRAD/DOD PHOTO

David Shahady, director of Air Force SBIR and Small Business Technology Transfer programs

"We're depositing $50,000 off a credit card in their bank account right here, today."

fit for them in the Air Force as opposed to them having to do that on their own dime.

Phase two is where you develop a prototype, do a demonstration and you show your applicability. We're allowed to do several phase two awards. Awards can be as much as $3 million on a phase two. Phase three is basically graduation from the [SBIR] program because somebody other than the SBIR program is investing.

Is that similar to the way Defense Advanced Research Projects Agency programs continue by transitioning to a military customer?

Yes. That's a great example. The neat thing about the SBIR law is that it's not service-specific or organization-specific. If you have an SBIR contract with any organization within the government, anybody else can capitalize on what you have been doing.

Some of the companies here told me that they were invited but they couldn't pitch because they had NASA SBIR funding not Air Force SBIR funding.

Every center, every organization sets the parameters on how they want to manage SBIR. When I took over, SBIR was very centralized with a lot of Air Force policies. I read through those and I read through the law and I decided that we were interpreting all of that wrong. I got rid of all of our Air Force policies and I tied it straight to what we were allowed to do legally. I gave that power back to all the commanders and the center leads so that they could best use this tool for them, making them the true owner in the process.

What's really special about what General Thompson is doing here is that he's bringing some of his own dollars to these programs. Companies are going from SBIR phase one, which is a concept, all the way to phase three almost in one fell swoop because we're awarding the phase two here and the General is picking some of them and putting some [SMC] dollars on those.

When people get $1.5 million or $3 million at Space Pitch Day are those SBIR phase 3 awards?

Yes. That's a really exciting proposition for me because traditionally it could take as long as five to seven years to see a program get to maturity where other people were investing in it. We got that time down to two to three years. But this is less than 12 months from somebody coming in with a proposal to somebody in the formal Air Force saying, "This is indeed something that we want to have as part of our programs of record." That's a tremendous, powerful message.

If they get $3 million today, does it mean they're going to be part of a program of record?

Well, it means they're on the road. Anytime you have somebody else investing, putting their skin in the game, they have a vested interest in seeing that program be a success.

How is the SBIR program changing?

The financial and the contracting community have knocked down lots of barriers, everything from shortened contracts to paying with a government credit card to giving people their initial money upfront. For the companies getting awards, we're depositing $50,000 off a credit card in their bank account right here, today. That doesn't sound like much, but to a small company their funding stream is their lifeblood. In the past, companies that won SBIR awards would take out business loans because they felt like it would be six to nine months >

< > before they got their first payment. If they can win an award and get paid immediately, there isn't the need to take that risk. They're now working on our dime instead of their own, which is the proposition that we want to see.

In the past, some small firms continuously worked on SBIR programs.

There was obviously a trend that had happened within SBIR. There were companies that did one SBIR after another and made a business out of that. I don't want that to be our model because the intention is to help them become a more mature part of the business community and the economy. We do a lot of things to help a company build a business plan. Many companies get so technology-focused that they don't spend any time thinking about their business and how they're going to make their business grow. It's easy to be satisfied that I got some small business money and I'd like to go back and get more small business money. But that's not teaching them how to fish. That's giving them a fish for the day.

Our intention is to make them a viable part of the economy. Let's make it so that the large prime contractors that are doing space assets or cyber assets or whatever see that small business as a great supplier. Or, maybe they're a great supplier directly to the military. I don't want them necessarily eating our seed corn for the rest of their business's life. I want them to become a mature business. It's OK for them to want to make money. They should be looking to make money. They should be looking to hire more people. I joke all the time [with entrepreneurs] that I'm looking forward to driving by their big houses and then going to my little house to eat ramen noodles. I'm OK with that. A lot of times we give small businesses the feeling that we don't want them to succeed as a company, but that's not the case. We want them to succeed.

Will Roper seems very enthusiastic about the SBIR program.

It's been great working with him. He's been such a tremendous advocate of the program. When he realized he had this pot of (SBIR) money, he asked, "Who runs that?" The next thing you know, we brainstormed about a lot of different things. He's in the position where he could give us the top-level support. All of a sudden, I found myself with almost an unlimited ability to make changes.

Will Roper, assistant secretary of the Air Force for acquisitions, technology and logistics, left, and Air Force Secretary Barbara Barrett, right, meet with small business partners Nov. 5 during Air Force Space Pitch Day.

Within the restrictions of the law?

That law has got a lot of room. If you embrace the spirit of these laws and see why Congress put these laws in place, it becomes really easy to do the right thing.

People at Space Pitch Day have been talking about co-investing or matching funds is that part of SBIR phase 3?

Yes. That's our way of us saying, "I'll put some of our money up, but I'd like to see that somebody else is also putting their money up." It's the model of, "Sure, we'll give you money for an associate degree. We'd like to partially fund a bachelor's degree. But I expect by the time you're getting a master's or a Ph.D. that somebody else is going to be footing the bill."

The idea of getting people to match funding earlier shows that somebody has an interest. People are more than willing to have you invest money if you're the only one taking the risk. But if they are investing also, there's a tendency for them to draw on it. That's why I mentioned the programs of record. If they're putting some of their money in, they're more incentivized to help that company succeed or to give it the attention that it needs to see if it's successful.

Could the matching funding come from commercial firms, military organizations?

Anywhere. I don't think we want to put any restrictions on a company. The more flexibility we give them, the better. If they can find it from the Air Force, that's ideal. If they can find outside money from state and local governments, other services, venture capital investors, large primes or even commercial sales, those are all great propositions because all of those things build up the industrial base. That's a huge part of competing in a global market.

If we give people better opportunities than maybe there's not a need to go to other outside suppliers. I am afraid of a time when as the Air Force I have to fight to get a small business to decide whether to work with us or whether to work with one of the folks that is not necessarily aligned with us. I want people to think the Air Force is great to work with, not that they can't get a fair shake with us, that they can't get traction with us. SN

(U.S. AIR FORCE PHOTO BY SENIOR AIRMAN CHRISTIAN CONRAD

★★★

SpaceNews established these awards three years ago to honor the well-known champions and the unsung heroes shaping the global space industry for the better. Some of this year's winners are preparing humanity's return to the moon. Others are helping us take full advantage of Earth orbit.

The **SpaceNews Award** winners profiled in the pages ahead were chosen by the *SpaceNews* editorial team following an open call for nominations in a September, an online reader poll in October and internal deliberations in November. The **Readers' Choice Award** winners listed on page 23 were the top vote-getters in the online poll. Five of these reader favorites were also chosen by the editorial team to receive the SpaceNews Award.

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COMPANY OF THE YEAR

ROCKET LAB

★★★

One of the more remarkable stories in the space industry in recent years is the wave of companies working on small launch vehicles. By some estimates, more than 100 such vehicles are in development, ranging from those actively being built and tested to ones that have yet to move beyond PowerPoint presentations. Either way, it's far more than even the most optimistic estimates of demand for launching small satellites.

One company, though, has emerged as the clear leader in the market. Rocket Lab moved into regular operations of its Electron rocket in 2019, performing six launches, all successful. While other companies continued to work on their small launchers, or suffered technical or financial setbacks, Rocket Lab launched small satellites for customers ranging from Earth-imaging company BlackSky to DARPA and the U.S. Air Force.

The year also signaled growing ambitions for Rocket Lab. It announced plans in April to develop a satellite bus called Photon, based on the Electron's kick stage, for missions in Earth orbit or all the way to the moon. Rocket Lab also announced a partnership with KSAT to give its customers access to that company's network of ground stations. Combined, it's intended to provide one-stop shopping for customers planning space systems, and sets the company apart from competitors that focus only on launch services.

Rocket Lab is also investing in reusability. In its latest launch Dec. 6, Rocket Lab tested upgrades to the Electron's first stage to control the stage through re-entry, a key step toward ultimately recovering and reusing the stage. That effort is driven by a desire to sharply increase its launch rate in the future without having to scale up its manufacturing capability by the same amount.

While it may be some time before the company reaches its goal of one launch a week enabled by reusability and other manufacturing innovations, the company expects to launch more frequently in 2020. It will also start operations from a second launch site, at Wallops Island, Virginia, early in the year, and begin flying Photon satellites. The company expects to hire more than 100 people over the next year at its facilities in the United States and New Zealand.

ROCKET LAB

Rocket Lab likely will see more competition in the next year as other small launch vehicle companies enter service. The company, though, has established that there is demand for dedicated small launch services and put itself in a position to lead, and even dominate, the market for years to come. SN

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

STARTUP OF THE YEAR

HAWKEYE 360

★★★

When HawkEye 360 was founded in 2015, it wasn't clear whether a cluster of microsatellites could detect radio-frequency signals emanating from ships and planes to pinpoint their precise locations. But Chris DeMay was optimistic.

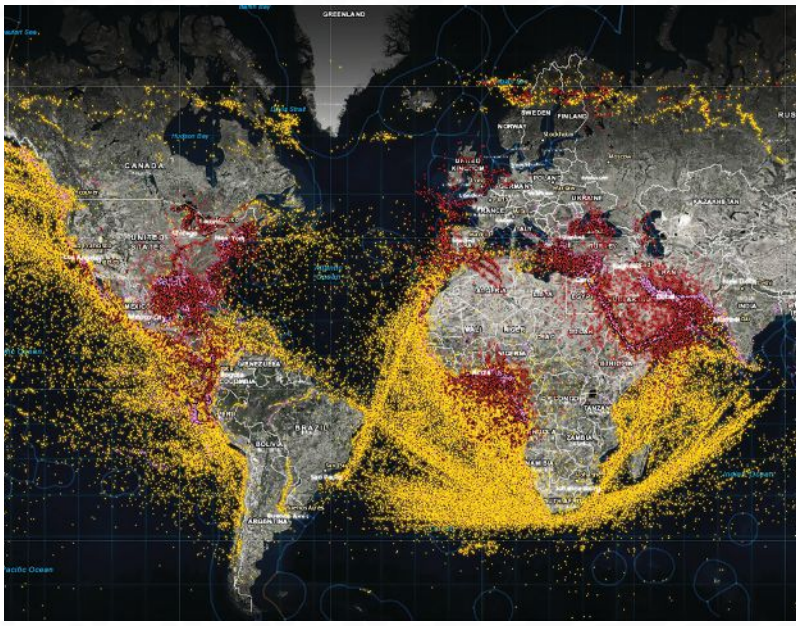
After 14 years working in U.S. defense and intelligence agencies, DeMay saw startups capturing optical imagery with small satellites and thought miniature spacecraft could employ similar technology to home in on RF signals. To find out, DeMay teamed up with software, signal processing and analytics experts, and John Serafini, a technology investor and startup leader who became HawkEye 360's CEO.

Earlier this year, the Herndon, Virginia, startup announced the results on Twitter. HawkEye 360's three Pathfinder satellites launched in December 2018 were "successfully geolocating a diverse variety of RF signals!" according to the Feb. 26 tweet.

The Pathfinder satellites, built by the University of Toronto Institute for Aerospace Studies (UTIAS) Space Flight Laboratory and equipped with software-defined radios, fly in formation 100 to 200 kilometers apart. When all three satellites tune into the same signal, the firm's algorithms identify the type of RF emitter and its location.

After announcing that its Pathfinder constellation worked as intended, HawkEye 360 began unveiling products for its intended audience: defense and intelligence agencies, maritime organizations, telecommunications providers and emergency responders. RFGeo, for example, is a product the company unveiled in April to help customers identify and geolocate maritime VHF radio channels, marine emergency distress beacons and vessel Automatic Identification System signals. In October, HawkEye 360 released an updated version of RFGeo to detect UHF band communications, including push-to-talk radios often used by cross-border smugglers and poachers in nature preserves.

In recent months, HawkEye 360 has stepped up fundraising. Its $70 million Series B round announced in August attracted venture capital firms as well as Airbus Defence and Space and ESRI, the geographic information system software giant. Raytheon Corp. led the startup's $14.9 million Series A-3 round in 2018. Overall, HawkEye 360 has raised more than $100.



HAWKEYE 360

With money in the bank, HawkEye 360 is turning its attention to expanding its constellation. The startup plans to operate six clusters of three satellites each to provide frequent daily observations of RF activity. The Series B round provides the company with enough money to build and launch its next five satellite clusters, Serafini said in a recent interview. HawkEye 360 is preparing to launch its next three-satellite cluster early next year. UTIAS Space Flight Laboratory is on contract to manufacture the next 15 satellites in the HawkEye 360 constellation. **SN**

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

BREAKTHROUGH OF THE YEAR

STARLINK

★★★

SPACEX

Anyway you slice it, the world's leading launch provider can now claim the world's largest satellite telecom constellation. SpaceX, which conducted a record 21 launches in 2018, took just two launches to deploy 120 of its Starlink broadband satellites into low Earth orbit this year.

Although SpaceX aims to deploy at least 12,000 Starlink satellites by the mid-2020s in a bid to blanket the globe with abundant, low-latency satellite broadband, SpaceX founder Elon Musk says the first 120 satellites alone can deliver a combined 2,000 gigabits per second of useful network capacity. That makes SpaceX's fledgling Starlink constellation nearly eight times more powerful than ViaSat-2, the highest capacity satellite broadband system currently in service.

And while traditional operators have next-generation geostationary satellites in development for 2021 promising 1,000 Gbps of throughput, SpaceX stands to add an equivalent amount of useful capacity to its Starlink constellation each time a Falcon 9 launches another 60-satellite batch into low Earth orbit. With two dozen such launches on the books for 2020, SpaceX is poised to rapidly expand Starlink's lead in on-orbit capacity and download speeds.

Starlink satellites have already shown they can deliver 610 megabits per second of secure connectivity to U.S. military aircraft, making Starlink's demonstrated in-flight downloads six times faster than the average U.S. internet connection and 25 times faster than the FCC's 25 Mbps threshold for services advertised as broadband.

Starlink is just several launches away from achieving sufficient coverage to roll out regional service. However, SpaceX has yet to announce customers or unveil affordable user terminals. Although LEO megaconstellations like Starlink won't suffer the same signal lag and slower speeds that tend to make GEO broadband a last-resort solution, they need a lot more satellites to provide continuous service over comparable coverage areas. That, in turn, creates a bevy of problems, including the need for more sophisticated user terminals than the relatively cheap set-and-forget dishes that work with geostationary satellites.

Like all breakthroughs, Starlink comes with its share of challenges. In September, the European Space Agency was given a scare when a deliberately deorbiting Starlink with its collision avoidance system turned off was due to pass uncomfortably close to ESA's Aeolus satellite. Unable to reach SpaceX, ESA decided to maneuver Aeolus and then tweeted its dismay. SpaceX has said it will tighten protocols for coordination with other operators.

SpaceX has also vowed to make Starlink less reflective, a pledge meant to address astronomers' concerns that telescope observations could be disrupted by the unprecedented number of satellites soon to be transiting the night sky.

It remains to be seen whether Starlink can achieve commercial success without proving a nuisance. But with just a tiny fraction of its constellation on orbit, SpaceX has again shown its knack for disrupting markets and putting the competition on notice. SN

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

GOVERNMENT AGENCY OF THE YEAR

NASA

★★★

At the beginning of this year, NASA was moving ahead with plans to return humans to the moon by 2028 in a methodical, deliberate way. It was in discussions with international partners on providing modules for the lunar Gateway that, once complete, would serve as a base camp for those lunar landings. In early February, NASA solicited proposals for lunar lander studies. Those proposals were due to NASA March 25.

The next day, everything changed. In a speech at a National Space Council meeting in Huntsville, Alabama, Vice President Mike Pence instructed NASA to accelerate its human return to the moon, landing within the next five years. Pence cited potential competition from China as one reason for speeding up those plans, as well as "racing against our worst enemy: complacency."

There's certainly no complacency at NASA now. Since Pence's speech, NASA has done a remarkable job revamping its lunar exploration plans, now known as the Artemis program, to support a 2024 landing. It accelerated work on a lunar lander while deferring much of the work on the lunar Gateway to after 2024. "At the end of the day we're going in 2024, whatever that takes," NASA Administrator Jim Bridenstine said not long after the speech.

That includes a strong reliance on commercial partnerships rather than conventional contracting. NASA plans to acquire logistics for the Gateway using the same commercial cargo model that supplies the ISS. A more ambitious step is to use such partnerships for human lunar lander development, ultimately buying landing services from companies, rather than the landers themselves.

NASA is doing all that while carrying out a full plate of other programs, like operation of the ISS, development of commercial crew, and major science missions such as the James Webb Space Telescope and Mars 2020 rover, all with their own sets of issues. Bridenstine has said on many occasions that he won't "cannibalize" other parts of the agency to pay for Artemis.

NASA/JOEL KOWSKY

NASA still faces technical and, perhaps more importantly, financial challenges to achieving that 2024 goal. Congress has yet to pass a 2020 spending bill, and House members in particular have been skeptical about the proposed $1.6 billion in additional funding requested to jump-start Artemis in part because the agency hasn't yet provided an estimate of what the overall program will cost. But it's clear that there is a new focus and urgency at NASA on returning to the moon not seen in many years. SN

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

GOVERNMENT LEADER OF THE YEAR (CIVIL)

JAN WOERNER

★★★

At a news conference Nov. 28 to mark the end of the European Space Agency's ministerial meeting in Seville, Spain, Jan Woerner, director general of the agency, smiled. "You have a happy DG in front of you," he said.

He had every reason to be happy. At the briefing, Woerner announced that ESA's 22 member states had agreed to provide 12.45 billion euros ($13.8 billion) in funding for the next three years, just shy of the 12.5 billion euros the agency requested. Every major program that ESA proposed was funded, including some that received even more money than the agency asked for.

That two-day ministerial meeting, called Space 19+, marked the end of a two-year effort by Woerner to secure the agency's future that started not long after the previous ministerial meeting in late 2019. "We started with a narrative, to have a clear picture of what ESA is doing," he said in an October interview. "That was very important from my point of view."

That narrative took the form of four "pillars" to describe all of ESA's activities: science and exploration, applications, enabling and support, and space safety. ESA also lumped programs into three categories of rationales: competitiveness, inspiration and responsibility. For months leading up to the Space19+ meeting, Woerner took every opportunity to emphasize those pillars and those rationales as key to the agency's, and Europe's, future in space.

That concerted effort paid off. Member states provided funding to ensure ESA will have a role in NASA's Artemis program beyond the Orion service module by funding initial work on two modules for the lunar Gateway and a large robotic lunar lander. Plans to cooperate with NASA on Mars sample return also won funding,

ESA VIA FLICKR

as did Hera, a near Earth asteroid mission that emerged from the ashes of the Asteroid Intercept Mission, which failed to win funding at the 2016 ministerial.

The meeting wasn't perfect — ESA's space safety pillar got less money than requested, forcing the agency to scale back a space weather mission to an instrument development program — but Woerner played down that setback. "We intended to get more, but this is life," he said. "It's not a disaster, not at all."

ESA now has to go carry out those ambitious plans, which brings with it a whole new set of challenges. Woerner, though, was able to secure the funding to make those projects possible, which is something the whole European space community can be happy about. **SN**

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SPACENEWS

GOVERNMENT LEADER OF THE YEAR (MILITARY)

U.S. AIR FORCE GEN. JOHN "JAY" RAYMOND

★★★

"This is absolutely the most exciting time to be in the national security space enterprise," Gen. John W. "Jay" Raymond is fond of saying, whether speaking to space industry CEOs, lawmakers or military troops.

Raymond, the four-star commander of U.S. Space Command and U.S. Air Force Space Command, impresses audiences with his passion and enthusiasm. It came as no surprise when President Trump in March nominated Raymond to lead U.S. SPACECOM, the newest of the Defense Department's 11 unified commands..

For Raymond, this was a capstone achievement after 35 years serving in national security space operations at every level. By Raymond's own account, planning for the unified command started in August 2018 when he was informed by the Pentagon that U.S. SPACECOM, which was absorbed into U.S. Strategic Command in 2002, would be reactivated. Once he got word, Raymond hunkered down with a small team to quickly formulate how U.S. SPACECOM would be organized. Raymond told a Washington audience in November that building a new command and then getting asked to lead it has been the highlight of his career.

Raymond's imprint is evident in how U.S. SPACECOM was organized to accomplish two key missions: provide space-based capabilities to U.S. and allied commanders in the field, and ensure that those capabilities are defended against electronic or physical attacks.

One of U.S. SPACECOM's components is a new organization that Raymond advocated for: the Joint Task Force Space Defense, which gives the U.S. military for the first time an operations-level command focused on protecting space assets. It was also at Raymond's urging that the military and the intelligence community agreed to work more closely on space matters. Should a military conflict extend to space, the National Reconnaissance Office will take direction from the commander of U.S. SPACECOM.

The military's space operators could not ask for a more steadfast advocate. Raymond has been a strong backer of the Trump administration's Space Force proposal. If Congress gives the OK, a separate military service dedicated to space would absorb Air Force Space Command, freeing up Raymond to focus on his combatant commander duties.

No matter what happens next in the space reorganization, Raymond will be a leading voice on all matters related to national security space. And he will be speaking for all space operators across all branches of the military. As he put it recently: "If you're wearing a space patch today and you're in the United States Air Force, Army or Navy, you have an extra bounce in your step." SN

U.S. AIR FORCE

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

CORPORATE LEADER OF THE YEAR

DAN JABLONSKY

KEITH JOHNSON FOR SPACENEWS

In his brief tenure at Maxar Technologies, Dan Jablonsky has navigated through rough water. The former naval surface warfare officer and nuclear engineer took Maxar's helm Jan. 13, six days after the company announced the failure of its WorldView-4 Earth-imaging satellite. At the time, Maxar leaders were publicly discussing whether to sell, shutter or scale back the firm's West Coast satellite manufacturing facility amid a global slump in geostationary spacecraft orders.

Jablonsky, who spent nearly eight years at DigitalGlobe rising to the rank of president, led a thorough evaluation of Maxar's structure and business components. In the end, the company opted to retain the satellite manufacturing business with a smaller workforce and to turn Maxar into a single operating company except for MDA of Canada, which remains vertically integrated. Maxar also worked to expand sales to U.S. and allied government agencies and to focus its resources on WorldView Legion, the Earth imagery constellation designed to double the company's capacity to collect satellite imagery with 30-centimeter resolution.

Maxar's effort to attract more government work seems to be paying off. In May, NASA Administrator Jim Bridenstine announced Maxar would develop the Power and Propulsion Element for the space agency's lunar Gateway under a $375 million firm fixed-price contract. Maxar's Power and Propulsion Element, designed to provide electrical power for the Gateway and move it through cislunar space using solar electric propulsion, is based on the firm's 1300-series flagship satellite platform.

The National Reconnaissance Office (NRO) announced in June the award of a study contract of undisclosed value to Maxar as part of the intelligence agency's effort to assess U.S. companies' abilities to task, collect, process and deliver satellite imagery. Maxar already supplies NRO with priority access to imagery from WorldView satellites and the company's digital archive under the $300 million a year EnhancedView Follow-On contract. Through the study contract, NRO is exploring whether U.S. defense and intelligence agencies should buy additional Maxar products and services.

Maxar won another government contract in July when NASA awarded the firm $79 million to send a pollution sensor into orbit as a hosted payload on a Maxar-built commercial communications satellite. Then in November, Maxar announced a commercial sale. An undisclosed customer ordered a geostationary communications satellite.

Improved sales are helping Maxar's financial situation. In the third quarter of 2018, the firm reported a loss of $289 million. In the third quarter of 2019, Maxar, under Jablonsky's leadership, reined that in to a net loss of $26 million.

It's too soon to say whether calm seas are ahead for Jablonsky. Two of Maxar's key markets, Earth observation and satellite communications, are changing rapidly. Rather than expressing concern, Jablonsky embraces the challenge.

"Ships are built to go to sea, and I'm built for an environment that is not completely safe and inside the harbor," he said in an interview earlier this year. SN

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

TURNAROUND OF THE YEAR

FIREFLY AEROSPACE

★★★

A Firefly technician integrates a Reaver engine with the Alpha rocket's first stage qualification unit.

Three years ago, things were looking dire for Firefly Space Systems. After an unnamed investor backed out of a new funding round, the company furloughed nearly its entire staff of 150 people, halting developing of its Alpha small launch vehicle. The company was on a path to bankruptcy and liquidation.

But in business, there can be life after death. One of Firefly's creditors, Noosphere Ventures, acquired the company's assets in an auction in 2017. Noosphere reconstituted the company, bringing back many of the original employees, including chief executive Thomas Markusic, under the name Firefly Aerospace.

Today, Firefly is closer than ever to realizing its original vision of a low-cost small launcher. At a site outside of Austin, Texas, the company is performing static-fire tests of the two stages of the Alpha launch vehicle, capable of placing up to a ton of payload into low Earth orbit for $15 million. Firefly is modifying a launch pad at Vandenberg Air Force Base formerly used by the venerable Delta 2 for Alpha, with a first launch now expected in the first quarter of 2020.

The company's projects, though, don't stop with Alpha. On the drawing board is Beta, a medium-class launch vehicle with a payload capacity of eight tons to LEO. In October, Firefly announced a partnership with Aerojet Rocketdyne that includes studying the use of Aerojet's AR1 engine to power the first stage of Beta. That agreement covers the use of other Aerojet technologies, such as in-space propulsion systems for an orbital transfer vehicle Firefly is also proposing to develop.

The company's ambitions extend to the moon. Firefly was one of nine companies that won a Commercial Lunar Payload Services contract from NASA last year, allowing it to compete to deliver NASA payloads to the lunar surface. In July, Firefly said it was partnering with Israel Aerospace Industries (IAI) to develop a lander, called Genesis. It will be based on the Beresheet lander IAI built for SpaceIL that attempted a landing in April.

Firefly is on a secure financial footing, as Max Polyakov, the founder of Noosphere Ventures, has committed to funding the company through the first Alpha launch, an amount neither he nor the company has disclosed. That doesn't guarantee success, particularly in the crowded small launch vehicle market, but does give Firefly a fighting chance — or, in this case, a second chance. SN

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

DEAL OF THE YEAR

VIRGIN GALACTIC IPO

★★★

Over the last several years, billions of dollars of private investment have flowed into the space industry, from massive funding rounds by OneWeb and SpaceX to small early-stage rounds for a wide range of small launch vehicle, smallsat and other space startups. The problem is judging how lucrative those investments are: there have been few major exits, in the form of acquisitions or public offerings, that have allowed investors to get a return on their money.

That environment is what makes Virgin Galactic's decision this year to go public so important. The suborbital spaceflight company is among the best known in the entrepreneurial space field thanks to its famous founder, Richard Branson, and its space tourism ambitions. However, development of its SpaceShipTwo vehicle had taken far longer than envisioned, and the company needed additional capital to get it into service.

In July, Virgin Galactic announced it would go public, but do so in a nontraditional way. Virgin said it would merge with Social Capital Hedosophia (SCH), a special purpose acquisition company that was already publicly traded on the New York Stock Exchange. That approach, Virgin executives argued, was faster and more efficient than a traditional initial public offering (IPO) of stock. (SCH traded on the exchange under the ticker symbol IPOA, for "IPO Alternative.")

The deal raised more than $700 million for Virgin Galactic, of which about $300 million went to buy out some existing shareholders. The rest will be used to fund operations of Virgin Galactic, which the company says will be enough to move into operations by the middle of next year, after completing a final series of tests of SpaceShipTwo. If all goes as planned, the company will be profitable as soon as 2021.

The merger closed in October, and Virgin Galactic started trading Oct. 28 under the new ticker symbol SPCE. It's been a rough start: the company lost about a third of its value in its first month, but has more recently stabilized. Virgin executives, though, say they're focused not on the short-term trends in the stock's price but rather its long-term ambitions for suborbital space tourism and, eventually, point-to-point travel.

If Virgin Galactic successfully transitions into a profitable company, it may encourage other space startups to pursue IPOs of their own, traditional or otherwise, in the near future. The investors that are putting billions into those companies will want to eventually get their money back, and then some. SN

VIRGIN GALACTIC

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

UNSUNG HERO OF THE YEAR

BROOKE OWENS FELLOWSHIP

★★★

Cassie Lee, Lori Garver and Will Pomerantz were heartbroken when their 35-year-old friend Dawn Brooke Owens died of cancer in June 2016. Looking for a way to honor Owens, Lee, who led space programs at Vulcan, Garver, the former general manager of the Airline Pilots Association and former NASA deputy administrator, and Pomerantz, Virgin Galactic special projects vice president, established the Brooke Owens Fellowship.

To date, the Owens Fellowship has paired 114 young women with paid summer internships and year-long mentorships. Through the extensive and competitive application process, Owens Fellowship leaders identify undergraduate women and gender minorities passionate about aviation and space exploration.

Rather than simply focusing on grades and test scores, they look for women with wide-ranging talents like Owens, a certified pilot who attended Embry-Riddle Aeronautical University and the International Space University, and worked at NASA, the White House, the FAA and the nonprofit X Prize Foundation. Outside of work, Owens performed slam poetry, raced triathlons and volunteered in Africa with children whose parents died of HIV/AIDS. In addition to submitting an essay highlighting their professional interests, Owens Fellowship applicants share a poem, song, dance or other creative composition about their character and personal interests.

Once selected, Owens Fellows, known as Brookies, are matched with internships at organizations like Ball Aerospace, Blue Origin, Boeing, Lockheed Martin, Northrop Grumman, Scaled Composites, SpaceX and ULA. They also are paired with mentors who offer advice on their internships and aerospace careers. Every July, the current Owens Fellowship class travels to Washington to meet one another, work together to solve a grand challenge and speak with congresswomen, astronauts, CEOS and entrepreneurs.

COURTESY BROOKE OWENS FELLOWSHIP

In the three years since Lee, Garver and Pomerantz created the Owens Fellowship, its reputation has grown dramatically. In 2019, 566 women from 15 countries applied.

"By the numbers, it will be harder to get into the Owens Fellowship class of 2020 than it was to get into, say, Caltech, MIT, or Naval Academy 2020," Pomerantz Tweeted Nov. 24. "Our number of applications significantly more than doubled our previous high."

It will take years to gauge the Owens Fellowship's impact on the demographics of the male-dominated aerospace industry. For individual Brookies, though, the benefits are enormous. In a single year, they gain invaluable experience and connections. Judging by the waiting list of more than 40 companies and nonprofits eager to hire Owens Fellows, aerospace leaders see the attraction too. SN

THE SPACENEWS AWARDS FOR EXCELLENCE & INNOVATION 2019

SPACENEWS

SPACE STEWARDSHIP AWARD

LEOLABS

★★★

Dozens of startups are sending small satellites into low Earth orbit. One is revealing the increased congestion there. When LeoLabs spun out of the nonprofit SRI International in 2016, the Silicon Valley startup already knew it could spot debris in low Earth orbit. SRI was operating a UHF radar near Fairbanks, Alaska, for ionospheric research but its observations were hampered by noise caused by all the debris in low Earth orbit.

Mike Nicolls, SRI principal investigator for the ionosphere research, became adept at culling noise from his ionospheric data. So good, in fact, that he joined Dan Ceperley, who ran SRI's space debris tracking program, and John Buonocore, former SRI principal research engineer and radar designer, to form a company to share the data.

LeoLab has raised about $17 million in two funding rounds. With that money, the company built a second UHF radar in Texas in 2017 and completed construction earlier this year of an S-band radar on New Zealand's South Island.

Perhaps more importantly as the megaconstellations begin to take shape, LeoLabs is creating tools to help companies and government agencies make sense of increased activity in low Earth orbit and pull space tracking data into their operations.

Rather than defining itself as a radar operator, LeoLabs sees itself as the Google Maps of low Earth orbit. Like Google Maps, the startup created a cloud-based platform and API that allows customers like Internet-of-Things startup Swarm and the New Zealand Space Agency to monitor spacecraft, rockets and debris.

With its two UHF radars, LeoLabs tracks anything softball-size or larger, about 13,000 objects in all. The Kiwi Space Radar can see anything bigger than two centimeters, another 250,000 objects orbiting from 160 to 2,000 kilometers.

"We founded the company on the promise that we would deliver this technology," LeoLabs CEO Ceperley told *SpaceNews* in October. "We're extremely excited to show the technology that we're going to take around the world."

With three radars online, LeoLabs pinpoints the location of objects to within 100 meters, determines their orbits and shares the data with satellite operators, regulators and insurance companies concerned about the risk to assets worth billions of dollars.

Space sustainability is a tall order with the thousands of satellites slated for launch in the next few years. It will take a village to keep collisions to a minimum. Alongside the astrophysicists, astrodynamicists and aerospace engineers in government agencies, universities and private companies keeping tabs on this global commons, is LeoLabs, a startup offering a new set of tools for low Earth orbit environmental monitoring. SN

SPACENEWS

READERS' CHOICE AWARD WINNERS

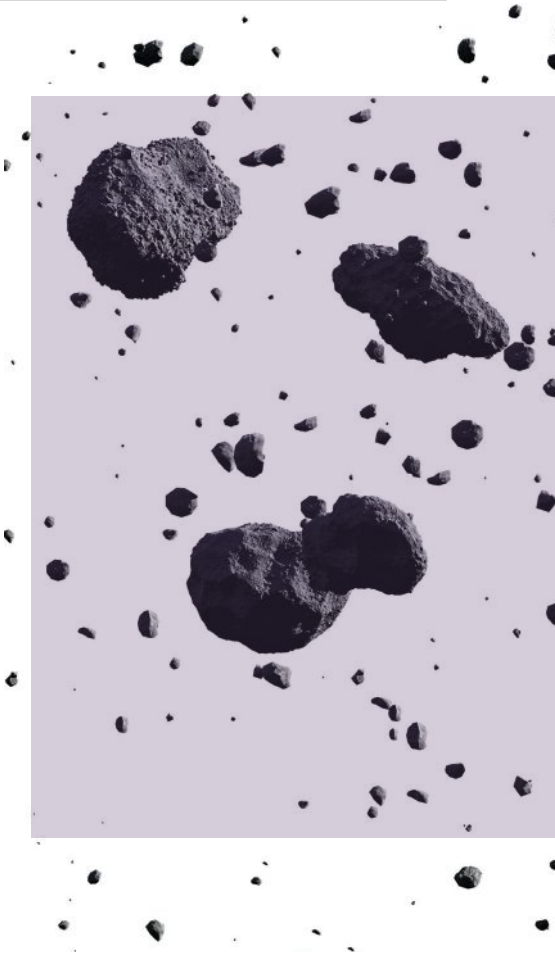
THE SPACENEWS AWARDS READERS' CHOICE

- **Company of the Year:**
  Rocket Lab
- **Startup of the Year:**
  Relativity Space
- **Breakthrough of the Year:**
  SpaceX's Starhopper
- **Agency of the Year:**
  NASA
- **Government Leader of the Year (Civil):**
  NASA Administrator Jim Bridenstine
- **Government Leader of the Year (Military):**
  Gen. John "Jay" Raymond, U.S. Space Command
- **Corporate Leader of the Year:**
  Maxar CEO Daniel Jablonsky
- **Turnaround of the Year:**
  Maxar Technologies
- **Deal of the Year:**
  Blue Origin's Artemis lander "national team"
- **Unsung Hero of the Year:**
  Brooke Owens Fellowship
- **Space Stewardship Award:**
  Iridium deorbits first-generation constellation

COMMENTARY Donald F. Robertson

Weapons into lunar and asteroid mining colonies

Why tapping the solar system's farflung resources woud be better than building new ICBMs



The United States is on the verge of making a profound strategic mistake. The nation is preparing to spend $85 billion replacing working nuclear-armed Minuteman intercontinental ballistic missiles with a new "Ground Based Strategic Deterrent." Like the old missiles, the new arsenal will consist of silo-based rockets with nuclear warheads.

This vast expenditure will make the nation's strategic deterrent exactly as overwhelming as it is today. It will have zero utility in any war the United States is likely to fight and survive. It will increase the national debt with no corresponding increase in economic productivity to pay off that debt. The $85 billion estimate assumes no cost overruns, or technological or logistical problems along the way. History shows that's extremely unlikely, especially since Boeing declined to bid for the contract, giving the program to Northrop Grumman by default.

Spending this kind of money should change the status quo, not simply maintain it.

No state actor (i.e., nation state) is likely to directly attack the United States with nuclear weapons today or in the foreseeable future. Doing so would result in their certain destruction by U.S. retaliatory forces. Perfect reliability is not required to effectively destroy any attacker.

Non-state actors — broadly, "terrorists" — might try a nuclear attack, although the technological and logistical challenges would be immense. Terrorists are not likely to be deterred by the threat of destruction by ICBMs, making missiles with nuclear warheads ineffective at deterring them.

Meanwhile, submarine-launched ballistic missiles remain hidden up to 240 meters beneath the oceans and are far newer. Twenty-four Trident missiles, with up to eight nuclear warheads each, arm reactor-powered USS Ohio-class submarines, which were commissioned starting in 1981. Eighteen Ohio-class ballistic missile submarines, each displacing 18,750 tons submerged, are in active service, although the four oldest have been seconded to special operations and conventional land attack.

These submarines are currently being refurbished and refueled in rotation. The submarine-launched ballistic missile force remains a secure, relatively modern deterrent.

According to a Congressional Research Service report published in November, the U.S. is preparing to build 12 new Columbia-class submarines to replace the Ohio boats for a Navy estimated cost of $109 billion. Likewise, the U.S. is well into procuring the new B-21 bomber for another $50 billion — all capable of delivering nuclear weapons to their targets.

New hypersonic weapons being developed by China, Russia, and the United States are unlikely to change this picture in practical terms in the near future. As Russia discovered earlier this year, these weapons will take time to develop and may not work at all. At the Nyonoksa State Central Navy Testing Range on Aug. 28, Russia experienced the apparent explosive failure of a possibly nuclear-armed cruise missile, possibly the 9M730 Burevestnik, or a nuclear-armed torpedo. The explosion killed several military and civilian personnel and irradiated the town of

SPACENEWS/ADOBE STOCK

Nyonoksa, which was evacuated. Some of the deaths appear to be from acute radiation exposure.

RESOURCES, NOT REPRISAL

Instead of "fighting the last war" by guaranteeing that we can more reliably destroy the world, $85 billion could buy the United States far more strategic, tactical and commercial power if used constructively. Political and military power derive as much from control of resources, and secure access to them, as from purely destructive military capacity alone.

The United States should use this money to reach the resources of the inner solar system. Most nonreligious wars between state actors are economic and over control of resources. Particularly fraught today are the heavy metals and rare earth minerals used in modern electronics, some of which have very limited sources of supply in exploitable concentrations. They are essential to the military, as well as to civilian commerce, yet they are often located in unstable countries or controlled by China.

Many of these critical resources are available in outer space. Since these elements were created in supernovae explosions of early generations of giant stars and scattered throughout the galaxy, they were incorporated into literally everything that went into forming the solar system. They still reside in asteroids, probably in accessible form.

In addition, some asteroids are the metallic cores of minor planets. When a relatively large body was assembled in the early solar system, the heat generated by its formation, and later from the decay of incorporated radioactive elements, caused it to melt. Very small bodies partially melted and quickly re-solidified, while larger worlds fully melted and remained partially molten for billions of years.

Heavy elements such as lead, nickel, platinum and radioactive and rare earth elements sank toward the centers of melted newly formed bodies. Lighter rocks rose to the surface forming crusts. Earth is so large that, more than 4 billion years after its formation, it is still mostly fluid, with a thin and fractured refractory >

Instead of building missiles that cannot be used without destroying human civilization, $85 billion would buy a lot of prospecting.

< > crust floating on top of a circulating mantle. That is also likely true of Venus, Mars, and Mercury. Even Earth's moon appears to have a remnant liquid core.

At some point in the long history of the solar system, a few early proto-planets were shattered in collisions with other minor planets. Fragments of their metallic cores were exposed and are now metallic asteroids.

One such asteroid, 16 Psyche, was discovered in 1852 and resides in a five-year orbit in the asteroid belt. Its average diameter is 226 kilometers, although it is probably shaped like a potato. Its composition is believed to be very similar to that of Earth's core: mostly iron and nickel, with minor amounts of many other heavy metals. Crucially, this metal does not need to be extensively refined — it is already separated from refractory elements.

Led by Arizona State University's School of Earth and Space Exploration, managed by the Jet Propulsion Laboratory in Pasadena, California, and assembled by Maxar Technologies near San Francisco, NASA's Psyche spacecraft will be the first mission to visit a metallic asteroid. Scheduled for launch in August 2022, the vehicle will use SPT-140 electric thrusters to swing by Mars in 2023, adjusting its orbit to reach 16 Psyche in 2026.

The spacecraft is designed to orbit the asteroid for at least 21 months, studying it with a multispectral camera, gamma-ray and neutron spectrometers and a magnetometer. Its radio link will map the body's gravity field and thus its internal structure.

The mission will also function as a prospector, determining what resources might be available on metallic asteroids.

Instead of building missiles that cannot be used without destroying human civilization, $85 billion would buy a lot of prospecting. If spent buying relatively inexpensive, semi-commercial launch services from private companies such as SpaceX and Blue Origin, $85 billion could build and deploy much of the infrastructure required to access these resources.

The resources go far beyond metals. Carbon is available on certain asteroids. Water, accessible on Earth's moon and some asteroids, is vital to almost everything.

Most obviously, humans and other organisms need water to drink. Once the oxygen is split from hydrogen, it can be breathed in artificial atmospheres, and used as oxidizer for rocket engines and other high-energy chemical reactions. Hydrogen is an ideal fuel for deep space rockets. Oxygen and hydrogen can be recombined in fuel cells to release part of the energy used to split the water molecules, creating efficient, long-life storage batteries. Placed around human habitats, there are few substances better than water at blocking galactic and solar radiation.

However, water is very heavy. If found in cislunar space, it does not need to be expensively lifted from Earth's deep gravity well. The earliest water source will likely be the probable polar deposits on Earth's moon. Even if water does not exist in accessible form at the lunar poles, some lunar and asteroidal rocks are heavily oxidized and the solar wind has deposited hydrogen in the their regoliths — allowing water to be manufactured in space.

Measured by its useful value, water is like the oil of the solar system. In the past century, they who controlled the oil controlled the world. In the century ahead, those who have access to water in cislunar space will control access to the increasingly important data, communications, and resources available in and from space.

Any nation that wants a say in that future should not be wasting $85 billion in borrowed money maintaining the status quo with tools that we all hope will stay in silos, forever unused. Using that $85 billion to build a polar lunar water mine and launch asteroid mining expeditions is the best way to ensure long-term security, strategic or otherwise, and to make war of any kind less likely. SN

DONALD F. ROBERTSON (@DONALDFR ON TWITTER) IS A SAN FRANCISCO-BASED WRITER WHO FOLLOWS THE SPACE INDUSTRY. ANALYST TIM KYGER PROVIDED INFORMATION USED IN THIS ARTICLE.

COMMENTARY Nicholas Nelson

Artist's concept of DARPA's Falcon Hypersonic Technology Vehicle

DARPA

DoD needs to demystify hypersonic weapons technology

Hypersonic weapons are drawing more media attention as China and Russia roll out new systems. These weapons, once deployed, will pose a critical threat to the United States at home and abroad.

Although this is an important national security issue, it is not one that is readily explained to non-expert audiences.

Hypersonic capabilities have the potential to rewrite the balance of power across land, sea, air and space. We need to demystify the technology to ensure the nation makes the necessary investments to secure U.S. leadership in hypersonics over the next decade. This is key in building a consensus around the implications of the rise of hypersonic weapons.

Gen. David Berger, commandant of the Marine Corps put it this way: "The people we have to convince in Congress, you can't talk over their head, you have to talk in plain language. No acronyms, no complications, straight-forward."

The simple way to explain hypersonic systems is that they're about speed. They can travel faster than one mile per second, with speeds ranging from five times the speed of sound or Mach 5, up to at least 10 times the speed of sound, or Mach 10. For comparison, a typical cruise missile such as the Tomahawk travels at 550 miles per hour, or just over Mach 0.5, whereas the supersonic Concorde traveled at Mach 2.

Despite the recent interest, it's important to note that hypersonic technology is not new. The first hypersonic test occurred at White Sands, New Mexico, in 1949 and was followed by tests of intercontinental ballistic missiles (ICBMs) during the late 1950s and 1960s, which regularly achieved hypersonic speed.

Currently, hypersonic weapons fall into one of two primary categories: hypersonic cruise missiles (HCM) and hypersonic glide vehicles (HGV). HCMs function as ultrafast, self-propelled cruise missiles. Conversely, HGVs are ground launched by a rocket, deploy at high-altitudes, and finally glide to strike targets.

From a military perspective, hypersonic weapons are game-changing due to their high speed, range, greater survivability, and unpredictability. These weapons can carry >

< > conventional or, in some cases, nuclear warheads. When compared to traditional ICBMs and cruise missiles, hypersonics fly faster than ICBMs and have the maneuverability of a cruise missile, as well as additional deception capabilities. If used by adversaries, they would pose a serious threat to U.S. assets globally, from ships at sea to overseas bases, as well as potential decapitation strikes on national leaders or key nodes.

"We don't have any defense that could deny the employment of such a weapon against us," said Gen. John Hyten, vice chairman of the Joint Chiefs of Staff and former commander of U.S. Strategic Command.

More recently, HGVs specifically, have overcome long-standing technology hurdles associated with reentry and structural integrity. And the forthcoming generation of these hypersonic weapons will drastically shorten decision- and reaction-times at the tactical and strategic levels. Because next-generation hypersonics don't need to travel a straight line to their targets, they are harder to shoot down. It's also harder to tell who fired them, which makes it difficult to deter a hypersonic attack or retaliate against one. This increases the risk of miscalculation and unintended escalation.

From a defensive perspective, traditional antimissile and other air defense measures are of limited effectiveness against hypersonic vehicles and have not kept pace with the evolution of offensive weapons. "Our adversaries have taken advantage of what I have referred to as a holiday for the United States," said Mike Griffin, undersecretary of defense for research and engineering.

Over this time frame, Russia and China have focused on developing hypersonic weapons, while the U.S. has been preoccupied by counterterrorism and counterinsurgency operations. This has allowed Russia and China to take the lead and potentially deploy weapons that threaten assets such as critical infrastructure, military bases and capital ships.

From a global perspective, the United States, Russia and China remain the global leaders, followed closely by India, which notably has a joint venture on a hypersonic weapon with Russia. Beyond these four nations, several U.S. allies are individually, or in cooperation with one another, pursuing hypersonic offensive and defensive capabilities, including Australia, France, Germany, Israel and the United Kingdom.

Within the U.S., the market is still largely concentrated on offensive weapons and countermeasures. Annual unclassified defense spending on hypersonic weapons is over $2.6 billion in fiscal year 2020 – including $157.4 million for hypersonic defense programs. Spending is expected to grow to $5 billion by 2025. Further, the international hypersonic market is predicted to grow at an annual rate of more than 7 percent over the next several years. In this environment, the Department of Defense is focused on building an offensive arsenal to act as a deterrent until a robust hypersonic defense strategy can be advanced and implemented.

Overall, while the U.S., China, and Russia are all working on both HCMs and HGVs, but Russia and China have pursued

Tomahawk cruise missile
Mach 0.5

Supersonic Concorde
Mach 2

Hypersonics
Mach 5-10

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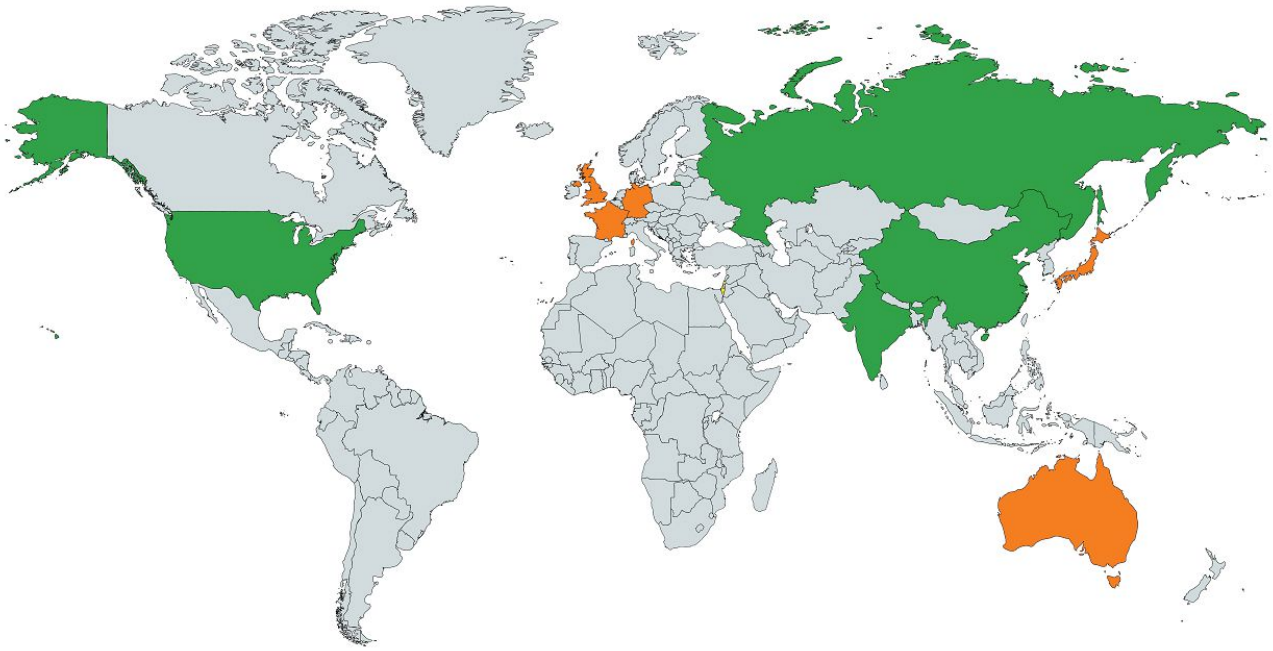

GLOBAL HYPERSONICS

The United States, Russia and China remain the global leaders in hypersonics, followed by India. Beyond these four nations, several U.S. allies are individually, or in cooperation with one another, pursuing hypersonic offensive and defensive capabilities, including Australia, France, Germany, Israel and the United Kingdom.

■ Hypersonic weapons and hypersonic anti-ballistic missile capabilities ■ Hypersonic anti-ballistic missile capabilities ■ Active hypersonics R&D pursuit

SOURCE: NICHOLAS NELSON CREDIT: SPACENEWS

a different approach in fielding these. They are doing rapid sprints to develop and deploy hardware, while the U.S. is taking a longer approach, working to create a family of hypersonic weapons and countermeasures, with over twelve separate programs currently in progress. Finally, Russia and China are advancing nuclear-capable hypersonic weapons, whereas the U.S. is concentrating on conventional weapons.

The first iteration of the next generation hypersonic weapons being developed by the Pentagon are expected to be ready by 2022. Meanwhile, Russia is already fielding multiple HCMs, and has an HGV which is expected to be ready this year. China is not far behind, having successfully tested its new HCM and HGV multiple times, with both expected to be deployable in 2020.

The U.S. needs to close this gap and align across these disparate programs. One step in the right direction for the U.S. would be to ensure hypersonic weapon programs across the Defense Department and the services are better synchronized. To do so, the Defense Department, Congress and the industry need to agree on a common language. Often the discussion of hypersonics descends rapidly into jargon. This obscures key issues and complicates even basic discussions. One way to address this is through the Defense Innovation Board (DIB), either by standing up a new subcommittee or utilizing the existing DIB science and technology subcommittee bolstered by Defense Department subject matter experts. This could help develop a clear, holistic strategy.

Further, the Defense Department should form an interagency team to assess, aggregate and articulate the hypersonic and anti-hypersonic capability requirements to support U.S. military strategy. With over a dozen programs and initiatives across the Defense Department and the services, aligning around a common, agreed upon goal is crucial for success. Instead of pursuing multiple disconnected lines of effort, this team would deliver an integrated set of requirements that would help the industry target its own investments.

Finally, emerging best practices in manufacturing from non-traditional defense companies and technology startups is critical to close the current capability gap. An ecosystem incorporating the Defense Department, traditional aerospace companies, the DIB, and non-traditional defense companies should be the goal.

Establishing a clear baseline of understanding across these disparate groups is necessary to widen engagement, ensure greater support, and improve return on investment. SN

NICHOLAS NELSON IS A STRATEGY MANAGER AT AN INTERNATIONAL CONSULTING FIRM, WHERE HE FOCUSES ON EMERGING TECHNOLOGIES IN SPACE AND UNMANNED SYSTEMS.

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Space insecurity

CONCERNS GROW ABOUT COMBUSTIBLE MIX OF SPACE CONGESTION AND MILITARIZATION

In a declaration issued Dec. 4 after the London meeting of the North Atlantic Council, member countries officially agreed to treat space as "an operational domain for NATO, recognizing its importance in keeping us safe and tackling security challenges, while upholding international law."

The statement from NATO is the latest sign of what security experts believe is an ominous march to war over the control of outer space.

"One of the big trends, and a worrisome trend, is the fact that other countries are following the U.S. lead in terms of creating space forces as part of their military establishment," said Stewart Patrick, a senior fellow for global governance at the Council on Foreign Relations.

Policy statements and efforts by nations to build up their space capabilities are reminiscent of how the nuclear arms race started, Patrick said Dec. 4 during a CFR podcast.

At this point, it appears to be too late for the United States or any other country to dial things back. "Realists would say, 'if it's not going to be us, it's going to be somebody else,'" Patrick said.

The French government this year announced that, like the United States, it will create a space force. China and Russia, meanwhile, are developing military space doctrines and technologies that could be turned into space weapons. "I would not be too surprised to see the Indians follow suit," said Patrick. "It sort of reminds me of the early nuclear age, where there's a pell-mell desire to sort of create one's own capabilities."

As more countries join the space race and seek to exploit the economic opportunities in space, players will be competing for limited real estate, and crowding can lead to conflict. But so far the world hasn't developed rules to solve space disputes or to manage the proliferation of space junk, which Patrick also considers a big problem.

He cited the 750,000 pieces of space debris larger than a pea but smaller than a softball that are currently being tracked. A satellite in the path of such debris is at risk of catastrophic damage. "And so the question is, how do we deal with all this space junk? Because if there's too much of an accumulation of space junk, it could render this outer space domain almost unusable."

There are no modern sets of rules to address both the military and economic implications of the use of outer space. "The granddaddy of all the treaties when it comes to how to regulate outer space is the 1967 Outer Space Treaty, which is getting pretty long in the tooth," Patrick said.

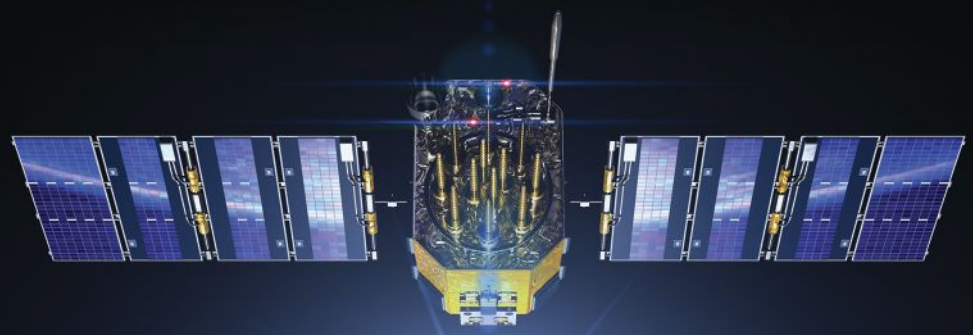
The treaty was designed to deal with Cold War concerns. It prevents countries from placing nuclear launch sites on the moon. But the people who created it were not thinking about space junk, or the possibility that private companies would one day be launching thousands of satellites.

Charlie Bolden, the former NASA administrator and retired Marine Corps major general, believes that President Ronald Reagan's "trust but verify" dictum applies to space, too. "I'm not sure that we have a way yet to verify that hostile nations are going to comply with the convention," he said during the CFR podcast. "But people in the national security apparatus have got to become much better negotiators and consensus builders than they've ever been before."

Deterrence is going to be important to prevent war from reaching the cosmos, said Bolden. The U.S. posture could be: "I've got everything in my arsenal to just wipe you out. But I don't want to do that. And I don't want to make this domain unusable for everybody. So don't make me do that. Let's reach some agreement."

"Space is so essential to our daily lives, and to our security, that it seems like we have no choice but to do whatever is necessary to protect it," said Bolden. "But the rush to protect something can itself lead to conflict."

The thing about space is that there is a very low margin of error, said Bolden. "Whatever damage we do could circle the Earth for centuries." SN



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How to succeed in spaceports without really launching

For most people, the term "spaceport" conjures up visions of launch pads and gantries, with rockets taking off vertically. Some expand that vision to spaceplanes, taking off from or gliding back to a landing on runways. In either case, it involves vehicles departing to, or returning from, space.

But for some, spaceports are becoming a place where businesses, rather than rockets, take off. A case in point is Houston Spaceport, also known as Ellington Airport. The airport received a spaceport license from the Federal Aviation Administration in 2015, but has yet to host a launch or a landing and has no prospects for doing so for the foreseeable future.

But the Houston Airport System, which runs Houston Spaceport along with the city's two major commercial airports, doesn't see that as a problem. "We determined that there were too few players, in terms of operators," said Arturo Machuca, general manager of the spaceport, during a meeting last month of the Global Spaceport Alliance in Houston. Instead, he said the spaceport is intended to "build a focal point for aerospace innovation."

From that perspective, Spaceport Houston is a success. The site has already attracted aerospace companies, including lunar lander developer Intuitive Machines. Earlier this fall, Flight Safety International announced it would build a 125,000-square-foot aviation training facility at the spaceport, part of the spaceport's initial phase of development that offers 165 acres to aerospace companies.

Other would-be spaceports are taking similar approaches to attracting business without launches. Midland International Air and Space Port got an FAA license, and changed its name, in 2014, expecting to host suborbital spaceflights by XCOR Aerospace. XCOR, though, went out of business, and no one else expressed an interest in launching from there. The hangar XCOR used there is now home to Avellan Space Technology and Science, which is using it to build smallsats.

Colorado Air and Space Port, formerly Front Range Airport outside Denver, received its license in 2018 despite concerns that launch activity there could interfere with flights at nearby Denver International Airport. While the spaceport still expects to one day host launches, its focus for now is on companies that want to do rocket engine testing and other activities.

Those successes appear to be encouraging others to pursue spaceports despite the lack of launch customers. Among those attending the Global Spaceport Alliance meeting were officials from places like Hancock County, Mississippi; Waco, Texas; and Yuma, Arizona, all of whom were in early phases of spaceport planning and undeterred by the lack of launch activity at other, licensed spaceports.

So why go through all the effort of getting a spaceport license — a multiyear process that often requires extensive, and expensive, technical and environmental reviews — when one could simply open up a business park with much less of a hassle? Some are still holding out hope that they can attract launch business, particularly for point-to-point suborbital spaceflight. "We do believe, without hesitation, that point-to-point transportation will become a regular way of traveling," Houston's Machuca said.

Despite some of the more optimistic assessments in industry, that seems unlikely to happen any time soon. Blue Origin and Virgin Galactic have taken far longer than originally expected to develop suborbital vehicles designed to fly from point A back to point A, which suggests that the far greater challenge of long-distance point-to-point flight, at the levels of safety people expect from passenger aviation today, will not be commercially available any time soon. Moreover, it's hard to imagine much demand for high-speed intercontinental transportation to and from places like Waco or southern Mississippi.

As long as spaceport advocates are up front about these challenges, there's little harm in other locations pursuing spaceport status, particularly if it's tied into broader economic development ambitions. Even if they're unlikely to launch rockets, they can instead be launchpads for aerospace businesses. **SN**

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