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For the U.S., a defensive shift away from monolithic satellites has proved harder than envisioned. **PAGE 18**

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Shaping the Future of Aerospace


DISAGGREGATI

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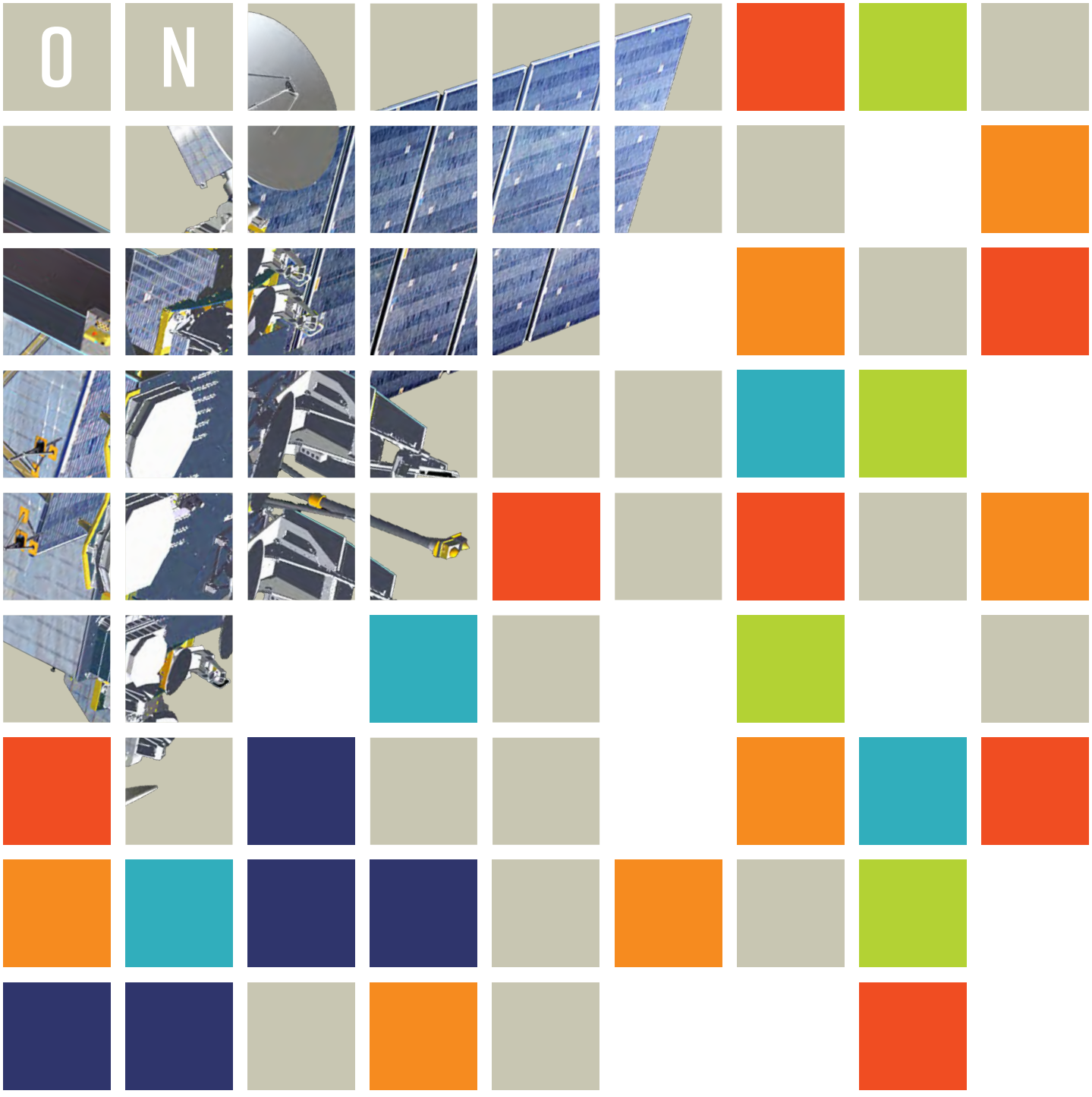

Some U.S. military strategists think the country's reliance on geosynchronous satellites for communications and missile warning make it vulnerable to a devastating attack in space. Why not spread technology across more spacecraft? Getting bureaucratic buy-in for disaggregation, and the related concept of distribution, has proved harder than anyone imagined. **Tom Risen** tells the story.

When he was active duty, Air Force Gen. William Shelton often brainstormed with his fellow generals about how to make America's defense satellite networks less susceptible to being knocked offline by an attack. He hoped a 2011 speech at the Space Symposium in Colorado Springs, Colorado, would be a turning point. Shelton described how a space mission, such as missile-launch detection, would be harder for an enemy to disrupt if the tasks were split among multiple satellites of varying designs. Shelton was referring to the fact that today the Air Force relies on a few handfuls of school-bus sized satellites in geosynchronous orbit to watch or provide communications within discrete regions of the globe. A single satellite high above the equator over Africa might cover Europe, Africa and Southwest Asia; one to the east over India might cover much of Asia and so on for nearly global coverage. Shelton recalls, "there were crickets in the room" when he finished his presentation about a proposed alternative strategy, called disaggregation. Shelton believes contractors incorrectly perceived that the concept might upend their existing deals to build military satellites, when in fact it was aimed at next generation satellites.

Six years after Shelton's speech, and with the operational lives of the current geosynchronous constellations ticking away, Pentagon strategists

Suspicious maneuvers

Actions in orbit suggest that the major space powers may be working on technologies to attack each other's satellites, even if the projects are not always described in those terms.

JANUARY 2007
China destroys one of its aging weather satellites. The U.S., U.K. and Japan criticize the missile launch and resulting debris.

FEBRUARY 2008
U.S. destroys one of its own spy satellites with a missile launched from a Navy cruiser. Stated goal is to prevent the nonfunctional satellite from crashing into the atmosphere causing a hydrazine explosion. Most experts see Operation Burnt Frost as the U.S. answer to China's anti-satellite test.

MAY 2013
China launches a rocket close to the geosynchronous satellite belt, where U.S. military satellites and numerous commercial communications spacecraft orbit. China calls the mission a science experiment.

FEBRUARY 2014
U.S. Air Force Gen. William Shelton declassifies plans to launch surveillance satellites to near-geosynchronous orbit to maneuver near "objects of interest" for enhanced surveillance. Two Geosynchronous Space Situational Awareness Program satellites are launched in July.

Lockheed Martin

Workers encase a U.S. Air Force Advanced Extremely High Frequency satellite into a nose cone for mounting on an Atlas 5. The first AEHF satellite will be 7 years old in August, half its projected lifespan.

remain undecided about the best way to make future constellations less vulnerable.

Experts have questioned the wisdom of such a drastic strategic shift and whether disaggregation would counter the nonkinetic attacks that might be the 21st century's biggest threats. At issue at a minimum are the designs that should follow three of today's geosynchronous constellations: the Lockheed Martin-built Advanced Extremely High Frequency satellites, whose Northrop Grumman-built payloads provide the most secure communications links for troops, commanders and the U.S. president; the Wideband Global Satcom spacecraft that provide less protected, but higher-volume communications; and the Space Based Infrared System satellites that detect such events as North Korean missile launches.

AEHF satellites have design lives of 14 years, and the first one will turn seven years old in August; SBIRS spacecraft have design lives of 12 years and the first one turns 6 next month; the first WGS will be 10 in October.

Nomenclature war

Advocates such as Shelton, now a board member of the Aerospace Corp. but not speaking on its behalf for this article, continue to carry the disaggregation torch while also pushing for a more recent, related

Sources: Aerospace America research; Xinhuanet.com; U.S. Air Force Fact Sheets; Russianspaceweb.com

APRIL 2015
Russian military satellite Luch/Olimp-K parks within 10 kilometers of the Intelsat 7 and Intelsat 901 communications satellites for five months. Russia gives no comment.

MARCH 2016
DARPA unveils the Robotic Servicing of Geosynchronous Satellites program, saying space drones would repair satellites in geosynchronous orbit with two multi-jointed robotic arms and a toolkit. Congress is debating the program amid a contracting policy conflict lawsuit filed by Orbital ATK.

JUNE 2016
China launches the Aolong 1 "Roaming Dragon" debris removal drone into low Earth orbit. It reportedly ends its mission in August 2016 after grappling objects with its robotic arms and tossing them back to Earth.

U.S. Air Force

U.S. Air Force Gen. William Shelton, now retired, has been advocating for years for a new approach to protecting military satellites' missions.

A Delta 4 rocket carries the seventh Wideband Global Satcom communications satellite into orbit for the U.S. Air Force in 2015. The first WGS will be 10 years old in October.

ULA

concept called distribution. With distribution, constellations of small, identical satellites would provide such services as communications, missile warning or precision navigation and timing. If a few satellites were destroyed or temporarily spoofed or blinded, all capability would not be lost over a specific region. By contrast, with disaggregation, distinct functions, such as tactical and strategic communications, would be separated onto satellites of varying designs.

Many of today's generals see advantages to disaggregation and distribution. "We must make ourselves less vulnerable to the disruption of large, monolithic systems," says Air Force strategist Brig. Gen. Stephen Whiting by email. "That means spreading our investment over a larger number of simpler and less expensive satellites, integrating commercial capabilities in new ways and through new business models," says Whiting, the director of Integrated Air, Space, Cyberspace and Intelligence, Surveillance and Reconnaissance Operations at Air Force Space Command in Colorado Springs.

Rep. Jim Bridenstine, R-Okla., likes the idea too, saying "any analysis of alternatives which doesn't evaluate disaggregation is incomplete."

The question is how and when to integrate one

Blame game

U.S. lawmakers and generals are fond of citing a list of provocations in space by China and Russia dating back to 2007. Not surprisingly, the way critics in those countries see it, the U.S. has taken actions that suggest the Pentagon wants the ability to go on the offensive.

There was Operation Burnt Frost in 2008, when a U.S. Navy cruiser fired a Standard Missile-3 into orbit and shot down an old U.S. reconnaissance satellite, just a year after China destroyed one of its own satellites with an anti-satellite missile. More recently, DARPA announced a project to create robot modules that would repair satellites in geosynchronous orbit with the aid of two robotic arms, a capability that in theory could be applied to clasp onto foreign satellites.

Retired Air Force Gen. Robert Kehler, a former commander of Strategic Command, doesn't see the U.S. as the provocateur. He acknowledges that "nations act in their own self-interests" but he doesn't think U.S. behavior has encouraged or provoked Russia or China to escalate their counter-space efforts. "All the actions the U.S. is taking to prepare for a conflict that extends to space are ultimately about deterrence," he says.

To counter the risk of escalation in space, however, Kehler would like to see more rules to create norms among satellite operators, just as maritime law governs activity when ships maneuver near one another in international waters.

One fact that no one doubts is that a war in space could have huge repercussions for the increasingly connected global economy. The potential to disconnect global networks by destroying satellites and the resulting debris that would threaten everyone's satellites makes such a war in no one's interest, says space historian Roger Lanius, now an associate director of the Smithsonian Institution's National Air and Space Museum.

ATTACKING A TACTICAL OR COMMERCIAL SATELLITE SHOULD ELICIT CONVENTIONAL RESPONSE. ATTACKING A STRATEGIC CAPABILITY WOULD BE MORE ESCALATORY."

– Rep. Jim Bridenstine, R-Okla.

United Launch Alliance

SES Government Solutions

▲ **The U.S. Air Force Commercially Hosted Infrared Payload**, or CHIRP, mission placed an experimental missile-warning sensor on a commercial telecommunications satellite. A 2016 Air Force study proposed using hosted payloads across six or eight satellites.

or both of these concepts into acquisition plans.

Shelton does not expect much movement on that score in the 2018 and 2019 budgets. The former commander of Air Force Space Command predicts that the military will decide to buy near-copies of existing Advanced Extremely High Frequency and Space Based Infrared System satellites, for instance.

He's not happy about that. "We have gotten ourselves to the point where a nondecision is a decision, especially when planning what comes next for our key strategic satellites," Shelton says. "It's frustrating because I think these decisions could have been made much earlier."

The Air Force declined to comment about future plans because the fiscal 2018 program budget review "is pre-decisional."

Planning and more planning

This lack of action, however, is not due to lack of questions from the Air Force to industry about how to build more defensible satellites. Air Force Space Command published requests for information as recently as February asking industry for ideas on how to disaggregate tactical communications from designs that will come after WGS and Advanced EHF. Today, the WGS constellation is complete, with six satellites in geosynchronous orbit. Three Advanced EHF satellites are in orbit, with a fourth planned for launch in the near future and two more in production.

The Air Force wants to find the best way to shift some of its tactical communications technology onto commercial or military satellites, a concept known as hosted payloads. The request seeks suggestions, including how commercial or military satellites might host a protected tactical waveform, a communications technology in development for secure, jam-proof connections between military and commercial networks.

An Air Force study that examined a successor to the Space Based Infrared System proposed a mix of hosted payloads with disaggregated missions across six or eight satellites. The Air Force has not decided whether to follow its recommendations. The third model of the Lockheed Martin-built missile warning satellite launched in January on an Atlas 5 rocket, and three others are in development.

One reason people talk less often about disaggregation than in 2011 is because "distribution" became a more widely used buzzword after major contractors considered disaggregation as a less palatable concept that could disrupt business as usual, Shelton says. Purveyors of small satellites, by contrast, expressed interest in helping to build larger constellations for the Air Force.

The military and industry have refined how they apply disaggregation and distribution in discussions

over resilience and mission assurance strategies. "I think if you look back to 2013, 2014, and earlier in 2015, people were using 'disaggregation' essentially as a replacement for the word 'resilience,' because they hadn't really thought through all the different ways you could achieve resilience," says Audrey Schaffer, director of space strategy and plans in the Office of the Secretary of Defense.

Retired Air Force Gen. Robert Kehler, whose final assignment was as commander of Strategic Command, says commercial satellites might eventually host tactical communications payloads, but that strategic missions like nuclear missile detection probably would never be hosted on commercial satellites. In the view of some, the concept of distribution could be extended beyond satellites to include conventional airplanes, drones or in some cases ground equipment. Kehler is skeptical about extending the strategy so broadly.

"As a global military there are some things we can only do in space," he says. "The communications connectivity in space is unparalleled."

Bridenstine, a member of the House space subcommittee, says the growing private space industry is key to helping the military with capabilities like communications and imagery, so the government should clearly define which satellites America considers vital to national security.

Bridenstine last year introduced the Space Renaissance Act with the aim of beefing up investment in U.S. space infrastructure. "It is important to differentiate tactical and strategic satellites. Attacking a tactical or commercial satellite should elicit conventional response. Attacking a strategic capability would be more escalatory."

Anti-satellite missiles could be one mode of attack, but since they would create debris that could collide with an adversary's own satellites, some strategists see these ant-satellite weapons as a less likely threat than hackers hijacking a satellite's network, or jammers disrupting communications with radio transmitters.

"The appeal to jamming is that you can turn it off, it doesn't create debris — all it does is disrupt the signal of the satellite," Kehler says. "Because of that we are going to encounter jamming."

Commercially available jamming technology is relatively inexpensive, and a ground-based transmitter could block a satellite signal from reaching a radius of more than 100 kilometers if it were powerful enough, says Martin Faga, a former director of the National Reconnaissance Office and assistant secretary of the Air Force for space. In theory, jamming could be done in space with a satellite, but that's unlikely because it is difficult to launch a large enough power source to do that effectively over the required distances, Faga says.

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Retired Air Force Gen. William Shelton

"The benefits of disaggregation are hard to be confident about," Faga says, because the strategy would likely not make them less vulnerable to hacking or jamming.

Disaggregation could also be more expensive than expected, says Loren Thompson, chief operating officer of the Lexington Institute think tank. Splitting mission functions across a larger constellation would require building several high-quality satellites instead of one to ensure top performance of the mission, he says. Technological advances could mean that better options for space resiliency would be available by the time the next generation of disaggregated satellites launches, along with new threats that would undermine their resilience, he says.

"Just designing, testing and launching the new spacecraft will take two decades," Thompson says. "I'm betting that 20 years from now we will have tech options we can't even imagine."

Launching pieces of an overall mission across a constellation, however, could be a chance to upgrade technology faster by launching a single one-function satellite instead of building a large satellite to replace an obsolete one, says Mark Lewis, a former chief scientist of the Air Force and former AIAA president.

For U.S. strategists, the main goal is to deter aggression in space so that disaggregation, distribution and resiliency are never put to the test. "The concept of war in space is so counterproductive," says space historian Roger Lanius. "Only insanity would lead us down that road." ★