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CONTESTED SPACE

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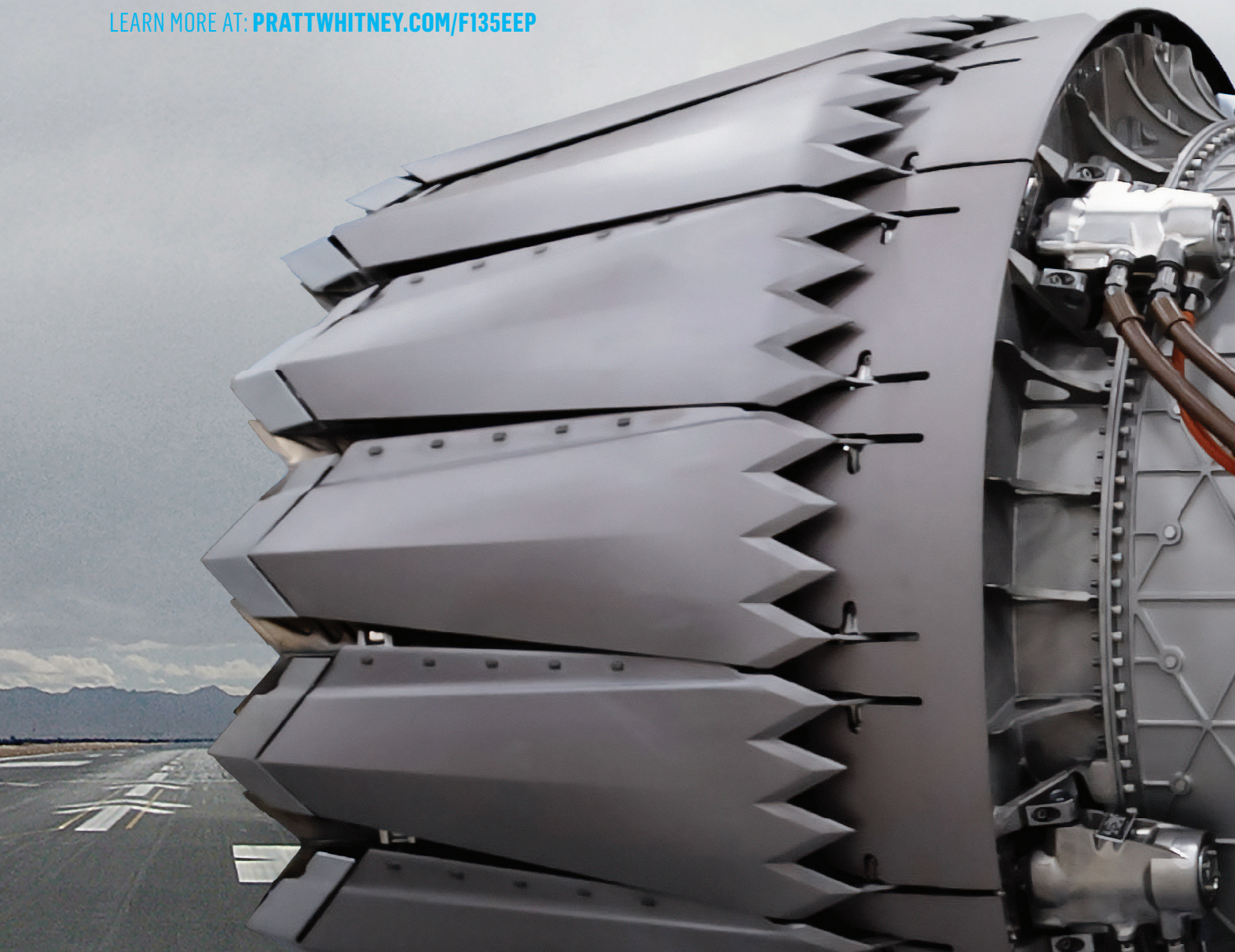

AIR FORCE

December 2021, Vol. 104, No. 12

Brian Rhodes/USAF

The Air Force likes the F-35's capabilities and combat performance, but it's more expensive to operate than the service predicted and can afford. See "Can a Service Contract Save the F-35?" p. 30.

DEPARTMENTS

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Mike Tsukamoto/staff; Hung Quach and PIRO4D/Pixabay

Russia hits a satellite with a missile fired from Earth. (Illustration) See: "Contesting the Space Domain," p. 36.

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By Tobias Naegele

Peril, Perspective, and Resolutions

Winding down to the end of 2021 and looking forward to the year ahead gives us an opportunity to count our blessings and take note of what ails us.

Here are some things we learned in 2021:

■ Our Republic is stronger and more resilient than we realize. The mob that stormed the Capitol on Jan. 6 tried but failed to disrupt the certification of the 2020 election. They shattered glass and shocked the system but left no permanent damage. Our institutions and Constitution survived intact. That's something to be proud of.

■ China grew more dangerous. The People's Liberation Army continued its bully tactics in the South China Sea, and it increased flights into Taiwan's air defense identification zone. But more significantly, China also tripled its nuclear arsenal and successfully tested a hypersonic glide weapon that gives President Xi Jinping a first-strike weapon for which the United States has no defense.

■ Russia grows more belligerent. Amassing troops on the border with Ukraine and fomenting a border crisis between Belarus and NATO-member Poland, President Vladimir Putin gains power from disorder. His destruction of a used-up satellite by means of a direct ascent weapon showed his disregard for others—including his own cosmonauts, who had to climb out of the International Space Station and shelter in their Soyuz space capsule after the satellite was destroyed while NASA tried to ensure the ISS would not be shredded by the space junk Putin's missile left in its wake.

The Air and Space Forces are unreasonably small, and dangerously underfunded.

■ Iran is still developing nuclear weapons. Like North Korea, Iran sees nuclear weapons as a guarantor of enduring power. Both nations are willing to let their people starve while they invest what treasure they have in illicit weapons development. Time is short before one, or both, have nuclear capability.

■ Allies question our resolve. The hasty and ill-planned withdrawal from Afghanistan rattled the confidence of every nation that has hitched its future security to American power and influence. Some, like Australia, will hold their ground. Others, like France, or Taiwan, or any number of countries in Africa and the Middle East, will hedge their bets by building alternative security ties elsewhere. Turkey's dalliance with Russia is instructive and risky.

■ America's military advantages are eroding. The most critical elements—our Air and Space Forces—are too small to meet the requirements of the National Defense Strategy and too busy, as a result, to keep up with the demands of combatant commanders. The Air and Space Forces have more missions than resources necessary to execute them. It's not that the COCOMs are being unreasonable, but that the Air and Space Forces are unreasonably small, and dangerously underfunded.

Solving these problems need not add to our national defense bill if defense resources are simply reallocated from the Army, which is no longer fighting ground wars in Iraq and Afghanistan, to the Air Force and Space Force, which will be indispensable in a peer conflict. Success depends on unity of effort across service and party lines and should begin with this bipartisan commitment: Never again should America finish a fiscal year without passing a budget for the next. Simply living up to that promise saves billions.

This year, as in 17 of the past 20, Congress failed to pass a defense appropriations bill by Sept. 30. As a result, the Pentagon has been living off a continuing resolution since Oct. 1. This has become routine. In 2017, it took 216 days—seven months—before Congress passed a defense budget. Last year's delay was 80 days. This year is all but guaranteed to exceed 90 days.

For the Air Force alone, a full-year CR would cost $11.8 billion in lost buying power, the service told the Congressional Research Service. Where does that money disappear to? In truth, into thin air. Delay causes uncertainty, and that, in turn, causes price increases. Time lost working through contingency spending plans or managing government shutdowns is time not used for more productive purposes. You don't get it back. And the more one pushes funds out to the end of the year, when the rush to "use it or lose it" leads to short-fused decisions, the less value is derived for those payments.

In 2019—the only time in the past decade when Congress passed a defense budget on time—the Air Force spent 25 percent of its funding in each of the first two quarters, 22 percent in the third, and 27 percent in the fourth. In other words, it was almost even. Last year, by contrast, the Air Force spent just 18 percent in a first quarter that was almost over before the budget was finally approved. Backloading spending like that makes cash flow harder for contractors and predictable deliveries harder to attain.

Sen. Jack Reed, D-R.I., Chairman of the Senate Armed Services Committee, estimated in November that a CR stretching the whole year long would cost $36 billion in lost buying power. That works out to roughly $3 billion per month, and given a best case for 2022, that means Congress will "only" waste $9 billion this year.

Let's consider what $9 billion might pay for:

■ The entire $3 billion request for B-21 Raider development, *and*

■ The entire $2.5 billion request for ICBM modernization—the Ground Based Strategic Deterrent—*and*

■ At least 42 F-35As.

Or, $9 billion would fund more than half the Space Force budget.

Now let's look at the impact of CRs over time. Since 2010, the Pentagon has spent 45 months operating under CRs (including 18 days when appropriations lapsed completely, which is worse). Estimating the average waste inflicted by CRs over that period conservatively at $2 billion per month, that adds up to $90 billion in total.

We could have can bought a whole lot of defense for $90 billion. That's enough to:

■ Cover the Department of the Air Force's entire personnel budget for two and a half years, or

■ Pay for 1,100 F-35As, or 62 percent of the entire planned buy, or

■ Fund 90 percent of the entire cost of the Ground Based Strategic Deterrent, which seeks to replace 400 nuclear-armed missiles in silos across the American West.

Lawmakers routinely lament their inability to find the funds to pay for all the Pentagon's needs. Yet they somehow sit back and allow this kind of waste to undercut our security.

How's this for a New Year's Resolution, Congress? Pass a budget on time—or don't get paid until you do. ✪

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LETTERS

What a Waste

Every time I read an article on the KC-46, like today, it just pisses me off more and more ["World: KC-46, F-35 Provide Lessons for Future Testing," November, p. 22]. All the wasted time, all the wasted money, reduced readiness, all because the armchair generals somewhere decided they knew better than the boomers who actually do the work and ignored their advice and requests when engineering the new tanker. We want, we need, they told the engineers, a direct view, eyes on the plane, refueling station. And what did they give them instead? I'm sad to say it is so typical these days.

MSgt. Kenneth Selking,
USAF (Ret.)
Decatur, Ind.

Gates' Failure

With great interest I read Tobias Naegele's editorial in the October edition of Air Force Magazine ["China, Trust, and Politics, p. 2]. Finally, it was publicly said what I've been saying for a few years now, that Secretary of Defense [Robert] Gates got it all wrong when he canceled the F-22 program at 187 airplanes. I was a contractor in the F-22 SPO at Wright-Patterson Air Force Base in Ohio when our production was cut off.

Listening to his reasons for doing so baffled me and many others. As Naegele said, "Gates saw the Raptor as 'exquisite' and superfluous to the wars in Iraq and Afghanistan." That thinking is just the opposite of what we were taught in our war colleges. You do not plan the next war based on the current one. How could he not see what was, and is, going on in China and Russia? After I retired a second time, I bought Gates' book just to see if I had missed something, and after a thorough read, it was clear the mistake was all his.

Col. Frank Alfter,
USAF (Ret.)
Beavercreek, Ohio

In my 26-plus years in the Air Force, I was primarily concerned with short-term operations; the next day's missions, getting ready to fly, or making sure our aircraft were mission ready. That is, except for a tour at the Pentagon, and even then it was only a five-year look ahead. So I was intrigued by what I have been seeing, hearing, and reading about concerning the threat to the United States. I believe, as you state, "once trust is broken confidence is lost." I believe that not only as a reaction to our "cut and run" in Afghanistan, but to actions, just to name a few, such as dropping sanctions against Iran, breaking trust with France (nuclear submarine deal), ... I could go on and on. These are all things that the world sees in their eyes as a weakening America. The government itself has issued contradictive statements as to our involvement as to the defense of Taiwan. How does that make South Korea feel? Trust?

What does Russia see from this? How does that make China see us? For that matter, even the Iranians and Taliban see our weakness. China has had a meteoric rise in both weapons systems and associated technology.

We have wasted the time we had to match the rise in the Chinese influence and war power. Who is responsible for that? Is it the population, the politicians, or the "warfighters?" My guess is that it is a mix of the last two. There seems to be an effort to increase the awareness of our position, as conducted through

WRITE TO US

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- **Advocate** for aerospace power, and promote aerospace and STEM education and professional development.
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groups such as the Mitchell Institute, but what other actions within our government are being conducted to correct some of the "bad judgment." It may have begun with then SecDef Gates, but why hasn't that error been corrected? Secretary [Frank] Kendall says, "We are out of time." I barely can agree with the CSAF that "it is not impossible," but it is going to take a lot more work than what is being done now to convince the politicians of the growing threat. We cannot wait!

Col. Mark W. Smith,
USAF (Ret.)
Chinook, Wash.

What a Day!

Air Force Magazine, you are marvelous in consistently relating to us the new and critical roles for our Chief of Staff of the Air Force, Gen. Charles Q. Brown Jr., most incidentally an African American. Additionally, the October issue of the magazine added into the picture the role of his wife to assist him in activities for the Defense Department's Exceptional Family Member Program ["World: The Browns, and the Needs of Exceptional Families," p. 33].

In September 195l, as a 15-year-old African American, I was accepted into the Air Force ROTC program at St. Louis University. I did not have the slightest conception of our Air Force Chief being an African American. Now, as an 86-year-old USAF retiree, I am thrilled that this, at last, has come about during my lifetime.

Lt. Col. Walter R. Jacobs Jr.,
USAF (Ret.)
Atlanta

Wilderness Voice?

I was just reading through my November 2021 issue of Air Force Magazine. As I read, it struck me (not for the first time) there seems to be an editorial bias in a lot of the writing and in the choice of some stories. Has the Air Force Association become the aeronautical arm of the Republican Party?

It's somewhat subtle. In Tobias Naegele's "Editorial: The Bill Comes Due," he refers, right in the beginning, to "wish-list social spending and how to tax wealthy individuals and corporations to pay for it all." In John Tirpak's "Gen. Colin Powell Dies at 84" there is a subtle tone of criticism hidden in the obituary. Those are two examples, but the bias seems to sneak through the entire issue.

I have been a part of AFA since I was an AFROTC Cadet and Arnold Air Society member (way in the distant past!). I'm quite fiercely independent of any political party. In the past I have voted both Republican and Democrat, deciding based on who I thought would do the best job for the country. I strongly oppose holding for one party no matter what.

I thought the mission of AFA was to support U.S. airpower and the issues that affect the U.S. Air Force? That should be a non-partisan mission, not one based on editorial party affiliation, shouldn't it? If the editors and AFA take sides, it can limit the effectiveness of the Association to carry out it's primary mission. In case the editors haven't noticed, 'divide and conquer' has not been working as well as cooperation and collaboration has in the past. If AFA's mission is to succeed, we need to work with elected and appointed representatives without regard to what party they belong to.

Is AFA losing sight of its mission?

Of course, I'm just one person who grew up 'cradle to grave' Air Force. Biased editors will probably dismiss my comment as being uninformed and wrong-thinking. Anyone who disagrees with our thinking must be wrong, correct? On the other hand, one voice 'in the wilderness' may also have a valid point to ponder?

Lt. Col. Robert E. Thibault II,
USAF (Ret.)
Milwaukee

VERBATIM

Find the 'Weak Spot'

"Start with the psychology of the aggressor ... not what we think would make a difference to us. Public shaming might mean nothing in some of these countries, right? But what makes a difference to them? You need to start there and you need to bring to bear all the instruments of power. But [adversaries] need to be properly mobilized and enabled by some degree of timeliness."

—The first U.S. National Cyber Director, **John "Chris" Inglis,** on how he wants his office to operate.

White House

Gotcha

"In execution of those offensive [cyber] operations, it's given us an opportunity to impose costs. Measurements in this space can be challenging, but when we know there was something we stopped, that's something we can measure."

—Lt. Gen. Charles Moore, deputy commander of US Cyber Command, at C4ISRNet's CyberCon, Nov. 10, speaking about the threat posed by China in cyberspace.

Mike Tsukamoto/staff

Wildfire

"I believe that when Russian bots are attacking our conversations with each other in ways that are meant to drive us to poles and separate us right down the middle, I worry a lot that that is a threat to the Constitution of the United States. ... I worry deeply that some of the norms that have kept us strong and have put us in a position of leadership around the world have eroded over time. ... We've got to be honest with ourselves. We're playing with fire if we can't figure this out as a people and come together and figure out a way to work out our differences peaceably."

—**Lt. Gen. S. Clinton Hinote** on DOD's formulation of guidelines to root out extremism in the troops, Washington Times, Nov. 6.

Can We Talk

"We had a hotline to the Russians because we were very concerned that a miscommunication with aircraft flying in close proximity in Syria would lead to a problem. ... I don't see any reason why a similar approach couldn't work for the space domain. ... The hotline that we used was to make as many of our operations as transparent as possible and attempt to avoid those miscommunications. ... A civilian satellite conducting surveillance, for example, could be mistaken for a hostile counterspace weapon."

—Lt. Gen. B. Chance Saltzman, U.S. Space Force's deputy chief of space operations for operations, cyber and nuclear, Global Milsatcom 2021 conference in London, Nov. 3.

Mike Tsukamoto/staff; Pixabay

Mike Tsukamoto/staff; USAF

No F-16s Either, Please

"As long as President [Recep Tayyip] Erdoğan advances his expansionist project in the Eastern Mediterranean, Turkey will continue to threaten our national security and the security of our closest allies in the region—Greece, Israel, and Cyprus. We urge you to act in our national interest and for the sake of stability in the Eastern Mediterranean by refusing to reinforce Turkey's aging arsenal of fighter jets, and we look forward to receiving your response."

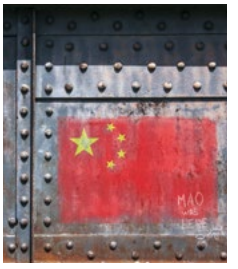
—Letter from **11 representatives in Congress** objecting to any consideration of selling Turkey F-16s. Turkey had planned to buy F-35s, but was dropped from the program after accepting delivery of Russia's S-400 air defense system.

Four (More) Years

Senior Airman Christopher Quail

"My dad always told me that four years never hurt anybody. Twenty-nine years later, I'm still trying to figure out [which] four years he was talking about."

—CMSAF JoAnne S. Bass, recalling advice from her father, a retired Army warrant officer, Nov. 11.



Mike Tsukamoto/staff; Stux_7273/ Pixabay

You Shall Not Pass

"Any attempts and acts of interfering in China's internal affairs or bullying against China are doomed to failure before the Great Wall of steel of the PLA."

—Senior Colonel Wu Qian, spokesperson, Chinese Ministry of National Defense, Nov. 5., response to report on Chinese military and security developments released by the U.S. Department of Defense.

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Ten fighter pilots, eight flying A-10 Thunderbolts and two flying F-16 Fighting Falcons, joined to plan, lead, and fly in formation from Osan Air Base, South Korea, in October 2021. Among Air Force pilots, 94 percent are still male, with a slim 6 percent female, and those numbers have held steady for years. The Air Force is working to expose more women and minorities to the pilot track, which officials see as essential to developing the best possible pilot corps in the future.

Tech. Sgt. Vernon Young Jr.

U.S. Air Force Capt. Orr Genish, a weapons systems officer, communicates on a land mobile radio as a B-1B Lancer prepares to land at Naval Support Facility Diego Garcia, Oct. 17, 2021. The Bomber Task Force mission marked the first return of BONEs to Diego Garcia in 15 years.

Staff Sgt. Hannah Malone

Among the best candidates to be future service members are the children of current service members. Some 120 military youngsters sat for the Armed Services Vocational Aptitude Battery (ASVAB) at Yokota High School on Yokota Air Base, Japan, in November 2021, which administrators said was the largest group yet to take the exam at one time on that air base. About 900,000 people take the ASVAB each year at more than 14,000 schools and Military Entrance Processing Stations.

Yasuo Osakabe/USAF

By John A. Tirpak

China's No Longer Peaceful Rise

There were two key takeaways from this year's Pentagon report on China's military power: China is clearly setting the stage for a fait accompli coercive takeover of Taiwan, and it is surging to produce a nuclear triad on a rough par with that of the U.S. and Russia early in the 2030s.

China is "preparing every contingency to unify by force" with Taiwan, which it considers a breakaway province, according to a senior Pentagon official who briefed the press on "Military and Security Developments Involving the People's Republic of China," released in November. The annual report, required by Congress, covers only the events of 2020, and it was two months late, so it did not capture recent large-scale air exercises in which China penetrated Taiwan's air defense zone, nor did it discuss China's recent tests of hypersonic and orbital bombardment systems.

Zeng Bingyang/Ministry of Defense

Chinese amphibious armored vehicles assault a beachhead during a recent landing operation at an undisclosed location.

China is developing a networked system similar to the American joint all-domain command and control system, and expects it to be operational circa 2027. This will support "more credible military operations"in a potential Taiwan action, the official said. China is preparing for such a conflict by practicing for a "blockade campaign" and large-scale amphibious landings, while continuing to deploy tactical ballistic missiles near Taiwan. It's also extending the range of its air defenses and placing front-line combat aircraft in the vicinity.

The goal of all these preparations is to discourage the U.S. from intervening if China decides to move against Taiwan, achieving reunification as a fait accompli, the official said. Beijing's military preparations are about "wanting to be able to deter, to delay, or otherwise to counter third-party intervention," the official explained.

The unclassified annual report is based on open-source material such as Chinese military writings and declarations, presentations at international arms shows, and sanitized U.S. intelligence reports about the size and posture of Chinese military forces.

Beijing's all-of-government approach is also "putting pretty heavy pressure" on Taipei with attempts at diplomatic isolation, information/disinformation campaigns, and cyber intrusions, the official said.

While he declined to comment on whether DOD thinks China has imminent plans to invade Taiwan, under the Taiwan Relations Act, the U.S. would treat with "grave concern" any action, including an economic blockade of the island. U.S. policy is deliberately ambiguous as to whether it would act to halt or reverse an invasion of Taiwan.

The State Department said the U.S. has no intention of changing its policy of making weapons available to Taiwan to "maintain a sufficient self-defense capability." The U.S. encourages Taiwan to take an "asymmetric security posture" toward China, given that Taiwan cannot match the sheer bulk of China's military power.

Asked to address the massive air exercises that took place after the report's timeframe—in which dozens of combat aircraft, electronic warfare aircraft, refueling aircraft and others penetrated Taiwan's air defense identification zone—the official noted that Chinese activity is expanding and clearly aimed at intimidating Taipei, creating the danger of "miscalculation," he said. In response, the U.S. and seven partner nations conducted joint aircraft carrier and other naval operations in the Indian Ocean and nearby waters in October.

China's approach to Taiwan is consistent with its island-building campaign in disputed waters of the South China Sea, where China has built up sandbars and reefs into large airfields and ports. Having air and naval bases there has allowed China to intimidate its neighbors fellow claimants on the area, which China claims as its national waters, and gives it a decided edge if the disputes turn hot, the Pentagon said.

CHINESE TRIAD

Part of China's intimidation campaign is the quickening pace of its development and fielding of a nuclear triad. China is on track to field more than 700 nuclear warheads by 2027 and more than 1,000 by 2030, versus about 200 noted in the 2019 edition of the China Military Power Report. This trebling of effort "exceeds the pace and size" the Pentagon estimated in 2019, it said.

China is also moving toward a "launch on warning" posture for its nuclear weapons.

According to the report, the People's Liberation Army Rocket

Forces (PLARF) are developing new ICBMs and sea-launched ballistic missiles, and have begun deploying an air-launched ballistic missile (ALBM) on its H-8 bomber force, collectively now giving China a true nuclear triad.

Satellite photos began circulating in August—again, outside the purview of the 2020 report—of new Chinese missile silo fields. China also demonstrated a hypersonic missile that circled the Earth before gliding to within miles of its target. That prompted Air Force Secretary Frank Kendall to say in September that he believes that country is pursuing a "first-strike capability."

The Defense Intelligence Agency (DIA) didn't go as far, saying Beijing intends a "credible second-strike" capacity; able to launch "multiple rounds of counterstrike" if attacked, and sufficient to deter an enemy with the threat of "unacceptable damage."

The U.S. now has 3,750 nuclear warheads fielded, the State Department revealed in October; down from 3,822 in 2018 and 3,805 in 2019. The decline is due to warheads being taken offline because of the decay of their plutonium cores and a sluggish pace of replacement. If that pace of decline continues, the U.S. fielded inventory will decline to around 3,100 warheads by 2030, three times more than China. Beijing will thus not achieve nuclear parity within this decade.

The Pentagon said it can't rule out further acceleration. The DIA noted that China is expanding its mining and processing of uranium and its ability to "separate plutonium, constructing faster breeder reactors and reprocessing facilities."

Beijing has consistently rejected invitations to participate with Russia and the U.S. in strategic arms negotiations, and is not a signatory on any nuclear treaties.

In a reference to the new silos, the Pentagon said the PLARF is constructing "at least three new solid-fueled ICBM silo fields, which will cumulatively contain hundreds of new ICBM silos." At the same time, production of road-mobile DF-26 intermediate-range ballistic missiles continues and China tested its "first hypersonic weapons system, the DF-17 hypersonic glide vehicle-capable medium-range ballistic missile" in 2020. This may have been the hypersonic missile detected on a globe-girdling test in August.

China has about 100 ICBMs in various basing modes including roll-out and road-mobile versions. The number of launchers "appears to be doubling … in some ICBM units," the Pentagon said. A new DF-5C missile is underway, and a new DF-32 may also be in the works.

The six sea-launched ballistic missile boats in China's Navy can each carry 12 CSS-N-14 (JL-2) missiles, and a next-generation boat—with upgraded missiles—should appear in the next few years, according to the Pentagon.

China's nuclear bomber is the H-6N, a derivative of Russia's Tu-16 Badger bomber, heavily upgraded. Chinese variants include a tanker version and an electronic warfare model, but the H-6N is specifically designed for long-range nuclear strike, having a refueling probe and recessed fuselage space for the ALBM, or up to six land-attack cruise missiles. With air refueling, it can strike targets in the "second island chain" of China's self-described perimeter from mainland bases. The H-6K naval variant can carry new YJ-12 missiles to the same distance, "significantly extending" China's maritime strike capacity.

In January, China issued a video teasing a new, large, flying-wing-style aircraft, which was hidden under a tarpaulin; a near-parody of a similar Northrop Grumman commercial touting that company's role as prime contractor for the Air Force's new B-21 bomber. The Pentagon said this new Chinese bomber will be stealthy, and may be called the H-20.

The bomber employs "many fifth-generation technologies," the Pentagon estimated, and it likely has a range of 8,500 kilometers with a payload of "at least 10 metric tons." However, it will likely take "more than a decade" to develop it, the Pentagon predicted. The Defense Department has been surprised before, however, at how rapidly China develops and fields advanced aircraft and missiles, often leveraging stolen technology from the West.

Taken together—rapidly fielding nuclear weapons, developing new nuclear weapons, and bolstering the nuclear infrastructure—China's nuclear activity "is certainly very concerning to us," the official said.

"It raises some questions," he observed. "We'd like to have more insight into their intentions. … They haven't really explained why they're doing it." Beijing's shift to a launch-on-warning posture is also worrying, as are recent military papers saying that while China has a "no-first-use" policy, "maybe that wouldn't apply" in all circumstances, the official pointed out.

The developments collectively also put greater importance on efforts to get China to the nuclear arms table, to pursue some "practical measures for risk reduction," the official said. To be "responsible," nations with nuclear weapons "need to have discussions with each other," he said.

AIR DEVELOPMENT

With 2,800 aircraft—not including trainers or unmanned systems—China's air force and navy together have the largest air capability in the Indo-Pacific, and "the third largest in the world," the report said. Of those aircraft, 2,250 are combat-coded fighters, bombers and multirole aircraft, and the Pentagon said that in the near future, the bulk of this force will be "fourth generation" or better; meaning they are on a par with Western F-15, F-16, F/A-18, and Mirage 2000 types.

These developments are "gradually eroding" the longstanding U.S. advantage in air power, the Pentagon said. The People's Liberation Army Air Force is "rapidly catching up to Western air forces."

China's air arms are transitioning from strictly air defense to "strategic" power projection, with an increasing proficiency in long range, abetted by an increase in air refueling systems.

China's fifth-generation aircraft—stealthy, and with advanced sensors and possibly sensor fusion—include the J-20 Mighty Dragon and the FC-31 Gyrfalcon. In October, images of a two-seat J-20 circulated on the internet, suggesting a role for the backseater either as a ground-attack weapons operator or manager of unmanned escort aircraft. Soon after, images of the FC-31 emerged, clearly showing its purpose as a naval aircraft, with wing-fold mechanisms and a catapult bar on the dual-wheeled nose gear.

Upgrades to the J-20 include more internal air-to-air missile carriage and possibly thrust-vectoring engines; whether those will be axisymmetric round nozzles or two-dimensional types such as the F-22 uses is not clear. The new indigenous WS-15 engines, will have "supercruise capability," enabling supersonic speeds without using gas-guzzling afterburners.

Non-government experts estimate China has about 100 to 150 of the jets. The FC-31 is still in development, and only a handful have been built. By comparison, the U.S. Air Force has about 180 F-22s and 300 F-35s, and is adding fewer than 50 F-35As each year.

China also has "new medium- and long-range stealth bombers" in development "to strike regional and global targets." It has taken delivery of all 24 Su-35 Flankers it ordered from Russia, the Su-35 being the most advanced version of the jet. It also fields numerous J-15 copies of earlier Flanker variants, and has developed a carrier-capable version.

Bottom line: The Pentagon expects China to achieve its stated goal of becoming a "world class military power" on par with the U.S. military by 2035. Indeed, it could achieve that goal by 2030.✪

The Air Force's Gender Disparity Review, released in September, indicated women are promoted at rates similar or greater to men. But those results masked another disparity. On further review, the Air Force found Black women are promoted at lower rates than their peers.

Johnny Saldivar/USAF

USAF Reviews Expose New Disparities, Workplace Issues

By Greg Hadley

The results of two new personnel studies released in November exposed new areas of concern for Air Force Leaders.

The first indicated black women are promoted at lower rates than their white peers, a fact masked in an earlier study, which indicated that women, overall, are promoted at rates comparable or greater than men. The second revelation, coming in a service wide survey, showed two in five active duty members experienced workplace bullying and that harassment, hazing, and violence are also problems for roughly 20 percent of the force.

Some disparities "were basically masked or hidden by better performance of White women, for example, relative to women of color," Air Force Secretary Frank Kendall said.

Specifically, White women were promoted at or above the overall rate for the Active-duty force from E-5 through E-8 and O-4 through O-6 from fiscal year 2016 to 2020, with the exception of O-6 below the promotion zone, while Black women were underrepresented at E-5, E-6, and E-7; Native American women at E-5 and E-6; and Asian American woman for E-8 and E-9 promotions, as well as most officer promotions.

The disparities were particularly apparent in operations career field officers, where most Air Force leaders get their start—White men remain by far the most common group in that category, while "except for Hispanic/Latino female [company grade officers], all female minority groups had below 1 percent representation of the entire operations career fields' force for all rank groups." In particular, there were no Black, Asian-American, Pacific Islander, Native American, or multiracial female general officers.

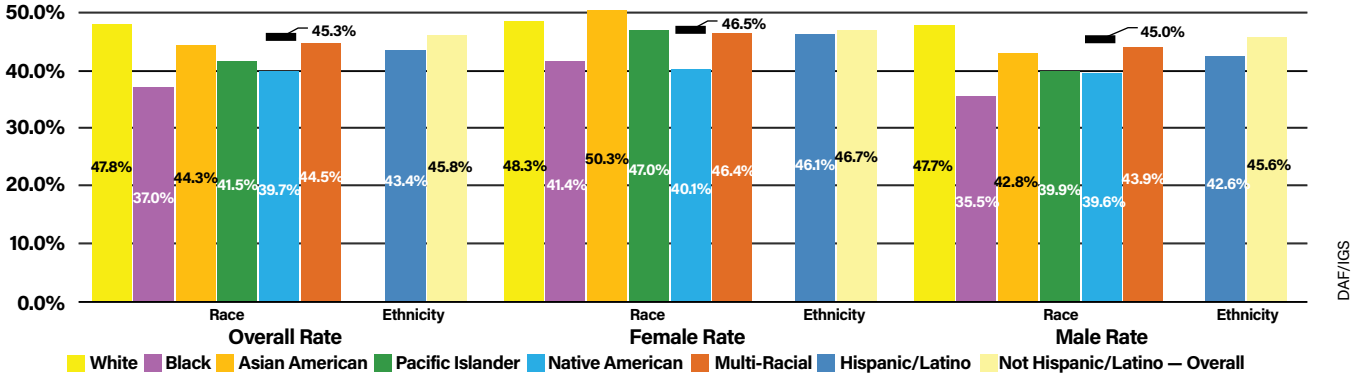
Other disparities also came to light, Air Force Inspector General Lt. Gen. Sami D. Said told reporters. As an example, he cited a finding that while Black Airmen as a whole are underrepresented in wing commander positions, Black men are actually overrepresented in those leadership roles—Black women, more specifically, face the disparity.

"In this slice and dice of the addendum, you could see the disparity becoming much more pronounced at higher officer ranks on the female side of the house, and that's critically important for the folks trying to deal with those problems instead of just aggregating male and female," Said noted.

The addendum was championed by Air Force Undersecretary Gina Ortiz Jones, herself the first woman of color to hold her position within the Air Force. When the second disparity review was released, she said it "very clearly talks about some of the disparities for minorities and for women, but it's not talking about disparities for female minorities. And when we think about having a very targeted approach to ensure that we are

Promotion Disparities Are Greatest at E-5

A study of promotions shows that White and Asian American women are promoted at above average rates to staff sergeant in the Air Force, while other women and men of all racial groups are promoted at or below average rates.



DAF/IGS

Source: AFPC/DYSA

addressing some of the unique challenges, some of the unique barriers faced by some of our Airmen and Guardians, we have to understand the intersectional challenges that are presented."

Ortiz Jones noted on Nov. 9 that further parsing the data meant dealing with smaller sample sizes—roughly 10 percent of Airmen and Guardians are women of color—"but given the challenges we face as a country, we're not going to write off the experiences of 10 percent of our force."

Said echoed those comments, saying that while the smaller groups made determining statistical significance from year to year more difficult, "when you look back 10 years, and [that disparity is] consistently there—that's very meaningful.

BATTLING INTERPERSONAL VIOLENCE

Also on Nov. 9, the Air Force released the results of a survey that found that tens of thousands of Airmen, Guardians, and civilians within the Department of the Air Force reported experiencing some form of interpersonal violence that resulted "in psychological or physical harm or that detracts from a culture of dignity and respect."

In the fall of 2020, the Air Force's Interpersonal Violence Task Force sent out a survey that garnered some 68,000 responses, roughly 10 percent of the department. Of those 68,000, 55 percent of respondents—more than 35,000—reported experiencing some form of behavior in the past two years that the task force identified on a "Continuum of Harm."

Those behaviors, 81 in total, included everything from physical violence to sexual harassment to workplace bullying and hazing.

"Some of the experiences are not what we would traditionally be tracking, based on the Department of the Air Force's definition of interpersonal violence, but we want to understand what is going on, especially at that left side of the continuum, so that we can get after that," said Brig. Gen. April D. Vogel, the Interpersonal Violence Task Force lead. "Because it is proven that when lower-level behaviors that are inappropriate are allowed to flourish, it creates an environment where worse, more egregious types of behaviors can happen."

In a briefing with reporters, Kendall noted that those who responded to the survey were self-selecting, likely pointing to an over-representation of those who said they had experienced such behaviors.

"But if you only take the fact that in the 10 percent that reported, roughly half reported some type of interpersonal violence, that's still 5 percent of the total people all by itself, which is too much," Kendall said. "So we know we've got a problem to address."

The survey also found that the majority of those who experienced interpersonal violence did not report the behavior. When asked to select the reasons they did not, a quarter of respondents said they didn't think anything would be done, and roughly a fifth said they thought it would make things worse for themselves.

Of those who said they did report it, the majority indicated they were not satisfied with the support services provided. This stood in contrast to more than 80 percent of command team members who indicated they felt they had the "resources, training, and authority" necessary to address interpersonal violence in the chain of command.

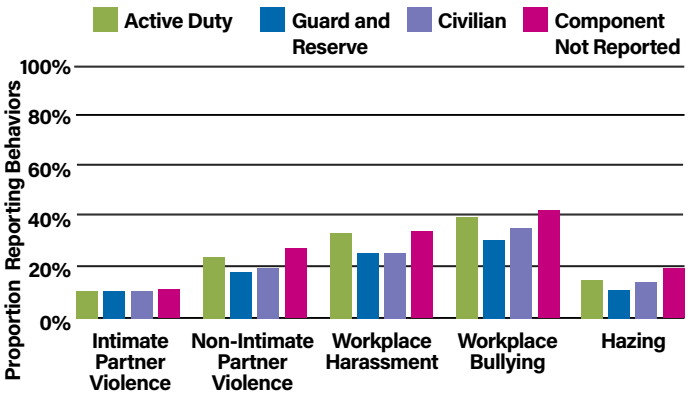
From those findings, the task force formulated three recommendations:

- Complete a cross-functional database review to improve data awareness and sharing.
- Pursue a one-stop policy for victims of interpersonal violence.
- Establish a cross-functional team to examine barriers to reporting.

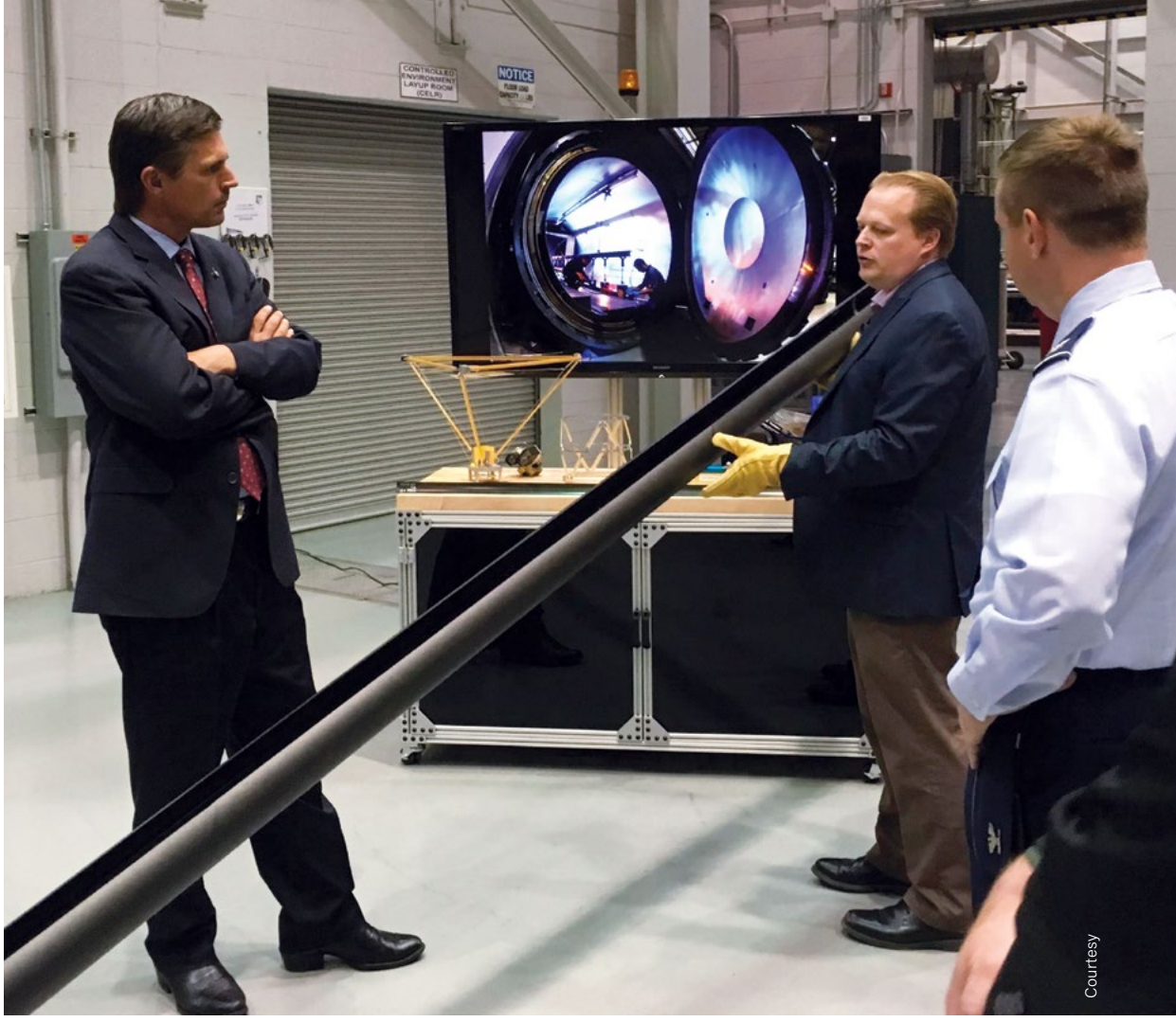
Ortiz Jones has advocated for a "no wrong door" policy, with one office of primary responsibility within the department to address domestic violence, harassment, and stalking. That policy, leaders said, will be included in the one-stop policy recommendation, rather than duplicate efforts.

Harassment, Bullying, Violence

Workplace bullying, harassment, violence, and hazing remain persistent problems in the Air Force workplace, affecting up to 40 percent of the Total Force workforce.



Source: USAF



Courtesy

Andrew Williams, center, the new Air Force Research Laboratory Deputy Technology Executive Officer for Space Science & Technology, explains the engineering of the Roll-Out-Solar Array, or ROSA, to U.S. Sen. Martin Heinrich during a visit to AFRL's Space Vehicles Directorate at Kirtland Air Force Base, N.M.

Space Force's S&T Matrix

AFRL's realignment is finally complete.

By Shaun Waterman

The Air Force Research Laboratory has finally filled a new post announced more than a year ago to be a single point of contact for its new customers in the Space Force—and those customers say the lab's realignment to work for two services appears to be succeeding.

Andrew Williams, an 18-year veteran of AFRL's Space Vehicles Directorate, will be the first full-time permanent deputy technology executive officer (D-TEO) for space science and technology, the lab said in a press release Nov 1.

The appointment means the changes the lab laid out last year to make it more responsive and useful to its new Space Force customers are finally complete.

Williams' new role "will ensure integrated development and execution of Space S&T efforts across AFRL and serve as the primary focal point for AFRL integrated Space [Science and Technology] activities," the announcement states. The role is that of a "conductor"—ensuring that all of the lab's directorates, not just the four centered on space, are focused on the needs of the new service as they plan and execute their research activities.

Williams takes the post from Kelly Hammett, the head of the lab's Directed Energy Directorate, who has been dual-hatted in the new role on an interim basis since September 2020. In that post, Hammett headed a working group that drew up the plans to serve the new Space Force by realigning the lab's governance, rather than reorganizing or restructuring it to break off the space-related parts of the institution.

"The lab has done an amazing job of setting up those forums and councils to make sure that we have an input into their processes," said Joel Mozer, chief scientist for Space Operations Command, whose job it is to tell AFRL what the new service needs for its operations.

The working group Hammett led recommended the creation of the deputy technical executive officer for space. Reporting directly to the commander, the new post is "a single voice that can speak to the customers across the Space Force, to hear their concerns, to get their demand signal, and to help prioritize it through the internal process" at AFRL, Hammett said.

JUST ONE PIECE OF THE PUZZLE

Why did it take more than a year to fill this vital new role? Hammett explained that the creation of the deputy TEO for space was just one element of a concept of operations the working group had developed to realign AFRL.

That CONOPS also proposed a series of changes—not to organization, but to governance—to make AFRL more agile in its responses to Space Force research and technology needs. The plan needed buy-in across the enterprise and from Space Force partners.

"It took months and months of effort to get everybody on the same page," recalled Hammett. Then there was a debate about who would provide the billet for the new post. "Is this a Space Force person, or is this an AFRL person? That's still not 100 percent determined. We are launching out with an AFRL person," he said.

Both Hammett and Mozer separately made the point that this was a post requiring exceptional talent and that headhunting for such a job always takes time.

Williams will now work with two new forums that bring together AFRL leadership to meet Space Force requirements:

■ The Space Science and Technology Board brings together the directors of the four major AFRL elements that were administratively transferred to the Space Force—Space Vehicles, Rocket Propulsion, Electro-Optical, and Systems Technology. According to Hammett, this group represents the 10 percent of AFRL resources focused directly on space.

■ The Space Science and Technology Group brings together management teams at the "action officer level" from every one of the lab's nine technology directorates, plus its functional directorates such as finance and personnel—and research partners such as AFWERX and the Transformational Capabilities Office, as well. "Everyone is there," said Hammett.

The group, he explained, is key to leveraging the 90 percent of AFRL resources that aren't focused directly on space "but may be very space relevant," such as research into materials, sensors, electronics, cybersecurity, and human performance. "There's a lot of that which we need to harvest to make the Space Force successful," he added.

The board meets every other week, the group weekly. That's a major shift up from the usual tempo of AFRL governance, points out Hammett. (For comparison, the AFRL Council, the lab's leadership body, meets quarterly.)

"It allows us to … make decisions and try to establish policy and respond on a very rapid timescale, to the types of demand signals we're getting from the Space Force, because they are moving fast and implementing," Hammett said. "They're in Year 2, and they want 'new this' and 'new that,' and so we really have to be able to respond at that speed."

And so far, so good, said Mozer. In the Wartech process, for instance, which helps AFRL incubate its top priority Vanguard R&D programs, "Space is doing just fine." With "a couple of space-focused programs out of a small handful, I would say that we are getting our fair share," he said.

However, he added, "It's still to be determined how well this works out in the long run." The Space Force is "very new and exciting" right now. But what would happen as the shine wears off? "The real question is as we go forward, do we revert back to our old ways of doing things? Or do we keep the same focus on it? And I think we will, but that's the thing we have to watch out for," he said.

Mozer described his job as being "the demanding customer for [AFRL], to really give them some meaty priorities and problems to work on," drawn from the strategic direction provided by the Chief of Space Operations Gen. John W. "Jay" Raymond.

"My role is to … translate CSO guidance into [science and technology] priorities for the lab and the acquisition community," he explained.

Mozer said his biggest challenge was balancing immediate needs against longer-term requirements. Raymond, for instance, had set resilience and survivability of current constellations as an immediate strategic objective. And AFRL was developing Navigation Technology Satellite-3 (NTS-3) as a more resilient alternative to GPS. "So that's a good example of where they know what our problems are, there's a clear need, and they're addressing it," Mozer noted. "Where it gets harder is how do you balance that against the longer-term needs to build cislunar"—the space between Earth orbit and the moon—"architecture or develop in-orbit refueling or repair. … How do you allocate resources between the needs hitting your windshield today versus a potential need that's coming down the pike and you have to invest now to develop options" to deal with it.

"That's where it gets fuzzy," Mozer said. It's made fuzzier still by the commercial space sector, which is racing to develop new capabilities—often innovating faster than even cutting-edge research institutions can in the military. "What we have to do is figure out what are the unique things that if the government doesn't invest in it and doesn't buy down the risk, or do something else that industry is not going to do, those things aren't going to happen. Those are the high priority things that we need to do."

To help think about resource allocation, Mozer has developed what he calls the nine matrix: Three rows and three columns.

The three rows are:

■ **Evolutionary Work:** Things that "make our current systems better, faster, more capable, cheaper."

■ **Revolutionary work:** Game-changers. A completely new way of doing things.

■ **'Tech surprise:'** "Scientific and engineering disciplines where we think there might be outcomes that could be surprises to us in a military sense, or things like quantum computing that we don't necessarily think that we are going to weaponize right away, but we certainly would be worried if somebody else did it when we weren't paying attention."

The three columns are:

■ Work that supports the current generation of satellites for the next five years.

■ Work that supports the next generation of overhead architecture currently being designed by the Space Warfare and Analysis Center, 15 years out.

■ The next generation after that, "which is really when you start thinking about these long-term ideas of expanding into cislunar space, and Mars, and space logistics."

"If you have a certain size of technology budget, you need to allocate it among each of those nine buckets," said Mozer. Right now, he said, the Space Force view was that the biggest investment, up to 30 percent of its total budget, should go on "game-changing, next-generation stuff."

The advantage of the matrix, he added, "from a prioritization perspective, [is] it allows us to turn the knobs if we decide, for instance, we want to take risk in the future to pay for the present or vice versa," Mozer said. "All we have to do is change the allocations between those nine elements then we can communicate that to the lab—it's a clear way to communicate what our tolerance for short-term versus mid-term versus long-term risk is." ✪

Here Are the Scoring Charts for the Air Force's New PT Test

By Greg Hadley

Scoring the New Fitness Test

TOTALS REQUIRED FOR MAXIMUM SCORE ON AIR FORCE'S NEW PT TEST (MEN)	UNDER 25	25-29	30-34	34-39	40-44	45-49
1.5 MILE RUN	≤ 9:12	≤ 9:22	≤ 9:34	≤ 9:45	≤ 9:58	≤ 10:10
20-METER HAMR	≥ 100	≥ 97	≥ 94	≥ 92	≥ 88	≥ 86
1 MIN PUSH-UPS	≥ 67	≥ 62	≥ 57	≥ 51	≥ 44	≥ 44
2 MIN HAND-RELEASE PUSHUPS	≥ 40	≥ 40	≥ 40	≥ 40	≥ 38	≥ 38
1 MIN SIT-UPS	≥ 58	≥ 56	≥ 54	≥ 52	≥ 50	≥ 48
2 MIN CROSS-LEG REVERSE CRUNCH	≥ 49	≥ 48	≥ 47	≥ 46	≥ 44	≥ 43
FOREARM PLANK	≥ 3:35	≥ 3:30	≥ 3:25	≥ 3:20	≥ 3:15	≥ 3:10

WOMEN	UNDER 25	25-29	30-34	34-39	40-44	45-49
1.5 MILE RUN	≤ 10:23	≤ 10:37	≤ 10:51	≤ 11:06	≤ 11:22	≤ 11:38
20-METER HAMR	≥ 83	≥ 80	≥ 77	≥ 74	≥ 71	≥ 68
1 MIN PUSH-UPS	≥ 47	≥ 47	≥ 46	≥ 42	≥ 38	≥ 37
2 MIN HAND-RELEASE PUSHUPS	≥ 31	≥ 31	≥ 31	≥ 31	≥ 28	≥ 28
1 MIN SIT-UPS	≥ 54	≥ 50	≥ 45	≥ 43	≥ 41	≥ 35
2 MIN CROSS-LEG REVERSE CRUNCH	≥ 47	≥ 45	≥ 44	≥ 43	≥ 42	≥ 40
FOREARM PLANK	≥ 3:30	≥ 3:25	≥ 3:20	≥ 3:15	≥ 3:10	≥ 3:05

Source: USAF

The Air Force released updated scoring charts for its revamped physical fitness test Nov. 12, with alternate exercises offered for the cardio, endurance, and strength portions of the test starting Jan. 1, 2022. Missing, however, was the 1-mile walk the service had said it would implement as a measure of aerobic fitness.

In a Facebook post, Chief Master Sgt. of the Air Force JoAnne S. Bass wrote that the walk was removed "until we are able to standardize the VO2 measurement equipment across every installation. We will continue working the logistics and evolution in the meantime."

Air Force leaders had previously said that a lack of equipment and facilities across every base made alternate exercises such as swimming, biking, and rowing untenable. The plan had been to use Airmen's age, weight, and heart rate at completion of the walk to determine their aerobic capacity, sometimes called VO2 max.

While the walk is out, the other alternate exercises previewed and tested on a cross-section of the force in recent months are all included:

- A 20-meter high-aerobic multi-shuttle run (HAMR) for the cardio portion.
- Hand-release pushups for the strength portion.
- Cross-leg reverse crunches or forearm planks for the endurance portion.

The traditional 1.5-mile run, pushups, and sit-ups are still available as well, and their scoring charts remain unchanged from the update released in May, when the Air Force shifted the PT test to lower minimum requirements across every age category for both men and women and also implemented five-year cohorts instead of 10 years.

The HAMR's point total is based on the number of times an Airman can sprint 20 meters to the tempo of a progressively faster recorded beep. The third consecutive failure to cross the 20-meter line before the beep terminates the test.

For male Airmen, the minimum number of shuttles required ranges anywhere from 10 for those over 60 years old to 36 for those under 25. The maximums are 71 and 100 or more, respectively. For female Airmen, the minimums go from one for those over 60 to 22 for those under 25. The maximum scores range from 48 to 83.

Hand-release pushups are scored by how many an Airman can do in two minutes. For men, the minimums range across age groups from 10 for the oldest group to 15 for the youngest group, and the maximums from 30 to 40 or more. For women, the minimums go from one to six, with the maximums going from 24 to 40.

Cross-leg reverse crunches are also scored in a two-minute time frame. Men under 25 will have to complete at least 21 and up to 49, while men over 60 will have to do at least seven and up to 35. Women under 25 will be scored on any total from 11 to 47, while women over 60 will need to do at least five and a maximum of 32.

Forearm planks will be scored based on how long an Airman can hold the pose. The lowest minimum time scored across age groups for men is 25 seconds, and the maximum time is 3:35. For women, the lowest requirement is 15 seconds for those over 60, and the highest maximum requirement is 3:30, for those under 25.

"While testing these components at various installations, we received a large amount of positive feedback," Lt. Gen. Brian T. Kelly, deputy chief of staff for manpower, personnel, and services, said in a statement. "The changes to the physical fitness assessments reflect what we learned and our desire to provide Airmen with additional flexibility in maintaining fitness standards."

In order to pass the PT test, Airmen have to score 75 total points while hitting the minimum requirements in all three categories. The cardio phase is worth a maximum of 60 points, and the strength and endurance phases are worth a maximum of 20 each.

As previously announced, the waist measurement is no longer part of the test, but Defense Department policy requires the services to measure body composition. The Air Force surgeon general has determined to use a height-to-weight ratio to fulfill that requirement and will be announcing further guidance "in the coming months," the service said in a press release.

DAF/MIT AI Accelerator/courtesy

Air Force Col. Tucker Hamilton, left, dons a virtual reality headset to assist Capt. Kyle McAlpin in collecting data for the Department of the Air Force/MIT AI Accelerator's project, Objective Performance Prediction and Optimization Using Physiological and Cognitive Metrics.

Airmen and Guardians are Accelerating AI From the Campus of MIT

By Amanda Miller

Airmen and Guardians working side by side with researchers in the field of artificial intelligence (AI) at the Massachusetts Institute of Technology are part of a unique military unit that's helping to steer some of the research studies while also attempting to guide the Air Force's and Space Force's wider adoption of AI.

Under the new research partnership, the Department of the Air Force and university jointly decided on 10 research projects to focus on, a departure from the typical top-down style in which the department advertises grant-funded topics, said Col. Tucker Hamilton, the Air Force's director of the DAF-MIT AI Accelerator. Started in January 2020, when projects got underway, the accelerator also differs because it doesn't focus solely on developing a military capability—it also benefits "the public good," Hamilton said.

The work that the accelerator's 12 Active-duty troops and four Reservists are taking part in is "meant to further the science of AI" in ways to be broadly applied—"not just in some military sense," he said. "Everything that we decided on with them to pursue had to have a use for a military application as well as a use for a societal application."

The research projects involve about 140 faculty members, researchers, and students from MIT and the federally funded, national security-focused MIT Lincoln Laboratory. The accelerator's director on MIT's side is Daniela Rus, who also directs MIT's Computer Science & Artificial Intelligence Lab and served on the Defense Innovation Board advising defense secretaries.

From Hamilton's perspective, "AI is ubiquitous right now," he said. "Everything is being influenced by machine learning. So how do we, as a military, approach the technology?"

HOW IT WORKS

Hamilton was an F-35 test pilot before becoming an MIT fellow with the Air War College, where he learned about the accelerator. Having the qualifications to serve as a program manager, he applied. The Airmen and Guardians assigned to the accelerator report to Hamilton, "so we work together as a military unit," but they also embed with research projects.

Officers and enlisted members assigned to the accelerator full time come from career fields that complement the projects but also bring some prior understanding of machine learning, Hamilton said. They're pilots, in part, but also weather, intelligence, and cyberspace operations officers as well as analysts in geospatial intelligence and operations research among others.

"We tried to, first and foremost, find the right people because right now, there are only a handful of people that truly understand this," Hamilton said.

Three of the four Reservists taking part in the accelerator fulfill a special role. They're "hugely important for this because," as CEOs in their civilian lives, "they're the ones that are actually running AI companies," Hamilton said. "They have the ability to understand this technology more than most people in the military can understand it."

The service members each embed with one or two of the research projects, ranging from the likes of AI-assisted autonomy for safe decision-making, optimization of training schedules, and personalized instruction in a foreign language.

"They help actually write some of the code, and they give [the researchers] perspective—like, 'Well, this is how a pilot would use this type of technology in the field.' Or, 'This is what a pilot would be thinking'—or any kind of operator," Hamilton said. "Our C-17 pilot—he's working on our project that helps pilot training students."

For the researchers' part, "It gives them a vast amount of clarity on their efforts, on their research, on the direction that they're moving—and also motivates them because they see an [eventual] outcome," Hamilton said. "They see something that is like a practical application, which excites people."

AI AMBASSADOR

Space Force Capt. Jazmin Furtado works with the accelerator part-time from across the country at Los Angeles Air Force Base, Calif., looking into how existing AI research relating to space domain awareness could benefit the DOD, "especially the Space Force," she said.

An Air Force Academy graduate, Furtado went to MIT for her master's and eventually was assigned to Kessel Run, the Air Force's software development hub, as a portfolio lead during its early pursuits of AI—where she was one of a handful of people directed to "do AI."

"It was a very vague statement, but it was a very big goal and vision," she recalled. "A lot needed to be done in terms of, 'How are we collecting data?'" That was also when she first connected with the accelerator.

Now on the heels of a fellowship at SpaceX, she's applying all that experience as a program manager in space command and control architecture for the Space Force's Space Systems Command. She's focused on "overseeing these enterprise data stores" and envisions helping to build a digital environment that's already optimized for AI, which all relies on quality data. "In order for it to be actionable, it has to be accessible," Furtado said.

Alongside helping to "mold" the research projects, the accelerator is also "accelerating the empowerment and implementation of machine learning—a branch of AI—"throughout the department," Hamilton said.

The work includes documenting methodologies for the wider adoption of AI—"the frameworks that are going to allow our Airmen and our Guardians to create machine learning solutions for their own organizations," Hamilton noted—as well as providing education courses taught by MIT personnel.

Hamilton believes that in the long run, AI will be best at "teaming with humans."

"Maybe it is in a situation where you have a pilot flying, and they are being fed pieces of information that the computer is seeing that the human couldn't decipher that helps them and enhances their performance," he said.

In hopes of guiding acquisition organizations in their use of AI, for example, a group of Air Force and Space Force acquisition program managers are assigned as fellows to the accelerator for four months—dubbed "Phantoms"—and developing the first toolkit-style document describing, "This is how you need to think about machine learning when you acquire it, when you contract for it," Hamilton said. "How should you think about this technology when you're diving into it—when you're trying to hire industry partners to solve a problem you have using machine learning? What are the things you should be thinking?"

Courses have ranged from a senior leaders' course for general officers; to leaders' courses for squadron commanders and civilian government executives; to a coders' course "that's very intense … for a select few," Hamilton said. "We're trying to teach people organic ability to code and to create machine learning algorithms and go through data."

Thanks to such a close partnership with "a world-class academic institution," Hamilton said, "We're making advancements revolutionary to the entire field—the entire world." ✪

GE Aviation to be Standalone Company

By John A. Tirpak

GE Aviation, which primarily makes military and commercial engines, will become the main focus of the GE conglomerate after it spins off its health care and energy businesses, the Boston-based company announced Nov. 9.

Three new companies will result from the action: GE Aviation, focused on military and commercial engines; GE Healthcare, focusing on advanced diagnostic gear and patient data; and GE Renewable Energy and Power. The moves will take effect by early 2024.

According to a company press release, "Following these transactions, GE will be an aviation-focused company shaping the future of flight." The company doesn't expect any regulatory or labor issues attending the split, and GE said there was no investor pressure behind the move.

In a statement, CEO H. Lawrence Culp Jr. said that "by creating three industry-leading, global public companies, each can benefit from greater focus, tailored capital allocation, and strategic flexibility to drive long-term growth and value." The move was spurred by a desire to focus and simplify its businesses, reduce debt, and improve share price.

Culp will initially head the GE health care company as "non-executive chairman … upon its spin-off. He will continue

1st Lt Savanah Bray

An F-15EX from the 53rd Wing takes off from Joint Base Elmendorf-Richardson, Alaska, in support of Northern Edge 2021 in May. General Electric will be the sole provider of engines for the F-15EX Eagle II under a new, $1.58 billion contract with the Air Force.

to serve as chairman and CEO of GE until the second spin-off, at which point he will lead the GE Aviation-focused company going forward."

The company said GE Aviation's focus will be "helping customers achieve greater efficiency and sustainability, and [to] invent the future of flight." It aims to offer "global leadership in propulsion and systems with the most competitive and innovative engine value." GE has the "youngest and largest commercial fleet and most diversified services portfolio," and it "powers 2/3 of commercial flights," according to the company.

Stock analysts value GE Aviation at anywhere from a low of $30 billion to a high of $100 billion. Culp has praised the company as the bright spot of the GE conglomerate, and leading analysts have said the bulk of GE's value is in its aviation business.

GE's major military business centers around the F110 engine in Air Force and export F-15s and F-16s; F404 and F414 engines in the Air Force T-7, Saab Gripen fighter, Navy F/A-18 Super Hornet, and Navy EA-18G Growler; and the T408 engine in the Marine Corps CH-53K. It recently won a $1.6 billion Air Force contract to supply F110 engines for the Air Force's F-15EX, and competitor Pratt & Whitney said it does not plan to challenge that award.

For commercial applications, the company makes the GE90, GE9X, GP7-200, CF-6 and GEnx, the latter of which may power the next Presidential Transport. GE was not selected in the recent Air Force competition to power the re-engined B-52 bomber.

The company said it fields 37,700 commercial aircraft engines and 26,500 military aircraft engines.

Another potential avenue of future GE business is the Adaptive Engine Transition Program, which has created two versions of a future fighter engine for the U.S. Air Force and potentially the Navy. GE's version is the XA-100, while Pratt & Whitney's in the XA-101. The Air Force has not said whether its acquisition strategy for the Next-Generation Air Dominance fighter will call for a single engine supplier or two, on a competitive basis, but GE is also hoping to capture some of the work for future propulsion of the F-35 fighter, on which Pratt & Whitney has been the sole supplier.

Just 20 months ago, Pratt & Whitney became part of Raytheon when that company merged with United Technologies/Collins Aerospace. Analysts said it's unlikely that another major defense prime would seek to merge with or buy the new standalone GE aviation before mid-decade. ✪

The Plan to Rescue Depots

By John A. Tirpak

Calling the condition of the military's depots, shipyards, and arsenals a "crisis," House Armed Services Committee Readiness panel chair John Garamendi (D-Calif.) gave Pentagon acquisition and sustainment officials three months to return a five-year plan for modernizing the military's organic industrial base, warning that the "request … will be enforced."

Although Pentagon leaders call the in-house industrial plants "national treasures," Garamendi said, the "supposed commitment" to their rehabilitation "is not translated into action," and the facilities are "chronically underfunded, to the point where [they] are relics of the past." The "crumbling, WWII-era depots are outdated for today's missions," Garamendi asserted, adding, "some are on the national historic register."

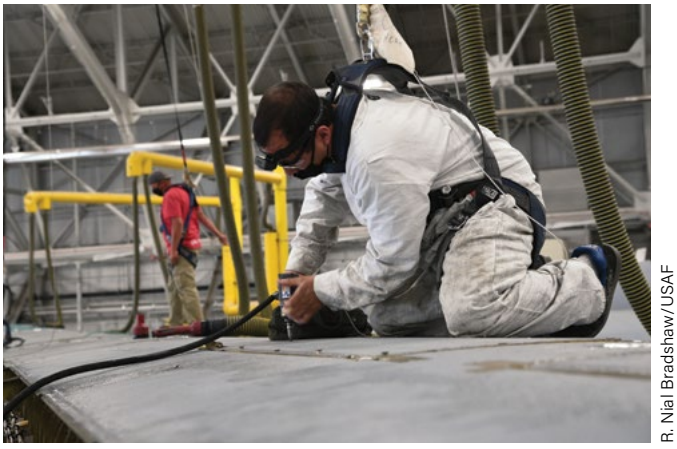
Citing a Government Accountability Office report, Garamendi said the depots are struggling with equipment that in many cases is a decade past its life expectancy. The conditions are hazardous, safety is threatened, and the system is inefficient, and not prepared for tomorrow's weapon systems, he charged.

Garamendi chided the services for supplying 20- to 25-year plans for modernizing the facilities. "I've told all the witnesses here today that there is no such thing as a 25-year plan," he said. "That is a cheap way of saying you don't have a plan." He added that he "cannot imagine any private-sector industry accepting a 20-year timeline to catch up to its competitors. But that is what the military is saying."

Within three months, Garamendi said the committee will expect a "detailed" five-year plan of the highest-priority projects for each service, with "the preliminary engineering and environment" assessment. He also wants detailed budget plans, saying, "Show me the money."

Committee ranking member Rep. Doug Lamborn (R-Colo.) agreed with Garamendi on most counts and echoed the demand for the five-year plan in three months

Garamendi was particularly incensed that depot projects were on the services' unfunded priority lists. Calling that a "resource play," he said such a move "sends the message that the facility and equipment optimization is optional; in other words, not a priority. … It can't be both 'absolutely essential' and then not prioritized."



R. Nial Bradshaw/USAF

Jon Pena, 309th Aircraft Maintenance Group pneudraulic systems mechanic, removes a panel from a C-130 wing at the Ogden Air Logistics Complex, Hill Air Force Base, Utah.

He said, "Both sides" of the aisle will "find a way … to know what you've proposed" in service budgets for depots in fiscal 2023 and after, "and then we'll find out what the Secretary approved, and if those don't match the five-year expectations of the committee, … your replacements will hear from us. This committee is not messing around."

While he said he understood that each of the witnesses are "acting" as service acquisition executives pending nominations and confirmations of political appointees, he warned them, as senior advisers to the eventual incumbents, to advise a straightforward and urgent plan to deal with the depots. "The heat is going to be upon you," he said.

Garamendi also said the committee "may do prioritization" of projects among the services, to make sure those most pressing are dealt with first. He also admitted that Congress bears some responsibility for the issue, as continuing resolutions instead of approved budgets have made it easier and sometimes necessary for the services to reprogram funds from the organic industrial infrastructure to pressing weapons programs.

Air Force acting acquisition, technology, and logistics executive Darlene Costello said the Air Force is applying "the same level of urgency" to the organic sustainment enterprise as it is to its combat capabilities.

"Our current aircraft inventory is becoming significantly more expensive to maintain as it ages," she said, increasing in cost 130 percent over 20 years due to its average age, "even with a 15 percent decrease in total aircraft inventory" over the same period. At an average age of 29 years, "the Air Force fleet is the oldest in the Department of Defense. Air Force depot workers are developing new processes and using new tools to speed things up, she said, and in 2021 delivered "602 aircraft, 316 engines, 141,353 parts, and 611 software bundles to the warfighter."

"But even with creative problem-solving, our challenge is exacerbated by the aging infrastructure, a dwindling supply and manufacturing base, and challenges recruiting highly skilled technicians and STEM workforce. It's essential that Air Force depots "stay ahead of future missions" and build infrastructure to deal with fifth-generation systems in volume, she said.

In 2019, the Air Force built a "20-year strategic plan to revitalize the depots" that would improve readiness. "We continue to refine that plan," she said, noting the Air Force has spent $2 billion over the previous four fiscal years to improve the infrastructure and equipment across the three complexes. The program is called "Keep Up, Catch Up, and Leap Ahead," and Costello said a congressional mandate of 6 percent of service spending on depots is regarded by the Air Force as "the floor. … We want it to be more."

Members and witnesses agreed that updated facilities would go a long way in recruiting and retaining essential workers, while antiquated facilities would cause them to leave. A majority of the depot workforce is nearing or at retirement age.

Most of the half-dozen members in the hearing questioned Costello and her peers at the Army, Navy, and DOD about whether they believed vaccination mandates were threatening to force many essential workers out of their jobs, but the witnesses said that vaccination rates are running above 96 percent and they have heard no widespread complaints. ✪

CYBERCOM Deputy Likens Cyber Warfare to Mixed Martial Arts

By Shaun Waterman

Some strategists have urged America's cyber warriors to think more like a hockey team than a football team. But the second-in-charge at U.S. Cyber Command prefers a different sporting analogy—the gladiatorial combat known as mixed martial arts.

"I've heard people say we probably want to get closer to what you see in hockey, which has much quicker transitions [between offensive and defensive plays]," Cybercom Deputy Commander Air Force Lt. Gen. Charles L. Moore Jr. said, discussing the relationship between offensive and defensive campaigns carried out as part of Cyber Command's strategy of persistent engagement. But he added that neither football nor hockey properly captured the freewheeling essence of cyber combat.

"In my mind, we want to get something a lot closer to mixed martial arts—you have people that are fighting one another, they're not thinking, 'Hey, right now I'm on defense, and I'm going to do something defensively.' Or 'OK, now I'm going to try some offensive moves.' It is much more inherently blended in and seamless. So that's how I would suggest we need to think about it and where we need to go."

In his remarks at C4ISRNet's CyberCon virtual event Nov. 10, Moore also touched on the need to defend U.S. military space assets in cyberspace; the vulnerabilities inherent in the Defense Department's joint all-domain command and control (JADC2) operating concept; the posture of North Korea's state-backed hackers; and the difficulties in measuring the effectiveness of cyber campaigns.

Moore said persistent engagement has been successful both defensively and offensively since Cyber Command adopted it in 2018. The strategy involves continuously infiltrating adversary networks, not just to prepare to take them down in a future conflict, but also to engage the adversary now and try to change their decision calculus about the use of cyberattacks in "gray zone" or hybrid war strategies.

Senior Airman Colin Hollowell

A defensive cyber network operator assigned to the 800th Cyber Protection Team, Joint Force Headquarters Cyber-Air Force, configures a cyber weapons system at RAF Fairford, U.K., in October.

Defensively, the command has been able to block some enemy cyber campaigns before they were even launched, Moore said, "In many cases, … we've been able to stop operations and attacks from happening to begin with." He added that U.S. operations into adversary networks have revealed "what they may be trying to do to our country, and to our friends and allies; what infrastructure they may be using; what tools; what malware or cyberweapons they may be developing." He said by publicly providing samples of malware being readied for adversary campaigns, "we've been able to … inoculate

not just ourselves, but the broader cybersecurity enterprise against them."

Moore said Cyber Command's presence on adversary networks put it in a position "to achieve the effects that we want to achieve on behalf of the ... nation in times of crisis or conflict." But it's also "given us more opportunities for access, more opportunities to impose cost." In many cases, he added, it's exposed campaigns in the planning stage.

Touching on the need to defend the nation's space assets in cyberspace, Moore said that of the 14 additional cyber combat teams funded in the current year budget, half of the them were specifically earmarked "to help us address defending our space capabilities, and also to present any type of offensive capabilities from a cyber perspective that we may need in that [space] domain." He said the teams would be up and running by the end of 2024 and fully trained within a year to 18 months after that, "so we're working very closely with the U.S. Space Command to get those teams stood up to get them bedded down and get them operating."

On the Pentagon's plan to create a fully networked and connected Internet of Military Things—known as JADC2—Moore said Cyber Command would have two key roles: first, to contribute the "cyber picture" to the common all-domain operating picture JADC2 requires. But also to defend the infrastructure that would make the common operating picture and decision-making tools of JADC2 available to commanders. Moore said the integration of all-domain sensing and decision-making would greatly multiply the potential cyberattack surface for adversaries.

"As you can imagine, potential vulnerabilities exist across all the different domains in the way that we gather the information and transport the information, make it visible to decision makers; and then how ... directions go back out to the broader force." Joining all those vulnerable systems together made them much harder to defend, Moore said, and added complexity—often seen as the enemy of cybersecurity.

"For every unit of increase that we have in effectiveness and efficiency gained by integration, which is really the goal of [JADC2], you probably have an increase in potential cyber vulnerabilities [of a power of two] at least," he said, jokingly analogizing his own rule of thumb to Moore's law, which famously predicted that computing capacity would double every 18 months. "Maybe I'll name that Charlie Moore's law," he said, "the point being that you have an increase in that net surface area of vulnerability that we have to make sure we're postured to help defend from the ground up."

Responding to a question about North Korea's prolific state-backed hackers, Moore said that they appeared more focused on financial cybercrime to provide hard currency to the regime, rather than more conventional computer network attack activities. "The North Koreans mainly seem to be focused really on revenue generation," he said. "They're not too focused, from what we see from a day-to-day perspective, ... on trying to perform operations against the United States, against our Defense Department Information networks, but rather very much trying to generate money to support the regime."

Although it was often hard to measure the effectiveness of cyber campaigns, Moore said, Cyber Command leadership sometimes got feedback "directly from our adversaries about what they're thinking and how they're responding" because U.S. cyber warriors had infiltrated the networks they use to communicate.

"That's very informative and tells us when we're on target or hitting something important," he said.

A One-Stop Shop for AR/VR Training

By Amy McCullough

Air Education and Training Command (AETC) has validated a new platform to keep track of disparate augmented and virtual reality (AR/VR) training programs across the command with the goal of speeding up the training pipeline and creating a digital training record that will follow Airmen throughout their careers.

The new technology, developed by Dynepic and dubbed the Member Operations Training Analytics and Reports (MOTAR) platform, will soon be distributed to AETC wings—and the rest of the Air Force is taking notice.

"Basically, what we are is the glue that pulls all these augmented reality, virtual reality mobile applications" into a "central portal," said Krissa Watry, co-founder and CEO of Dynepic Inc. MOTAR enables applications from various companies to be "distributed into courses," creating a "seamless user experience for the student and instructor."

It also collects user data into a single interface, creating digital training records for Airmen, and includes live learning dashboards so instructors can monitor students' progress.

The company won the AFWERX Mixed Reality Challenge in 2019 followed by a series of Small Business Innovation Research Phase 1 and 2 contracts then a multiyear Phase 3 contract supporting AETC's Maintenance Training Next program, which has since evolved into Technical Training Next.

USAF

MOTAR, or Member Operations and Training Augmented Reality, is a new idea that could revolutionize aircraft maintenance using augmented reality to reduce human error and increase training speed.

During the pilot program, MOTAR powered a revamped Crew Chief Fundamentals Course at Sheppard Air Force Base, Texas, with a single login and consolidated dashboard for various AR/VR applications, according to a company release. The web-based, device-agnostic platform also hosted 360-degree videos, documents, and assessments so participants in the crew chief course could learn whichever way suited them best.

Dynepic also won AFWERX's 2020 Recruiting, Reimagined Challenge, adding recruiting elements to the MOTAR platform for both the Air and Space Forces, and it was one of seven

companies to win AFWERX's Accelerating Pilots to Combat Ready Aviators Challenge, adding another 15 products to the MOTAR platform in support of aircrew training.

Andrea Hagen, a program analyst with Air Combat Command's Capability Development Engine Room, told Air Force Magazine that although the command is much earlier in the process than AETC, the platform could one day play into ACC's Reforge fighter pilot training plan. Reforge looks to cut in half the time needed to transform a recently graduated student pilot into a fighter flight lead by pairing the new T-7 Red Hawk's in-jet simulation capability with ground-based virtual reality and artificial intelligence.

"One of the things we are missing is a [Learning Management Sytem] we can use across different FTU school houses," Hagen said. "We have multiple around ACC. They're kind of all doing their own thing, but we're looking for one common platform, and MOTAR kind of fits that bill."

The Air Force Life Cycle Management Center Simulators Division at Wright-Patterson Air Force Base, Ohio, also selected MOTAR for its new Lightweight Simulators Ecosystem (LSE) during its Simulators Pitch Day, according to a company release.

Margaret Merkle, AFLCMC'S chief innovation officer for simulators, told Air Force Magazine the service is striving to bring together various digital training assets and capabilities into one platform so Airmen can access them from anywhere anytime they need it.

"Today, things are stovepiped in certain areas where they are developed, and that's very hard to … reach back into those records from different disparate systems," she said. "This gives us a platform to make that connectivity of all that performance data for those Airmen across the commands," and though training remains with the individual major commands, Merkle said, "We see this as a tool to enable that to be done easier and delivered more quickly."

Merkle and Hagen were among the 300 people from various commands, including AETC, ACC, Air Force Special Operations Command, and AFLCMC, to attend the MOTAR Expo at Joint Base San Antonio's Kelly Field on Nov. 4.

The expo offered Air Force units a chance to share how they are using the platform and showed those considering adopting AR/VR tech in the future ways it might be useful for them. Air Force representatives had a chance to interact with 28 different MOTAR vendors and learn how they are advancing immersive technologies and using the MOTAR platform to rapidly distribute it.

"What we're looking to do here is to get cross communication between all of the different parties … and learn lessons from each other, share progress with each other," Merkle said. "What MOTAR brings to bear on this is the fact that we can share digital assets underneath these various projects to allow each project to build faster towards their end point and not repeat steps early in the development cycle."

She offered the example of taking an aircraft offline to make digital scans of it. Those scans can then be shared with different entities looking to build training programs centered around that aircraft. One group may be looking to build a training program to teach the proper way to load weapons on that aircraft, while another will teach how to maintain it, and yet another could use the simulation for pilot training.

"We could take that one digital model and share it with all three of those projects," Merkle said. "And each one of them will progress a little faster because they don't have to do the same things over and over again." ✪

Airman 1st Class Jonathan Ramos

Airman 1st Class Matthew Jasper works on an Air-launched Cruise Missile (ALCM) at Barksdale Air Force Base, La., Oct. 18.

Pentagon Solicits Allies' Input In Drafting Nuclear Posture Review

By Greg Hadley

The U.S. has consulted with allies regarding its ongoing Nuclear Posture Review and will continue to do so, the Pentagon said Nov. 8 after a media report indicated other nations have been pressing President Joe Biden not to change American policy on the use of nuclear weapons.

"Without getting into specific details, I mean, for understandable purposes, what I can tell you is that we are, as appropriate, consulting with allies and partners in the course of this review and certainly remain open to listening to and hearing out their perspectives," Pentagon Press Secretary John F. Kirby told reporters during a briefing

The Nuclear Posture Review, scheduled to be released in 2022, will likely set U.S. policy for its nuclear weapons arsenal and comes at a key moment. China has dramatically built up its array of intercontinental ballistic missile silos in recent months, while U.S. lawmakers continue to debate whether to modernize several aging legs of the nuclear triad or extend them.

Biden has said in the past that the U.S. should move to a policy of "sole purpose" whereby the sole purpose of American nuclear weapons is to deter nuclear use against the U.S. or its allies. Others, meanwhile, have pushed for a "no-first-use" policy, whereby the U.S. would pledge to never use nuclear weapons first in a conflict.

The Financial Times reported Oct. 29 that U.S. allies, including the United Kingdom, France, Germany, Japan, and Australia, were all lobbying Biden not to commit to a "no-first-use" policy, arguing that doing so would weaken deterrence against China and Russia.

Citing two anonymous sources, the Financial Times also indicated that the U.S. sent a "questionnaire" to allies "who provided an overwhelmingly negative response to any changes in nuclear policy."

On Nov. 8, Reps. Mike Rogers (R-Ala.) and Michael McCaul (R-Texas), ranking members of the House Armed Services Committee and House Foreign Affairs Committee, respectively, announced they had sent a letter to Secretary of State Antony J. Blinken and Defense Secretary Lloyd J. Austin III, requesting a copy of that questionnaire, as well as "copies of

each response received from U.S. allies, and any other cables or memos conveying ally views regarding a potential change in U.S. nuclear declaratory policy."

That same day, Kirby declined to comment on the letter sent by Rogers and McCaul, saying he had not seen it. Yet while he did not directly confirm the Financial Times report, he did indicate that partner nations were welcome to provide their input on the Nuclear Posture Review.

"I think across the review itself, the views and perspectives of our allies and partners are important and consultations with them and hearing them out and their perspectives has been and will continue to remain important as the review continues down the path," said Kirby.

"I'm certainly not going to speculate one way or the other about policies inside that review and what that's going to look like," Kirby added. "But I would tell you just two things. It has been and remains an inclusive, comprehensive process that's looking at the broad swath of our strategic deterrent capabilities here in the United States. And No. 2, any policy decision of that nature is going to ultimately be made by the President of the United States."

C-130 Catches an X-61 Gremlins Vehicle in Airborne Recovery Test

By Amanda Miller

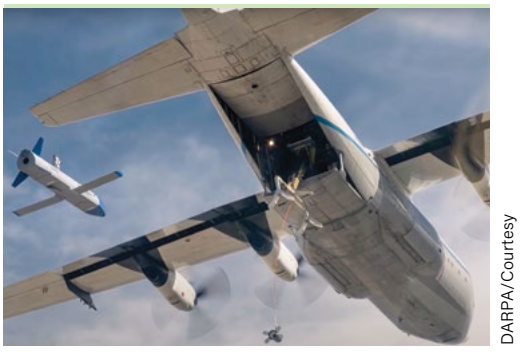
The Defense Advanced Research Projects Agency (DARPA) crashed one of its four remaining Gremlins air-launched drones during a flight test in October but not without demonstrating some of the autonomous swarming program's key objectives.

In tests, the X-61 Gremlins Air Vehicles, or GAVs, launch from the wing of a C-130. October's test at the Army's Dugway Proving Ground, Utah, both "successfully validated all autonomous formation flying positions and safety features" and "ultimately demonstrated airborne recovery to a C-130," according to a Nov. 5 DARPA news release. Dynetics is the prime contractor on the program, and Kratos Defense builds the X-61s.

A video posted to YouTube shows the recovery. It begins with an X-61 in flight. A mechanical arm and a tether with a node on the end, described by the program as a bullet, extend from the back of a C-130. The X-61 connects with the bullet then the vehicle's wings swivel 90 degrees until they're stowed parallel with the main body. Next the X-61 is reeled in by the tether until it's secured in the grip of the mechanical arm, which hauls it the rest of the way inside the C-130.

Lt. Col. Paul J. Calhoun, the Gremlins program manager in DARPA's Tactical Technology Office, said in the release that the recovery operation "demonstrates the feasibility of safe, reliable airborne recovery," and "was the culmination of years of hard work."

In addition to the autonomous formations and the recovery performed during the course of four flights of single X-61s, DARPA demonstrated that it could refurbish an X-61 after a flight and have it flying again within 24 hours. Plus, "many hours of data were collected over four flights including air vehicle performance, aerodynamic interactions between the recovery bullet and the GAV, and contact dynamics for airborne retrieval," according to the release.



DARPA/Courtesy

One of DARPA's autonomous swarming Gremlins crashed, but the October test confirmed many of the program's key objectives.

Intended to collaborate as a swarm, recoverable air-launched autonomous vehicles promise to "dramatically expand" the distances at which drones can be deployed and their potential uses, DARPA says.

The first airborne Gremlins test in January 2021 demonstrated some fundamental aspects such as data links and the vehicles' ability to transition to powered flight. An X-61 also crashed in that test after a parachute didn't deploy, but the parachute was only meant for the test.

A DARPA spokesperson confirmed that after the second crash in October, from an electrical system failure, the agency now has three working X-61s and those will be enough to prove, mathematically, the ultimate goal of flying and recovering four X-61s in under 30 minutes.

'Confirmation Bias' Cited in Afghanistan Strike That Killed 10

By Abraham Mahshie

Three days after 13 Americans were killed at Hamid Karzai International Airport in Kabul, a U.S. Central Command strike cell in Qatar made a series of assumptions over the course of eight hours based on the intelligence available at the time, leading to the death of 10 innocent civilians, including seven children, according to the final report by the Air Force inspector general.

Lt. Gen. Sami D. Said interviewed 29 individuals, including 22 directly involved in the operation, as part of a 45-day investigation directed by Defense Secretary Lloyd J. Austin III and ordered by Air Force Secretary Frank Kendall before briefing senior defense officials.

"Individuals involved in this strike that were interviewed during this investigation truly believed at the time that they were targeting an imminent threat to U.S. forces on HKIA," Said relayed.

He said the strike cell made a "reasonable" conclusion that the white Toyota Corolla driven by aid worker Zemari Ahmadi was a vehicle of interest, based on "intelligence available that correlated the Corolla to particular locations."

Said stated the strike was made in self-defense during a vulnerable time when 13 service members had just been killed. Ground intelligence was not available and there were many known terrorist threats as the evacuation deadline neared.

The inspector general, however, said confirmation bias then crept in, making analysts believe Ahmadi was acting suspiciously. A stop at a suspected ISIS location and handover of a computer bag was one example, since a computer bag was used in the Aug. 26 HKIA attack.

Despite the execution errors, he said the investigation "found no violation of law."

"What likely broke down was not the intelligence, but the correlation of that intelligence to a specific house, the inference that what the intelligence is talking about is that house and that car," he added. "There's an art to that, and that's where the disconnect and correlation broke down."

Assignment of accountability may still come through the chain of command. Possible repercussions may include de-credentialing, firing, or retraining individuals involved, according to the Pentagon.

Navy's Grady Tapped to Succeed Hyten as Vice Chairman of JCS

By Greg Hadley

President Joe Biden nominated Adm. Christopher W. Grady, head of the Navy's Fleet Forces Command, to take over as Vice Chairman of the Joint Chiefs of Staff.

The Senate received the nomination on Nov. 1, and Grady's confirmation hearing is expected to begin on Dec. 2, according to reports.

USAF Gen. John E. Hyten, who took on the role of vice chairman in November 2019, announced last year that he would not seek another term as the military's No. 2 officer behind the Chairman of the Joint Chiefs. Throughout his tenure, he has criticized the overclassification, bureaucracy, and risk aversion in the Pentagon, warning that China could soon overtake the U.S. in military power if action is not taken.

USN

Adm. Christopher Grady

Petty Officer 1st Class Carlos Vazquez II/DOD

USAF Gen. John Hyten

With Hyten scheduled to depart in late November, Grady's nomination would have to be rushed through in near-record time to avoid a vacancy. Hyten's nomination process stretched on for more than five months, and every Chairman and Vice Chairman in the last decade has taken at least a month to be confirmed by the full Senate.

Grady has led the Navy's Fleet Forces Command/U.S. Naval Forces Northern Command since May 2018. He has also held the duties of commander for U.S. Naval Forces Strategic Command and U.S. Strategic Command Joint Force Maritime Component since February 2019.

Grady also served as commander of the 6th Fleet and the Naval Striking and Support Forces NATO, as well as deputy commander of U.S. Naval Forces Europe and U.S. Naval Forces Africa, and on the staff of the Joint Chiefs of Staff and as an aide to the Chief of Naval Operations.

Army Gen. Mark A. Milley ascended to the role of Chairman in October 2019, and his term is set to last until 2023.

Guard Chief: 'Entire Fighter Fleet' And More Needs To Be Modernized

By Greg Hadley

The Air National Guard badly needs to modernize its fleet, not only for operations in the homeland but also for its warfighting mission, the head of the National Guard said Nov. 10.

Army Gen. Daniel R. Hokanson, chief of the National Guard Bureau, said the ANG's "entire fighter fleet" needs to be modernized, with aging F-15C/Ds and F-16s swapped out for newer F-15EXs and fifth-generation F-35s.

"We want to … make sure that we have a pathway to modernization for each of our fighter squadrons because it's an incredible capability," Hokanson told reporters during a Defense Writers Group event in Washington, D.C. "But it's also a capacity issue for our nation, to make sure that whatever we get asked to do, … we can do."

As of fiscal 2021, the Air National Guard had some 470 F-15C/Ds and F-16s, with an average age of over 30 years, and just 19 F-35s. Lt. Gen. Michael A. Loh, Air National Guard director, said in September that roughly 20 F-15Cs in the fleet were grounded because the backbones of the aircraft were cracked. A number of Air National Guard units are slated to receive either the F-35 or F-15EX in the coming years.

But it's not just fighters that need to be upgraded.

Increasingly, the Guard has been called upon to combat wildfires in the West, and to do so, several of its C-130s have been outfitted with the Modular Airborne Firefighting System (MAFFS).

With MAFFS, C-130s are able to drop 3,000 pounds of retardant on a wildfire in less than five seconds, fly back, refill, and be in the air again in under 20 minutes. But the system needs improvements to keep up with the increasingly high tempo required.

"We've got to make sure that we're completely modernized so that they can perform the missions that they're being asked to do," said Hokanson.

FACES OF THE FORCE

Airman 1st Class Anna Nolte

Five members of the 18th Aeromedical Evacuation Squadron came to the aid of a fellow passenger during a commercial flight from Okinawa to Tokyo Sept. 10, assisted by a flight attendant who translated for the crew and the Japanese national in distress, **Capt. Andrew Jimenez, Senior Airman Joshua Egler, Capt. Geryn Lee Paguio, Senior Airman Deanna Adkins, and Staff Sgt. Elliot Sotnek** administered oxygen, documented the symptoms and medical steps taken to aid the passenger, passed that information to medical providers on the ground, and even diagnosed the issue—apparent decompression sickness after scuba diving—which can be fatal. The aircraft diverted and made an emergency landing, and the passenger was transported to a medical facility. When asked how it felt to save a life, Egler said, "It's a nice feeling, but it's what all of us medics do. That's why I became a medic, I wanted to help people, and it's the reason I put this uniform on."

Tell us who you think we should highlight here. Write to afmag@afa.org.

Courtesy/Hope for Warriors

Harry Fenstad, an 83-year-old USAF veteran, started offering water to cyclists in 2001 when he and his wife were building their dream home atop Sugar Loaf Mountain in Lake County, Fla. At first, he refused to take any payment for his act of kindness, but when cyclists began leaving money regardless, he started donating the funds to veteran's groups, then mounted a donation box next to the watercoolers. Over the past 20 years, the former pilot has raised more than $50,000, and even as his 84th birthday approaches sees no reason to end his efforts.

NASA

Retired Col. Guion "Guy" Bluford Jr. received the 2021 Air Force Reserve Officer Training Corps Distinguished Alumnus Award during a ceremony at Penn State. Graduating in 1964 with a bachelor's degree in aerospace engineering, he commissioned through the university's Air Force ROTC Detachment 720 program and went on to log over 5,100 as a fighter pilot during the Vietnam War, before being accepted into the NASA astronaut program in 1978. He became the first African American in space while a crew member aboard Space Shuttle Challenger in 1983.

USAF

On Sept. 1, Air Force Reserve **Lt. Col. John Marks** of the 442nd Fighter Wing at Whiteman Air Force Base, Mo., became the only Airman ever to log 7,000 hours in the autocannon-toting A-10C Thunderbolt II attack plane. His resume boasts 13 combat deployments in multiple theaters of operations, and he said that the best part of his job is being able to "mentor and fly with the next generation of fighter pilots." Marks' story spans over three decades, beginning during the Cold War. He is well-known for destroying 23 Iraqi tanks in a trio of missions.

Airman 1st Class Trenton Jancze

Rosemary Cook, the 97th OSS commander's secretary and a Navajo Nation native, received a 2021 Society of American Indian Government Employees Military Meritorious Service Award, which honors military members, veterans, and Department of Defense employees who have risen above and beyond the mission and whose character best represents the core values of their military branch. Cook serves as her commander's trusted representative, executing over 3,000 tasks and overseeing more than 140 additional duties. She is the "lifeblood" of the 97th OSS, said 97th AMW executive officer Capt. Caleb Egli.

Courtesy

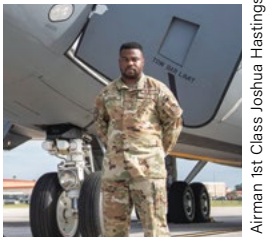
Military spouse **Jessica Saum** knew students and staff had gathered in the Panther Arena at the Stagecoach Elementary School in Cabot, Ark., for a reading pep rally. What she didn't know was she was also about to be announced as the 2022 Arkansas Teacher of the Year during a surprise celebration. Saum's parents had flown in from South Carolina to be there and her husband, Lt. Col. Shane Saum, also recorded a special video for the ceremony since he is currently on a one-year unaccompanied assignment to Lajes Field, Azores, as the 65th Air Base Squadron commander.

Airman Jared Lovett/USAF

1st Lt. Gabriel Houston, 786th Civil Engineer Squadron engineering chief, and his wife **1st Lt. Merrick Choate-Houston,** 86th CES installation Management Flight deputy, played key roles in Ramstein AB's Afghanistan evacuation support operations. He created a plan to build a secure living area for tens of thousands of evacuees, designing the blueprint for pods that had to be built in a matter of days. She oversaw the transition of the sustainment of the pods to contractors, allowing Airmen to return to their primary missions. Now, they are working to reconstitute materials used in the pods and prepare the flight line for normal function.

Jason Wilkinson/USAF

On Aug. 18, Senior Airman Brian Chambers found his young daughter choking and drove her to the JBSA-Lackland Fire Station 1. **Jacob Mathie,** lead firefighter for the 502nd Air Base Wing at JBSA-Lackland, was able to perform first response triage and unblock the child's airway. "I ... was doing some laundry when a vehicle pulled up front," Mathie said. "A gentleman jumps out of his car holding a blue, limp baby that's not moving or breathing—he hands the baby to me and says, 'Help me.' ... After about a set and a half of the Heimlich, I was able to get the hot dog out of her throat. I rubbed her chest to get her to breathe, and she started breathing."



Airman 1st Class Joshua Hastings

Master Sgt. Michael Fulton received AMC's 2021 Gen. Robert "Dutch" Huyser Outstanding Aircrew Member Award, Boom Operator category, for sustained excellence in Airmanship. He was deployed to Al Udeid AB, Qatar, where he served as the 50th Expeditionary Air Refueling Squadron's first sergeant, providing guidance on emergency and tactical procedures impacting operations Inherent Resolve and Freedom's Sentinel. He was also awarded the Air Force Commendation Medal for actions that resulted in saving the life of a member, and his unit was recognized with the 2020 Senior Master Sgt. Albert Evans Outstanding Air Refueling Section Award.

The Air Force likes the F-35's capabilities and combat performance, but it's more expensive to operate than the service predicted and can afford. A new contract give Lockheed Martin a fresh chance to bring those sustainment costs down. Here, an F-35 readies for takeoff from Joint Base San Antonio-Kelly Field, Texas.

Brian Rhodes/USAF

Can a Service Contract Save the F-35?

Chronically high operating costs might be tamed with a new deal.

By John A. Tirpak

The Air Force is pleased with the F-35's performance in combat, and plans on it being the "cornerstone" of the fighter fleet over the next 30 years. The jet's high operating costs—$36,000 per hour—threaten the program, though, and the Air Force only plans to buy minimal numbers of the fighter until those costs close on what was originally planned: $25,000, by 2025, in 2012 dollars.

A new sustainment contract between the F-35 Joint Program Office (JPO) and Lockheed Martin, inked in September, will give the company a chance to bring down operating costs over the next three years. If it can, it stands to earn even bigger contracts and be the sole-source provider of future F-35 sustainment services over decades. If it can't, F-35 users could bring the sustainment work in-house, performing the work themselves, or potentially bringing in other contractors.

High operating costs are "an existential threat to the F-35."
—Lt. Gen. Eric Fick, Joint Program Office director

There's little doubt that operating costs are the central issue with the F-35. House Armed Services chair Adam Smith (D-Wash.) recently referred to the F-35 as a "rathole" because of its chronic sustainment issues. Air Force Chief of Staff Gen. Charles Q. Brown Jr. said that if F-35 sustainment costs don't come down, the Air Force will either have to fly the fighter less often—reserving them just for "high-end missions"—or buy fewer of them. House Armed Services Readiness panel chair John Garamendi (D-Calif.) promised no typical budget boost in F-35 purchases, because buying more jets was just forcing users to spread limited spare parts over too many airframes.

The Government Accountability Office (GAO) issued two reports on F-35 sustainment so far in 2021: "Enhanced Attention to and Oversight of F-35 Affordability Are Needed," in April, and "DOD Needs to Cut Billions in Estimated Costs to Achieve Affordability," in July.

In the July audit, the GAO advised the Pentagon—and Congress—that buying more F-35s should be "contingent on DOD's progress" in constraining F-35 operating costs.

"There's a substantial and growing gap" between what the services thought they'd be spending on F-35 operations and what they actually are, the GAO said. By 2036, it expects that gap to widen to $6 billion without corrective action soon. For the Air Force alone, the gap will be $4.4 billion in 2036.

Joint Program Office Director Air Force Lt. Gen. Eric T. Fick acknowledged that high operating costs are "an existential threat to the F-35."

But Fick, in a wide-ranging discussion with reporters in September, also said the F-35 is already close to "delivering fifth-gen capabilities at high-end fourth-generation costs." By comparison, the F-15EX and F/A-18E/F cost about $29,000-$30,000 per hour to operate, and the new sustainment contract stipulates that Lockheed will get F-35 operating costs down to $30,000 per hour by the end of 2023. The Air Force wants the F-35 hourly cost comparable to the F-16, historically around $22,000 per hour, but in fiscal 2020 it was up to $27,000 per hour.

The $30,000 per hour goal by 2023 is for the entire air vehicle,

Defense Contract Management Agency/Courtesy

The COVID pandemic slowed down production at the F-35 line in Fort Worth, Texas, seen here, and among the enterprise's parts vendors. The jets have needed more upkeep and their stealthy coatings have required more attention than anticipated.

including the Pratt & Whitney F135 engine, Fick noted, but sustainment contracts with Pratt are negotiated separately from Lockheed Martin. The grand number includes "a placeholder for propulsion," he said.

What are the main problems? Garamendi zeroed in on a big one: The F-35 fleet is growing all the time, but vendors have a limited capacity to make parts for jets both on the production line as well as those in the field. Because of different variants and configurations of the F-35, there are several versions of many parts. The COVID pandemic has slowed production of jets and parts alike, and the F-35's stealthy materials have needed more upkeep than anticipated.

Another is the Autonomic Logistics Information System, or ALIS. It was meant to automatically sense and schedule needed maintenance actions, but it's had teething problems, is hosted on obsolete hardware, and suffers from false alarms driving unnecessary parts changeouts. A successor system, ODIN, for Operational Data Integrated Network, is already taking over.

None of this is news. Former Pentagon acquisition and sustainment chief Ellen M. Lord said in 2018 that "right now, we can't afford the sustainment costs we have on the F-35. And we're committed to changing that."

Soon after, Lockheed Martin "table dropped" a Performance Based Logistics, or PBL proposal, on Lord's desk, Fick said. Lockheed said the new approach—which would provide an agreed level of aircraft readiness and manage the fleet accordingly—would get the Air Force to its $25K by the 2025 target. It also said that achieving the target without a PBL couldn't happen.

"There was reluctance, particularly on the part of the services, to hand the keys over … to do all of the F-35 sustainment," Fick said. Users were "unsatisfied" with the sustainment results up to that point, but are willing to explore Lockheed's proposal, he said.

Lord empaneled a working group headed by then-Navy acquisition executive James Geurts—who oversaw the F-35 program at that time—to "assess everything from a 'tip to tail' PBL" to annual maintenance contracts to find the right solution, according to Fick. The team included representatives from the Navy, Air Force, Marine Corps, a consulting group, the Office of the Secretary of Defense, operational experts, and others.

Skeptical of putting Lockheed completely in charge, the group looked for "something in the middle, where you can achieve most of the benefits" of a PBL "by focusing just on the supply chain management and demand reduction piece," Fick explained. The rest could be "offloaded onto [an annual] companion contract."

The task force created a memorandum of understanding signed by Geurts, then-Air Force acquisition executive Will Roper, Fick and Greg M. Ulmer, Lockheed's then-F-35 program manager, creating the terms of the contract awarded in September.

"We knew as a department that we did not want to be trapped into a bad deal … a bad PBL" that could be "weaponized" by Lockheed, Fick said. The "base year, plus two optional years" contract "puts us on a glideslope … in the right direction."

It was a carrot and stick approach. The carrot to Lockheed was the prospect of many years of exclusive F-35 maintenance. The stick was that the company had to provide, before or at the

ALIS to ODIN

The F-35 program is transitioning the troubled Autonomic Logistics Information System—ALIS—to a new system called the Operational Data Integrated Network (ODIN).

The ALIS has "historically ... been a trouble spot," F-35 Program Executive Officer Lt. Gen. Eric Fick acknowledged. Two years ago, the plan was for a swift turnover from ALIS to ODIN, but now it will be more of an "evolutionary transition," he said.

"ODIN has three parts," he explained. "It's about hardware, it's about an integrated data environment, and it's about software." The hardware on which ODIN will be hosted is already being fielded and upgrades to ALIS are being hosted on it.

"Over the next 12 to 18 months, we will be flowing this new ODIN-based kit, or OBK, as we call it, to 14 different installations, replacing their legacy hardware with this new and improved ODIN hardware," Fick said. The new gear is "90 percent lighter, 70 percent smaller, and about 30 percent cheaper" than the old, bulky ALIS equipment, he noted, while offering "substantially increased performance."

The system will make the F-35 more affordable due to the "increased performance alone," Fick said, because maintainers will spend less time keying-in codes and getting false alarms. The system shifts largely to barcode-type inputs rather than laborious entry codes.

This "should allow us, in time" to reduce the number of maintainers involved in ALIS, so they can work on the airplane, or, if they're contractors, to "take them off contract entirely. So, we're reducing that workload," he said.

Fick said the Joint Program Office has established the National ALIS Support Center, where it's consolidating system administrators "to help them adjudicate problems and challenges from the field to a centralized location," rather than at various bases. The results so far have been "positive," he said.

Software deliveries for ALIS/ODIN have also changed from "every two or three years" to "quarterly," Fick reported. These are aimed at "reducing user pain points," to make the system "more agile, easier to execute ... less people, less time."

The ODIN will "give us a quantum increase in our ability to support the fleet," Fick said, while in the near term, "we're ... making ALIS friendlier and easier to use. Putting it on faster hardware is goodness."

same time a PBL deal is signed, "the provisioning and cataloging data" that would allow the services to organically take over F-35 sustainment if Lockheed didn't perform, Fick said. The information is "the technical data associated with ordering the bits, parts, and pieces of the system—not full-up design data—that would allow an item manager to provide those ... pieces to the organic depots."

Originally, the F-35 program was a "TSPR" deal, or Total System Performance Responsibility; not unlike a PBL, but where Lockheed held all those data as its proprietary property.

"We're using, really, the incentive of a PBL to help us get some decent pricing on the tech data required," Fick observed, so that, at the end of the initial period, "the services and the department have an option" to go a different way.

"If it comes to pass that Lockheed really 'kills it' and we end up with great performance, then why would we not sign up for another PBL?" Fick asked. But if not, "then we have the data that allows us to do something different."

That would most likely be an "organic approach," Fick said, rather than an open competition with industry. Still, there are "some elements" that could be competed, he said.

Fick cautioned that a PBL arrangement after the initial 2021 to 2023 annual options contract "is still not a done deal." But if things go well in the first three years, the first PBL would run 2023 to 2027, and after that, the JPO would consider five-year agreements with Lockheed, he said. Also, Congress will have something to say about the approach, as will "other stakeholders."

The JPO already regularly does a five-year "business case assessment" on the F-35, examining exactly such issues as the best way to contract for maintenance. In September, the most recent assessment was still in final draft, but provided a "conscientious examination" of the options, Fick said.

Underlying the approach to the PBL is a desire for competition in what has been, thus far in the F-35 program, almost entirely a sole-source arrangement since Lockheed won the winner-take-all Joint Strike Fighter program in late 2001.

"I'm a strong supporter of competition," Fick stated. "I think it improves the breed in a significant way. It drives supportability and responsiveness [with] a focus that a sole-source environment doesn't." He said the program is looking at other ways to "inject" competition into the F-35, but couldn't be more specific.

Fick warned that bigger costs are coming with the F135 engine that will severely challenge the F-35 enterprise to keep costs down.

"We do expect to see annual costs for propulsion sustainment to increase," Fick said, explaining that "we are coming up on the first scheduled overhaul for many of the engines" in the 700-plus inventory of F-35s worldwide. "We will see a bit of a bump on the costs on the propulsion side" as those engines reach 2,000 hours of service.

Fick said that in September, 42 F-35s were down for engine parts, a number which has been fairly consistent in recent months, but he said that number is down a bit. The Air Force canceled some air show demonstrations of the jet to preserve training sorties.

Amanda Glode, Pratt & Whitney's director of sustainment for the F135, told reporters at a plant visit in October that engine costs will be going up "at the exact point the U.S. services and the entire program want the costs to be decreasing." Pratt is meeting its contractual requirements that no more than 10 percent of F135s are down for maintenance or overhaul, but only just, at nine percent. The goal is six percent, and through much of the program, Pratt has achieved 4 percent, Glode said.

She also noted that planned investments in the F135's depot at Tinker Air Force Base, Okla., were raided to pay for other needs, with the result that the depot is "five years behind, in terms of where it should have been based on the program design and architecture."

Even so, Tinker is accelerating the time it takes to fix engines. Glode said the target is for the depot to generate 40 power modules in a year, a goal that it will "significantly" exceed this year, after only generating 14 modules last year. The time needed to do a power module is also dropping from 200 days to 120.

Pratt continues to make improvements to parts and materials that will keep the engines in service longer, Glode said. She

Paul Shirk/USAF

An F-35 takes off from Tinker Air Force Base, Okla., where the F-35's engines are serviced by the Oklahoma City Air Logistics Center. Most F-35 engines are coming due for their first big overhauls, adding a major expense just when the enterprise is trying to reduce maintenance costs.

noted a new fan blade coating that's giving the engine greater resiliency against desert dust, specific to the Middle East, that degrades them with moderate exposure.

Fick said policymakers should be cautious about how they approach reducing sustainment costs, even though he acknowledged they are "the place to go in looking for affordability" on the F-35. While Brown said the Air Force might fly F-35s less frequently to save money, there's an equation there that may not be obvious, Fick warned.

There's "cost per tail, per year" and "cost per flying hour," Fick said, "and you have to look at those both, not just independently."

To drive down cost per flying hour, "I do that by flying a ton," he said, which allows amortizing fixed costs over a greater number of flying hours. But "that actually drives my cost per tail per year up, because I'm flying more; I'm burning more gas and using more parts." Looked at another way, "I can reduce my cost per tail per year by flying less. … [By] offloading sorties to a simulator. But that will artificially drive my cost per flying hour up, because I'm now flying fewer hours and those same fixed costs are amortized over a smaller subset of hours."

Only a "holistic view" of both of those approaches gives a realistic picture of how to "reduce cost in a meaningful way."

It's an equation that will become more important because, Fick said—echoing leaders of Air Combat Command—it will be increasingly difficult to practice certain tactics and operations in the open, where adversaries can see what's happening. Only "in a synthetic environment" can F-35 pilots really practice their best tricks, away from prying eyes.

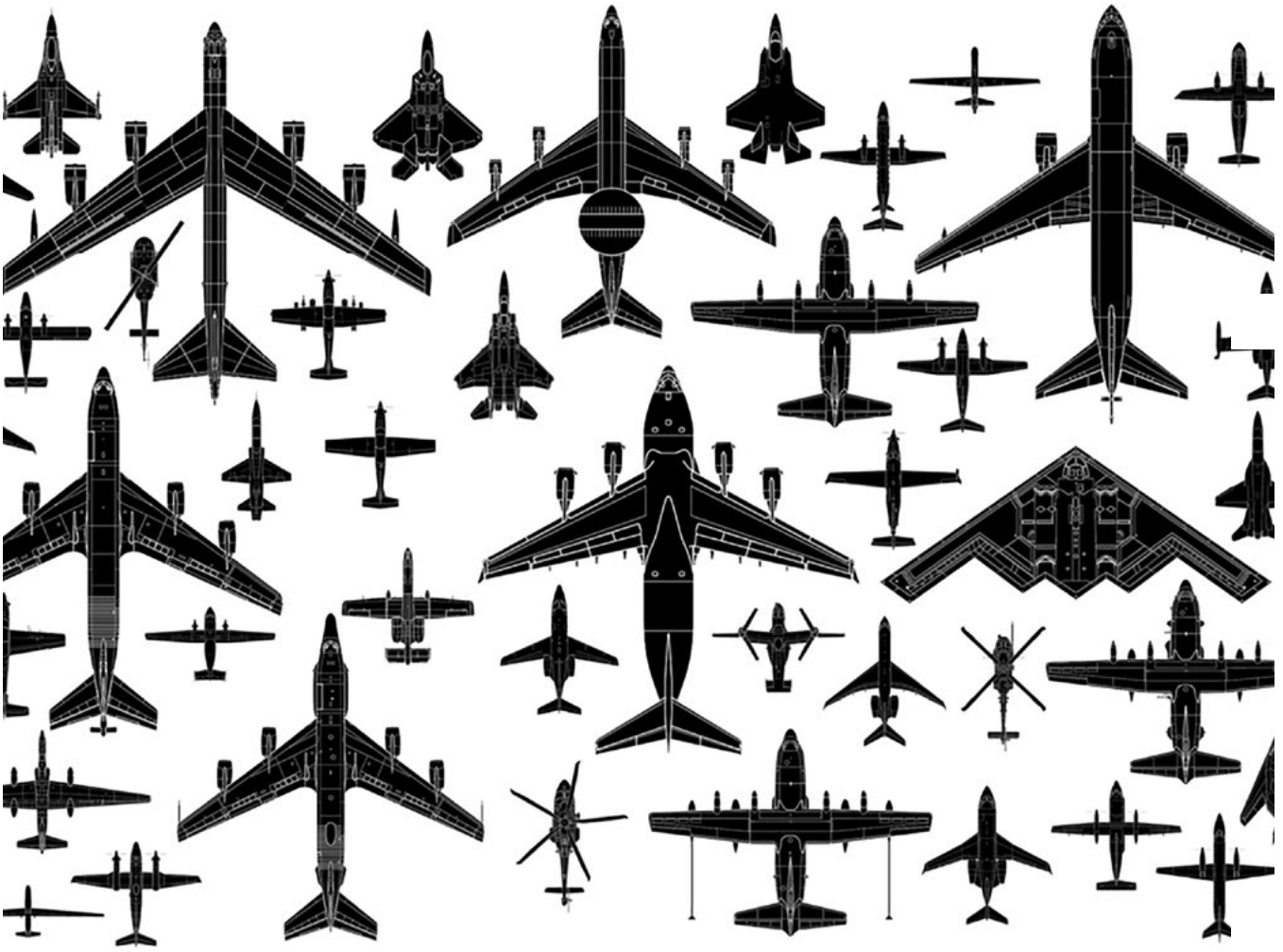
The services have to get the Joint Simulation Environment (JSE)—a wargaming system for assessing weapon effectiveness in large force-on-force exercises—working well with the F-35, he said. The F-35's full-rate production declaration has been put off for two years largely because of delays in integrating the F-35 with the JSE.

"The whole reason the JSE exists is … we knew we couldn't fly" the F-35 in the open "against the threats we saw off in the future." To train against the most advanced threats, it must be done virtually, so "those are places where you might choose to offset open-air flight with some simulator work."

He added that there are "some things you'll never do in a simulator, and some things you'll always do in a simulator. And you've just got to figure that out."

The JPO, responding to the GAO's July audit, said F-35 sustainment cost increases are not as dire as the GAO said. The true increase is about seven percent, in 2012 dollars, or $42.8 billion over the life of the program, and that these numbers were verified by the Pentagon's Cost Assessment and Program Evaluation Office. That's still a huge amount, but the JPO also said GAO's projections may not come to pass.

It noted that the Pentagon has decided to extend the end of the F-35's service life from 2064 to 2077, and this has artificially "added 23 percent" to operating and sustainment costs. An increase of total aircraft to be bought, from 2,443 to 2,456, also added a half-percent to O&S costs, the JPO said, because planned flying hours over a 60-plus-year operating period have increased from 14.9 million to 15.6 million. That may well be sharply modified by how much is "offloaded" to simulators, Fick noted. ✪



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Contesting the Space Domain

Russia's ASAT test rattled the world. The Space Force was already working on solutions.

Mike Tsukamoto/staff; NASA; Pixabay

By Amanda Miller and **Shaun Waterman**

As a derelict Soviet surveillance satellite dating from the 1980s soared hundreds of miles above the Plesetsk Cosmodrome on Nov. 15, a Russian missile rocketed upward to meet it.

The Nudol anti-satellite weapon, a ballistic missile that propels a kinetic kill vehicle (KKV) into orbit, was right on target. The two-and-a-half-ton Cosmos 1408 electronic signals intelligence satellite burst into pieces on impact, spreading a cloud of 1,500 "trackable" pieces of space junk into low-Earth orbit, plus hundreds of thousands more specks too small to track.

The debris field will spread out and remain a danger to other objects, including crewed spacecraft, for years and perhaps decades to come.

"This had to have been approved at the level of Putin."
—Scott Pace, Space Policy Institute, George Washington University

Aboard the International Space Station, a crew of seven, including American and German astronauts and Russian cosmonauts, took cover in the space capsules that will eventually return them to Earth. They remained in the SpaceX Dragon and Russian Soyuz capsules for two hours following a NASA warning as the ISS crossed near or through the debris field on two orbits 90 minutes apart. The second and third passes came the closest before their proximity naturally diverged because of different orbital trajectories.

By Nov. 17, two days later, commercial space-object tracking firm LeoLabs said it had identified 288 trackable pieces, reporting that the number would "grow significantly" as objects "further separate from one another in their new orbits." The company said "some objects" will continue to cross into the path of the

ISS. The higher that debris scattered after impact, the longer it will remain in space, threatening to collide with something else such as the ISS.

U.S. and spacefaring allies predictably condemned the test as "reckless" and "irresponsible." They also wondered and speculated on Russia's motives and timing.

WHY IT MATTERS

"We're estimating that the probability of a hit to Dragon would be lower than the rest of the ISS," a voice advises Air Force Col. Raja Chari. It's a gesture of reassurance, captured in a recording posted online. NASA's Johnson Space Center in Houston had just warned the crew on the ISS to take cover in their capsules because their orbit was about to pass by the new debris field for the second time—this time, too close for comfort. As Chari, an F-35 test pilot, came to grips with the situation, NASA reminded him:

"Heads-up. 15 minutes to the next debris field pass."

NASA's crew of four had launched to space on a SpaceX Crew Dragon, only the third fully operational mission with that design. Chari and Navy Lt. Cmdr. Kayla Barron, a submarine officer, along with U.S. and German civilians, had arrived just four days earlier. Two cosmonauts and another U.S. astronaut were already on board the ISS. Not far away, in a similar orbit, three Chinese taikonauts were working on board China's Tiangong space station.

The Nudol ASAT weapon, unlike the American Ground-Based Midcourse Defense system, which was designed to defend against intercontinental ballistic missiles, appears purpose-built as a direct-ascent ASAT weapon, according to "Global Counterspace Capabilities—An Open Source Assessment," a report from the Secure World Foundation in Broomfield, Colo.

The head of the European Space Agency's Space Debris Office Tim Flohrer put the expected effects into context, telling Space.com that the debris would require twice as many collision-avoidance maneuvers for satellite operators in coming years. He said the peak increase in required maneuvers could be "even significantly higher."

NASA Administrator Bill Nelson, a former U.S. senator, said in a statement that he was "outraged by this irresponsible and destabilizing action." Russia's "long and storied history in human spaceflight" had been ignored, he said, putting astronauts and Russia's own cosmonauts at risk.

The ISS passed closely enough "near or through" the debris, according to the statement, in only its second and third passes after the test, forcing the crew to shelter in their capsules for two hours.

Canada decried the "increased risk to the sustainability [and] stability of outer space [and] human space flight." Germany said Russia's "irresponsible behavior carries a high risk of misjudgment and escalation" and would "impair the free and unhindered use of space for all countries for years."

As thousands of new satellites are launched into LEO, among them small sats forming the Starlink and OneWeb internet constellations, risk could grow. Observers worry that any single collision could spark others, creating a cascading effect in which the clouds of debris multiply until, potentially they shred everything in orbit in a theoretical phenomenon known as Kessler Syndrome.

WHY NOW

Why Russia chose November 2021 to launch its test is an open question.

"They've had a capability like this, for a direct-ascent ASAT, in its current form, for a long time," said Scott Pace, former executive secretary of the National Space Council and now director of George Washington University's Space Policy Institute. Yet he characterized Russia's decision to destroy one of its satellite relics as "not expected, but not a surprise."

Elements of the Russian government "knew exactly what would happen," he said. "This had to have been approved at the level of Putin. There's no way this was done by anybody below that."

But why Putin chose to launch now is worth wondering about, he continued. "What could possibly have been his motivations, knowing the blowback and irritation this could cause?"

Three theories are gaining traction among academics, Pace said:

- First, the test was a "display of strength" in "the larger geopolitical context." Russian has been massing troops on the border with Ukraine, which may have encouraged Belarus to create a migrant crisis on the Polish border, and continues to intimidate other neighbors.
- Second, self-doubt over whether the Nudol weapon would actually work, despite non-destructive rocket tests, may have prompted the live test. Perhaps Putin "frankly just didn't trust the results" and wanted to see "an actual, verifiable kill."
- Third, the test coincided with the creation of a United Nations open-ended working group on space norms of behavior. Russia was one of only eight countries to oppose the creation of that group, which could lead to a binding space arms-control agreement. Pace said Russia and China have wanted their own binding arms-control agreements advanced but that the U.S. has acted reluctantly toward their proposals, which he said are "pretty much hypocritical and self-serving and aren't verifiable."

WHAT THE SPACE FORCE IS DOING

The Russian test highlighted the vulnerability of orbital assets on which the U.S. military increasingly relies, and it dramatically demonstrated why a new U.S. Space Force research and development program is focused on defensive technologies, according to experts and military officials.

Brian Engberg, director of the Space Control Technology Branch at the Air Force Research Laboratory, said Russia's test showcased the kind of weaponry the Space Force will have to counter in its mission to ensure critical communication, navigation, timing, surveillance, and other capabilities to U.S. forces in combat with a peer competitor such as Russia or China.

"Our current priorities are on establishing defensive measures and resilience for our satellite platforms," Engberg told Air Force Magazine. Even in the midst of an attack by weapons like Russia's Nudol, the Space Force must continue to "provide critical space-based services like communications, navigation [and] timing, operational awareness, [and] information dominance, which then enable strong offensive and defensive advantages" on land, at sea, and in the air.

Brian Weeden, an author of the Secure World Foundation's counterspace report, said the Nudol's kinetic kill vehicle has no warhead, containing only a guidance system to enable last-minute course corrections to steer it into the target. "At the speed the KKV is traveling in low Earth orbit, probably already moving at six or seven kilometers per second ... It's just BOOM! From launch to impact, you may have as little as

five or 10 minutes."

Countering such a weapon is extremely difficult, given the time needed to detect the blast, communicate with the satellite, and initiate a motor burn to move it to a different orbit. "So I think it's very, very difficult to counter that," he said.

Making maximum use of the minimal time available to maneuver satellites away from ASAT threats is a major focus of AFRL's research, Engberg said. This includes developing "satellite autonomy" so that, using artificial intelligence, a satellite can "make a decision about protecting its own capability when you cannot wait for a human on the ground to receive data, make a decision, and send up a command to avoid a potential threat."

Autonomy is especially important for countering lasers or other directed-energy weapons attacking at the speed of light, Engberg said. "We anticipate there will be scenarios and threats for which a human in the loop commanding a satellite or a system of satellites from the ground will not be fast enough to defeat certain threats, especially speed-of-light threats."

The strategic calculus embedded in the Space Force's R&D focus on defensive capabilities is that deterrence by denial—hardening U.S. space systems—is a more productive strategy than deterrence by destruction, Weeden said, especially because the U.S. military relies more heavily on space than potential adversaries.

Engberg said the Russian test and its impact on the ISS also demonstrate the growing danger that a war in space might create. Weeden said that's why strategists favor nonkinetic attacks on orbital assets, especially if they can be reversible.

Historically, Engberg said, "the high risk of collateral damage from offensive space weapons means no one will really benefit from escalating a [kinetic] conflict into the space domain." For its part, Russia maintains that risk is overblown. Earlier this year, AFRL Commander Maj. Gen. Heather L. Pringle cut the ribbon on a 26,000-square-foot, $12.8 million Space Warfighting Operations Research and Development lab called SWORD. The lab supports a few dozen scientists, engineers, and support staff and is part of the Space Vehicles Directorate at Kirtland Air Force Base, N.M.

"AFRL is not investing in offensive space capabilities," Engberg said. "Our goal is to provide a safe flight environment [in orbit] through [domain] awareness and reliable services [to warfighters] through agility and survivability." That includes, he added, being "prepared for irresponsible behavior."

The U.S. has tested kinetic space weapons successfully in the past, first in 1985 with a missile launched from an F-15 and again in 2000 from a ship. The first instance demonstrated what happens in a destructive ASAT test, and the second demonstrated that doing so at a lower altitude minimized lingering debris. Weeden said it's generally accepted that the U.S. still possesses that ability.

"Many of us assume that existing U.S. missile defense interceptors ... could be used to target satellites with basically just a software change," Weeden said. And the U.S. may be able to destroy or interfere with satellites in other ways. "We know the U.S. has done a lot of research on technologies for rendezvous and proximity operations—getting close to other satellites—that could be used in co-orbital attacks. We know there's a lot of research being done in lasers and other directed-energy weapons. We know the U.S. has probably the best cyber offensive capabilities in the world.

"So a lot of us assume that the U.S. has more capabilities than what they've revealed," he concluded. The same might be said for both China and Russia.

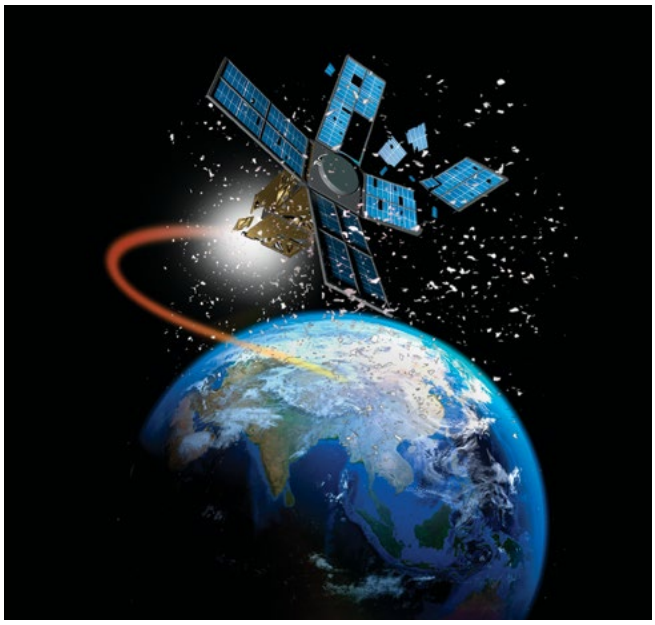


Illustration by Mike Tsukamoto/staff; Hung Quach and PIRO4D/Pixabay

The destruction of a defunct Russian communication satellite scattered thousands of bits of space debris across low-Earth orbit, threatening other satellites as well as the astronauts and cosmonauts aboard the International Space Station.

Past Tests

Timeline of orbital debris-generating, direct-ascent anti-satellite weapon tests:

Jan. 11, 2007
Country: China
ASAT system: SC-19
Launch site: Xichang
Target: FY-1C satellite
Altitude: 865 km
Trackable debris: 2,087 pieces

March 27, 2019
Country: India
ASAT system: PDV-MKII
Launch site: Abdul Kalam
Target: Microsat-R
Altitude: 283 km
Trackable debris: 125 pieces

1985 1990 1995 2000 2005 2010 2015 2020

USAF

Sept. 13, 1985
Country: United States
ASAT system: ASM-135
Launch site: F-15
Target: Solwind satellite
Altitude: 525 km
Trackable debris: 285 pieces

USN

Feb. 28, 2008
Country: United States
ASAT system: SM-3
Launch site: USS Lake Erie
Target: USA 193 satellite
Altitude: 240 km
Trackable debris: 174 pieces

Nov. 15, 2021
ASAT system: Nudol
Launch site: Plesetsk
Target: Cosmos 1408 satellite
Altitude: about 480 km
Trackable debris generated: about 1,500 pieces

Sources: "Global Counterspace Capabilities—An Open Source Assessment," Secure World Foundation; "History of On-Orbit Satellite Fragmentations, 14th Edition," NASA; Space-Track.org; "Analysis of the 2007 Chinese ASAT Test and the Impact of its Debris on the Space Environment," Center for Space Standards and Innovation

Guardians in Training

The Space Force is luring would-be pilots at the U.S. Air Force Academy to consider an alternative path shaping the future of a new domain.

Staff Sgt. Seth Stang

U.S. Air Force Academy Cadet 2nd Class Zachary Szvetecz, left, and Cadet 2nd Class J.R. Cook both want to join Space Force.

By Abraham Mahshie

AIR FORCE ACADEMY, Colo. —

The moment Cadet 4th Class Zachary Szvetecz took control of the FalconSAT-6 satellite, he knew. Over the next eight minutes, it occurred to him that maybe he wasn't destined to be an Air Force pilot after all.

Seated in a control room and peering into a video screen he took control of the satellite, the only operational mission element at the U.S. Air Force Academy (USAFA), a satellite designed and operated by students.

"That was just like nothing I had ever done before," he said in a recent interview. "I think that was the day that I was really hooked."

A few months later, the Space Force was born. And not long after, Col. Jeffrey H. Greenwood was asked to take on a special role as a sort of Space Force ambassador to future Guardians at the Academy.

We really wanted "to expand and integrate the Space Force at the Air Force Academy," said Greenwood, who transferred from the Air Force to the Space Force in January.

"I started to realize all the opportunities that were starting to exist" in the Space Force.

— Cadet 2nd Class Zachary Szvetecz

As the Space Force liaison at the academy, he oversees how the school incorporates Space Force knowledge and understanding into the curriculum. The Space Force will take about 10 percent of each Air Force Academy class, meaning about 96 cadets will be commissioned as Space Force officers. Today, there are 31 Guardians assigned to work with cadets, about 5 percent of the officers among the faculty and staff. Eventually, the Space Force hopes to more than double that total, to about 70 Guardians, Greenwood said.

Szvetecz has another 18 months or so as a cadet and hopes to commission into the Space Force to be a space intelligence officer. Getting hands-on operational space experience at the academy is a big reason why.

An astronautical engineering major—one of the academy's toughest—he was attracted immediately to the Academy's I-5 Club, the Institute for Applied Space Policy and Strategy, which is responsible for the FalconSAT-6, a satellite developed and designed by cadets.

"I was seeing what the Space Force was doing—and U.S. Space Command, what they were doing—and I started to realize all the opportunities that were

starting to exist," Szvetecz said. "A lot of cadets here, myself included, are beginning to figure out that the space domain is the future of everything that the military does."

'TWO SERVICES, ONE ACADEMY'

The first opportunity for cadets to learn about the Space Force is Doolie Space Intro Day, a two-hour talk during the first week at the academy. There, Space Force officials explain the new service and its career fields, its mentoring programs at the academy, senior leader engagements, industry and commercial space partnerships, and the space-related clubs, coursework, and majors, including astronautical engineering or "astro;" space operations; physics; and a new minor in space warfighting.

Beginning this past summer, the academy is identifying cadets interested in the Space Force, inviting them to fill out a survey for more information. More than 230 of the 1,000 incoming first years signed up, nearly a quarter of the class of 2025. If interest holds, the Space Force will be able to be highly selective, choosing less than half of those attracted to space careers.

The survey asked cadets to say why they chose the Air Force Academy and what they hoped to do once they graduated, Greenwood said. Not surprisingly, their interest began with wanting to fly. What was surprising was what was next. "By far, No. 1 was still pilot. Folks are coming to the Air Force Academy because they want to fly. But easily, hands down, No. 2?—join the Space Force," Greenwood said. "Basically, we are two services, one academy … the Space Force academy is the Air Force Academy."

Like the Marine Corps, which draws about one-sixth of each class at the Naval Academy, the Space Force must attract a portion of each Air Force Academy class, so it was natural for Greenwood to look to the Naval Academy for inspiration. In addition to its selection process, which is modeled on the Naval Academy's, the Space Force and Air Force Academy developed Azimuth, a rigorous new three-week training program for Space-option cadets based in part on the Marine Corps' Leatherneck program for Marine-option midshipmen from the Naval Academy. The first test of that program will run next summer.

The Air Force Academy will be more than just another commissioning source, Greenwood promised. "We're the *premier* commissioning source for the United States Space Force," he said. "We're designing, we're developing, building, and flying satellites. And our cadets are doing that on a daily basis."

As with the Air Force, the majority of new Space Force officers will have science and engineering degrees in astronautics, mathematics, space operations, and physics.

In 2020, only two astronautical engineering majors were commissioned into the Space Force from the academy. In 2021 that number was up to 10, and it's on track to be 10 again in 2022.

"That's where the Space Force wants us to focus," Greenwood said. "When we talk about this very technical service, I need to attract more folks into those degrees."

CHASING SATELLITES

The walls that form a ring around Col. Luke Sauter's astronautics classroom looks like a museum of tinfoil and aluminum boxes, each one an engineering model of the satellites designed, built, tested, launched,and now controlled by students.

Some are wrapped in bright gold foil. Others look like the mini-fridges found in college dorms, with plastic and metal components fastened to their sides. The attachments are the mission modules that contain cameras or other sensors or rocket motors that can propel the satellite to change its orbit with short fuel burns.

Joshua Armstrong/USAFA

USSF Col. Jeffrey Greenwood informs cadets about the opportunities in the new service. "We really want to expand and integrate the Space Force at the Air Force Academy." Greenwood transferred from USAF's Space Command staff to the Space Force and works as the space liaison at the Air Force Academy.

Abraham Mahshie/staff

Col. Luke Sauter describes the FalconSAT-1 in the astronautics classroom. Sauter said he has 30 to 40 astro majors, with about half aspiring pilots and another 20 percent engineers. Those students have a storied history of successes building and controlling satellites.

Each one can cost $30 million or more, funded through a partnership with the Air Force Research Laboratory which encourages the use of experimental features.

"Our motto here in the astronautics lab is 'learning space by doing space,'" said Sauter

Sauter helped build his first satellite as a USAFA student, then went on to earn a master's in aeronautical and astronautical engineering at MIT and a doctorate in electrical engineering at the University of Surrey in the U.K.

"They will actually go through the build, the test, the operations, and all the way out into actually flying the satellite and then recovering the satellite when it's done," Sauter said. Remarkably, the 260 students in the Space Operations Squadron do all that as an extracurricular activity, the largest such program at the school.

Astronautics is about space systems—everything in orbit, traversing through orbit, or coming back from orbit, Sauter said. "It's how you build things to survive in that space," he said. "We are 100 percent giving them every experience they would see as an acquisitions officer, building, buying satellites, or flying and operating satellites."

In 1997, a student-made satellite got a ride on an Atlas-Centaur upper stage rocket that propelled it past geostationary orbit, going on to help prove that radio GPS navigation was possible beyond the GPS constellation.

FalconSAT-6, launched in 2018,conducts experiments with its broadband signal, an experimental solar panel, a carbon nanotube, a Boeing retroflexor, an ion thruster, and a contamination measurement experiment.

"They'll talk to it, they'll get data down, they'll tell it what to do next," Sauter said. "The cadets are operating it every day, and it's been doing great. Hundreds of cadets have had the opportunity to fly this satellite and [so will] hundreds more."

Large rooftop antennas link the astro department to the satellite and ground stations at Edwards Air Force Base, Calf., and half-way around the world in Ghana.

Three cadets communicate daily with the satellite: an upperclass commander, a ground station operator, and a spacecraft systems operator. That's the same structure they will experience in the Space Force, said Sauter.

Students even participate in U.S. Space Command's Sprint Advanced Concept Training (SACT) exercise, helping to hone space domain awareness as a Red asset that SPACECOM uses its sensors to hunt down.

"We'll scoot around and see if they can try to find us," said Sauter.

Cadets get exposure to operational activities and an active mission. "Every day when they fly and they get data, that data is going out to the [Air Force Research Lab]. It's going out to other DOD customers who are using this data for real-world operations and effects and technology demonstrations," Sauter noted.

The newest student satellite, FalconSAT-8, launched in 2020 from the Air Force's highly secretive X-37 spaceplane. Cadets will eventually take over that mission and run experiments in cooperation with the National Reconnaissance Office.

"That's why astronautics is really neat," said Sauter. "It's taking all this stuff we know and understand about how to build things on Earth and we are applying it now to a drastically different environment in space. And that's why the advent of the Space Force and what we do is so important."

MORE THAN ENGINEERS

Cadet 2nd Class J.R. Cook, 20, still wants to be a pilot someday, but he has higher hopes.

"I had aspirations when I came here to become an astronaut," he told Air Force Magazine. He's hoping that might be a possibility in the future. "The Space Force right now is a really exciting opportunity. But they still don't have a path for astronauts yet."

Jeff Spots/United Launch Alliance

A United Launch Alliance Atlas V rocket carrying the USSF-7 mission with the X-37B spaceplane for the U.S. Space Force rolls from the Vertical Integration Facility (VIF) to the launch pad at Space Launch Complex-41, Cape Canaveral Space Force Station, Fla. The X-37B is also acting as a delivery spacecraft for FalconSAT-8, a small satellite studying electromagnetic propulsion and antenna technologies for the U.S. Air Force.

For now, Cook fulfills his space itch as president of the I-5 Club, where he's helping to develop the next generation of space-minded leaders.

"We're not just interested in the satellites of today, but we're interested in the starships of tomorrow," he said. "We have the opportunity right now, even as cadets, to directly influence the culture and the future of this new branch of the military. I saw that as an opportunity to really take initiative and help kind of shape the space domain into what I would like to see it grow into in the future."

Yet Cook, aspiring astronaut, pilot, and space pioneer, isn't an astrophysicist or engineering student, but rather a history major. That's part of the diversity of knowledge and interests every military service needs.

"It's vital that we all have a knowledge and understanding of just how deeply embedded and integrated space is into the joint warfighter today," he said.

Szvetecz, I-5's vice president, agreed. Membership in the club has skyrocketed, with 200 new members from the class of 2025 alone.

"There's a huge demand right now for space and opportunities with space," Szvetecz said. "In the past, you either came here and you wanted to go pilot, or you didn't. But now we're seeing the Space Force is becoming a large share of what cadets are interested in."

Seven research departments, including astronautics and physics, conduct space-related research

Air Force Lt. Col. Timothy Goines, assistant professor in the department of law, has seen that firsthand, with growing interest in space law.

Goines said cadets are not restrained by conventions. "With a new Space Force, they have to think differently," he added. "We have to operate differently."

Indeed, having placed cadets as interns at the U.S. Space Command and Peterson Space Force Base legal offices, Assistant Professor of Cyber Law and Policy Jeffrey Biller said both students and commands have benefited.

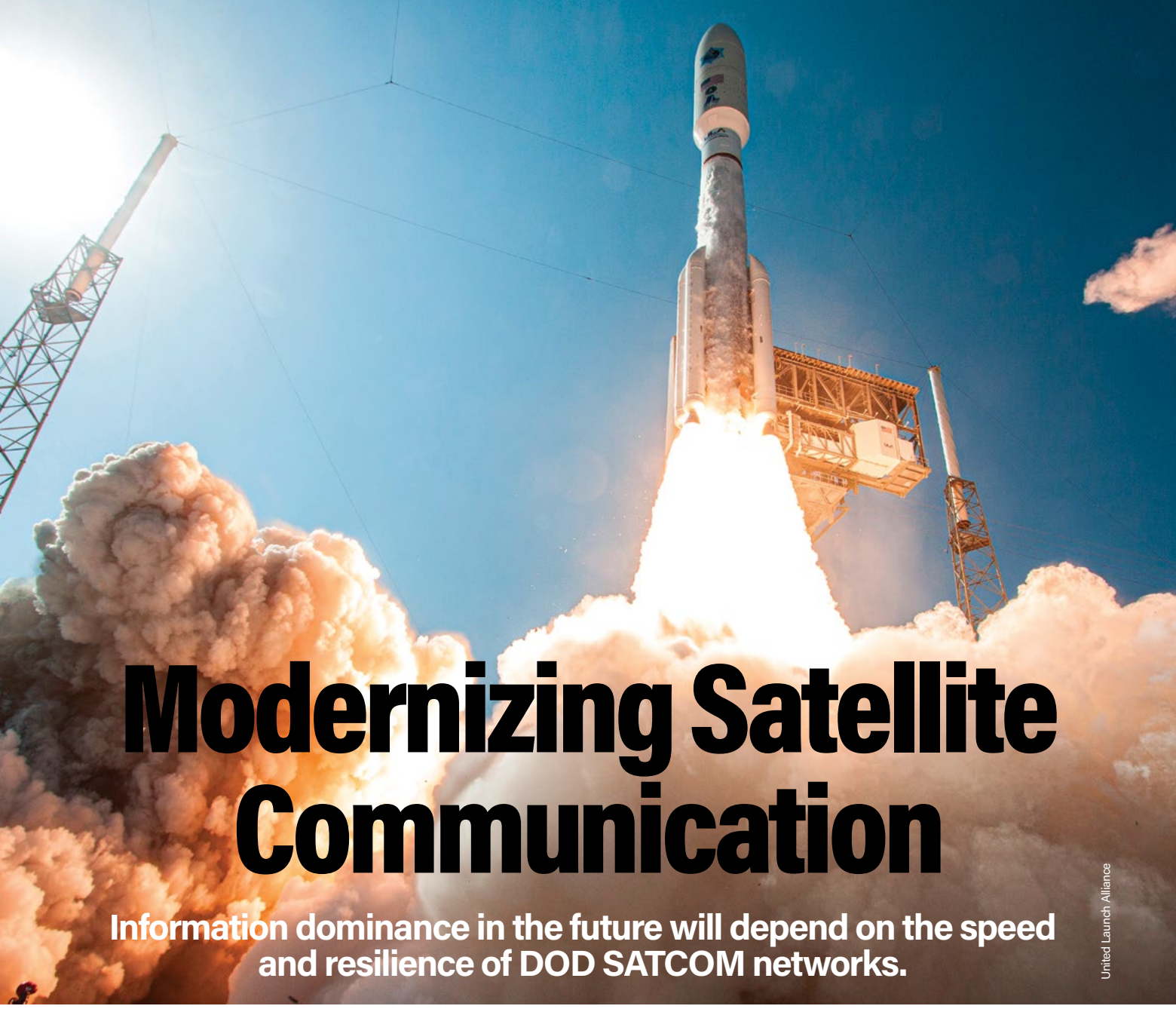
"We've gotten amazing feedback from senior leaders who said, 'We love their ideas, we love … their flexibility of thought, their ability to look at problems in a new way,'" Biller said.

Several cadets from his spring 2022 space law course will get the chance to present ideas directly to Space Force leaders at a Space Law Conference in April, he said, and others are pursuing independent research projects on remote proximity operations—that is, operating satellites very close to other satellites.

Greenwood said drawing from all majors is helpful in getting at all the possibilities presented in space. "We need diverse thoughts," he said. "You don't want to just take a bunch of engineers and throw them into the Space Force and call it good."

Consider Cook, the history major and aspiring pilot and astronaut who's become the I-5 Club president. He said the club wrestles with strategic issues like the lunar cooperation agreement between China and Russia, whether it's appropriate for the military to operate on the moon, and what space mining might look like.

"There's an overwhelming consensus that they want to know what we, as cadets, think," said Cook. "That's just an exciting thought, because senior Space Force and even Air Force leaders, as well, want to know what we're thinking about the future of space." ✪



Modernizing Satellite Communication

Information dominance in the future will depend on the speed and resilience of DOD SATCOM networks.

United Launch Alliance

A United Launch Alliance Atlas V rocket takes off, launching a nearly 7-ton AEHF-6 communications relay satellite into geosynchronous orbit. In the future, constellations of smaller satellites in lower orbits could deliver faster speeds, more bandwidth, and greater survivability in the event of attack.

By Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.)

Robust satellite communications are key to achieving decision superiority for U.S. forces, but the U.S. military's SATCOM enterprise has not kept pace with the capabilities China, Russia, and others are developing to degrade or disable U.S. communications in space. Further, U.S. SATCOM were not designed to support the speed, scale, and complexity needed for military operations in the information age.

Consolidating military SATCOM capabilities under a single military service—the new U.S. Space Force—presents a once-in-a-generation opportunity to rethink the enterprise and chart a new path to achieve the assured connectivity necessary to defeat peer powers. DOD's future SATCOM enterprise must enable command and control as well as information sharing around the globe, and must leverage both mature and emerging space technologies, such as laser communications and constellations of small satellites, to overcome today's dependence on resource-intensive, limited range, and increasingly vulnerable line-of-sight radio communications.

Small constellations of large satellites make U.S. communications links vulnerable to enemy attack.

Since first proven in combat during Operation Desert Storm in 1991, DOD's satellite communication networks have only grown in importance over the past 30 years. Yet because those capabilities developed largely in the absence of credible threats, the military came to take for granted the expectation of instant, always available SATCOM links. Because DOD added incrementally to its networks, generally procuring improved versions of the same kinds of systems acquired in the past, the Pentagon failed to keep pace with strategic competitors, who increasingly exploited

more cutting-edge technologies. Today, U.S. satellite capacity and capability are largely indefensible and there are too few satellites to provide resilience in case of attack.

Most U.S. military communications satellites are in geostationary orbits high above the Earth's equator. This ensures continuous coverage over most of the planet, an extremely efficient and flexible approach that can enable three evenly distributed satellites to provide continuous worldwide communications coverage over almost the entire Earth, excluding only polar regions and areas obscured by mountains, canyons, or other terrain features. Because geostationary satellites appear to be in fixed overhead locations, maintaining their orbits is simplified, precluding the need for complex and expensive satellite tracking equipment. On the downside, however, geostationary satellite signals are comparatively slow, imposing significant latency as signals traverse tens of thousands of kilometers from Earth to the satellites and then back down to Earth. This latency is incompatible, however, with modern applications that must operate at machine speeds.

Over time, as the size, capability, and complexity of DOD's communications satellites grew, so did cost and acquisition cycles. Predictably, greater cost meant fewer satellites, which in turn drove evermore aggressive requirements. Today, acquisition cycles stretch out over a decade or more, leading to obsolescence in the midst of production, which often means costly retrofits. "All these dynamics tend to reinforce one another," creating what a former vice commander of Air Force Space Command called the "vicious cycle of space acquisition." With just 36 core military communications satellites today, the loss of even just a few platforms could lead to critical failure of the system.

Given that today multiple countries have proven anti-satellite capabilities, the U.S. is at serious risk in the event of conflict.

Military planners are wary of concentrating too much critical capability into too few platforms, concerned about reduced wartime effectiveness. But DOD developed its space networks during the Cold War at a time when the risk of counterspace attacks seemed minimal. More recently, as China, India, and Russia demonstrated anti-satellite capabilities, the U.S. was engaged with less capable adversaries, perpetuating the notion that space is benign.

At the same time, U.S. SATCOM systems evolved as a byproduct of technological advances and to meet specific user needs rather than in response to a unified enterprise strategy. With numerous authorities spread across the combatant commands, the military services, DOD agencies and multiple acquisition organizations, little consideration was given to enterprise-level requirements. Proprietary vendor equities and overclassification only make matters more difficult.

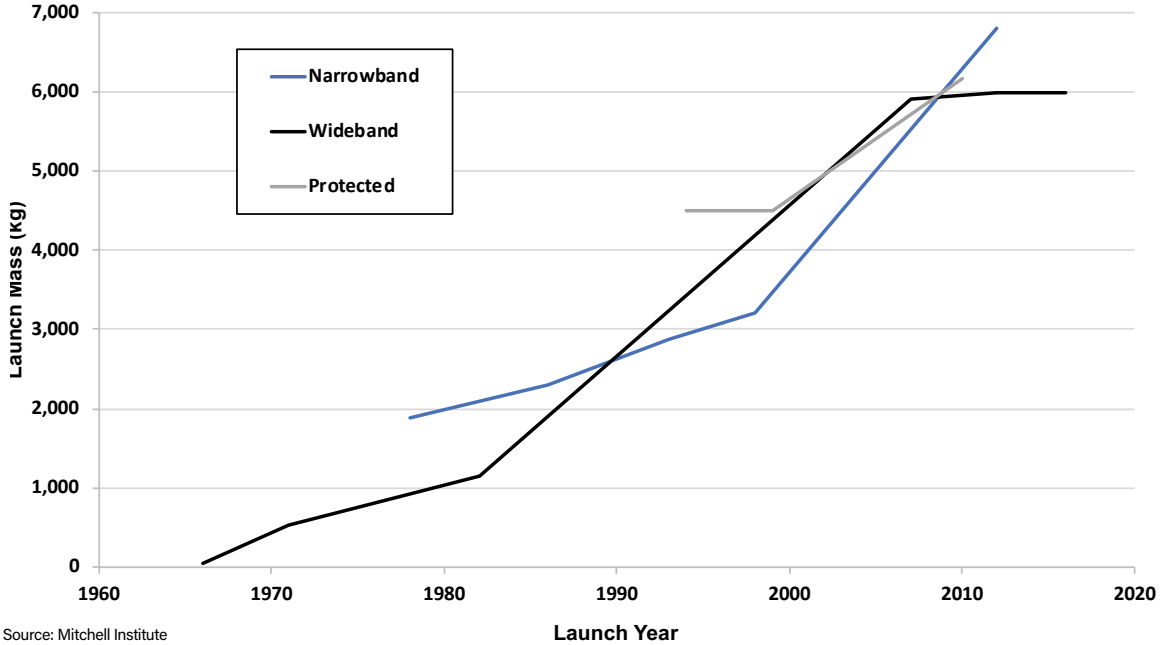
THE NEED FOR A NEW APPROACH

With China and Russia undertaking massive buildups of their respective militaries, the United States cannot expect to regain competitive advantage simply through like-for-like replacements of legacy communications systems. Instead, DOD must develop new capabilities and force designs capable of supporting highly dispersed, all-domain operations in every theater. Rapid and seamless data-sharing will enable faster decisions and better integrate the actions of all available forces. The U.S. strategy seeks both physical and psychological advantages by enabling friendly forces to operate inside its adversaries' decision cycles, where it can impose multiple, simultaneous dilemmas to confound and even paralyze the enemy's ability to respond. To achieve this, DOD must ensure its communications systems can operate under attack, negating adversaries' efforts to degrade or negate them. DOD's existing SATCOM systems are not up to this challenge and must be replaced with new command, control, and communications systems that can provide both the speed and resiliency needed to support operations in the information age.

DOD's Joint All-Domain Command and Control (JADC2) strategy aims to achieve that operational advantage by leveraging artificial intelligence and cloud computing to accelerate data-sharing and analysis across every domain in near-real

Is Bigger Better?

As time and technology matured, the size of military communications satellites increased, more than doubling in size from 2000 to today.



Source: Mitchell Institute

Ministry of Defence of the Russian Federation

Russia has successfully jammed U.S. and allied satellites with its mobile R-330Zh Zhitel system. To maintain information advantage, U.S. forces need a new approach to assure space connectivity in combat.

time. Space-based communications will be the backbone of that initiative, theoretically enabling any sensor—air, land, sea, undersea, in space, or cyberspace—to instantly connect to the shooters best equipped for any given target at any given location.

Terrestrial communications links can pass targeting data over short line-of-sight distances, only satellites can efficiently cover the range envisioned by DOD's emerging warfighting concepts. At the same time, DOD needs more bandwidth, less latency, and interoperability that today's SATCOM enterprise cannot support.

■ Bandwidth poses a persistent challenge. New weapon systems are reliant on external sources of information to complete their missions. New applications that use high-definition imagery and video, support remote piloting of unmanned systems, or employ artificial intelligence also require greater bandwidth to operate smoothly.

■ Latency poses an issue for many systems. While latency times of one or two seconds may not be a problem for short text messages, for example, it's not an option for applications and decisions requiring precise timing, such as targeting using real-time video, or trying to intercept an incoming missile. The only way to reduce SATCOM latency is to reduce the physical distance data needs to travel by leveraging satellite orbits satellites closer to Earth.

■ Interoperability is critical to enable disparate systems to interact. Improving joint, interagency, and coalition data-sharing is a longstanding issue. Unlike cell phones, which seamlessly switch from one cell tower or network to another, SATCOM systems are purpose-built, proprietary systems; they don't allow users to roam freely from one network to another.

Meanwhile, both China and Russia seek to hold U.S. satellites at risk. The two believe U.S. dependence on vulnerable space systems can be exploited, and they have developed military doctrine, organizations, and capabilities with that in mind. Both prioritize information superiority as their main line of effort in future conflicts, believing that will provide a decisive warfighting advantage. China's and Russia's counterspace weapons now include direct-ascent missiles, co-orbital weapons, ground-based lasers, high power microwaves, cyber tools to compromise information networks, and electronic warfare capabilities to jam or otherwise interfere with satellite communications. These weapons are supported by robust networks of space surveillance capabilities that can locate, characterize, track, and otherwise facilitate counterspace targeting.

A NEW SATCOM STRATEGY

The standup of the U.S. Space Force presents a unique opportunity to chart a new path forward for DOD's SATCOM enterprise. The future architecture must have greater bandwidth, higher speeds, improved interoperability, and the ability to counter and survive emerging threats. To build it, DOD must leverage advancements in space technologies that to date have been driven largely by the commercial sector: smallsats, optical communications, and their associated manufacturing, assembly, and testing.

Proliferating smallsats in low- and medium-Earth orbit (LEO and MEO) will reduce latency by reducing the distance data must travel. It will also improve capacity and resiliency against some forms of counterspace attacks. Satellite miniaturization and reduced launch costs, also driven by the commercial sector, have significantly improved the cost-effectiveness of LEO and MEO constellations. DOD's efforts in this arena are led by the Defense Advanced Research Projects Agency (DARPA), through its Blackjack program, and the Space Development Agency (SDA), which is developing a "Transport Layer" to serve as the communications backbone for its National Defense Space Architecture.

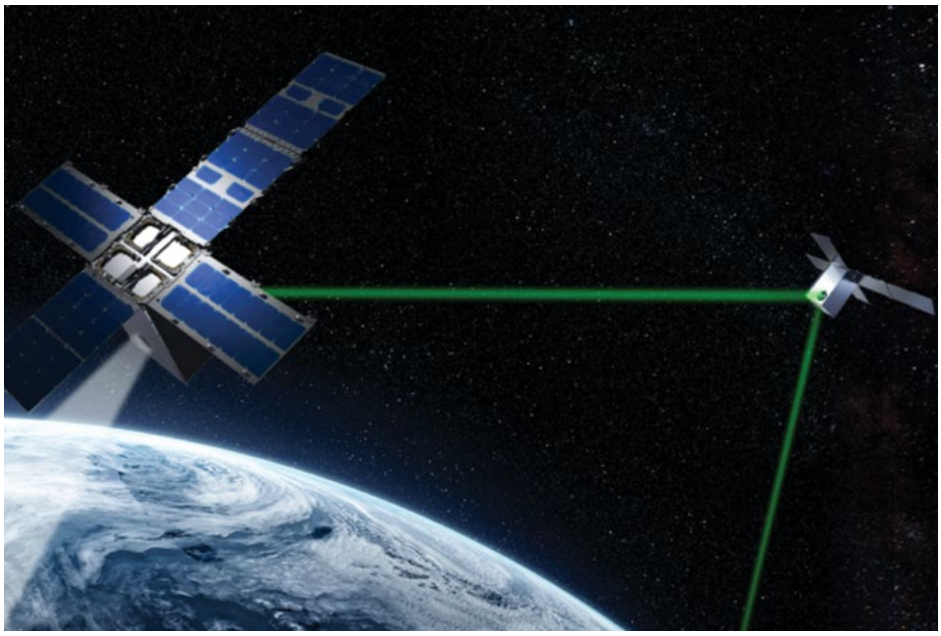
One of the most promising aspects of satellites in LEO is reduced latency. Compared to the latency for returning signals from satellites in GEO, which is around 600 milliseconds, LEO SATCOM services could have latencies as little as 50 milliseconds or less. That allows data to travel from sensors to "shooters" in real-time. In fact, at longer distances an LEO SATCOM constellation could offer lower latency than even the fastest currently available terrestrial networks. For a hypersonic missile traveling at Mach 5—covering a kilometer in 600 milliseconds—that can be the difference between a successful intercept and a mission failure.

Instead of just a few satellites, as in GEO, a LEO satellite constellation would have to number in the tens or even hundreds to provide continuous coverage of a given geographic area. Where once this made LEO constellations seem infeasible and not cost effective, today the cost of building and launching smallsats is such that LEO satellites now can be economically deployed to provide global coverage. Using a combination of

orbital inclinations, proliferated LEO constellations will offer better global coverage for the U.S. military than GEO, which lacks coverage in some critical areas, including the Arctic.

The larger numbers of LEO satellites makes the network more resilient and provides greater overall bandwidth. Even though large GEO satellites have greater bandwidth on a per-satellite basis, the large number of small satellites within a LEO constellation generally has more capacity. Finally, the proximity of LEO satellites to Earth means it takes less power to transmit a signal to Earth. This means smaller antennas and power amplifiers, easing integration.

LEO constellations that consist of large numbers of highly dispersed smaller satellites will make it more difficult for an enemy to degrade their operations. Where the loss of a few monolithic satellites in GEO orbit would result in a catastrophic failure of the entire system, a proliferated LEO constellation could withstand the loss of a relatively large number of satellites. Plus, satellites in LEO can be reconstituted more rapidly and far less expensively than larger satellites.



General Atomics Electromagnetic Systems

Switching from conventional radio frequency links to laser-based optical communications could result in higher data rates, greater security from jamming or interference, and more compact form factors for terminals.

OPTICAL COMMUNICATIONS

The linchpin to realizing the full potential of future SATCOM constellations is optical communications. Satellites today use radiofrequency (RF) communications to transmit and receive data. Inherent performance limitations are often a bottleneck and RF communications can be disrupted and denied by means of jamming electromagnetic signals.

Optical communications, by contrast, can modulate data onto a low-power laser beam that transmits its signal through free space to a receiver. Using lasers operating in much shorter wavelengths, data transfer rates are at least an order of magnitude greater compared to RF communications, and require lower power levels. Using highly directional, narrow laser beams minimizes the potential for interference from adjacent satellites and enhances the security of transmissions by reducing the area within which signals can be detected and intercepted. Even if detected and located, optical communications are incredibly difficult to disrupt, improving resiliency. Together, LEO satellite constellations and laser technologies form the basis for far more secure, resilient, and high-bandwidth communication networks.

A good initial application for optical communications is for satellite crosslinks—known as optical intersatellite links (OISLs)—to enable satellites to pass data directly between each other instead of routing their signals through a ground station. In the vacuum of space, these links could exceed rates of 10 gigabits per second—enough to transmit an entire high-definition movie in about three seconds. Data in such a network would travel from satellite to satellite until it reaches one within line-of-sight of the intended user, making it possible to deliver collected sensor data to warfighters in near-real time without ever touching terrestrial networks in non-secure locations.

Equipping each satellite with several OISLs will allow them to communicate with multiple adjacent satellites simultaneously, forming redundant satellite "mesh" networks. Mesh networks with an autonomous mission management system onboard each satellite is the basis for a "self-healing" network that can reroute traffic in the most efficient way possible if a node suffers either a temporary or permanent failure. If compatible, OISLs could connect disparate satellite constellations, potentially allowing other military and commercial intelligence and SATCOM providers to plug directly into the network.

Satellites equipped with optical communications could also connect with aircraft and other terrestrial systems, providing a high bandwidth, covert communication link that is incredibly difficult to jam. In practical terms, this would support far more information-sharing at faster speeds than is otherwise possible.

IMPROVED TERRESTRIAL INFRASTRUCTURE

Realizing advances in orbit will require corresponding investments in terrestrial infrastructure, beginning with more widely deploying phased-array antennas for ground control stations and user terminals that can simultaneously track and contact multiple satellites across different frequencies and orbits. Because non-GEO constellations include scores of satellites rapidly moving across each receiver's field of view, these systems require sophisticated tracking to manage up to dozens of satellite beam handovers per hour. Traditional parabolic-dish antennas are poorly suited for this task because they require mechanical steering mechanisms and only communicate with one satellite at a time. Likewise, the single contact parabolic antennas used in most ground stations have limited capacity to transmit and receive telemetry, tracking, and control (TT&C) data.

Instead, DOD should field flexible terminals that can roam between different satellite networks operating in different orbits and frequency bands. Flexibility at the terminal should be combined with enterprise management and control to autonomously determine why, when, and how communications

move on one or another network. This would enable changing based on mission needs, threats, and operational status. The first step to this dynamic ground architecture is replacing existing analog Intermediate Frequency (IF) interfaces with an open, interoperable Digital standard that essentially turns the flow of data into an Internet Protocol (IP) network. This would follow best practices for network design.

RECOMMENDATIONS

The ability to securely command, control, and communicate with highly distributed forces in the Indo-Pacific and other theaters is critical to successful combat operations. For America's military to achieve the necessary information and decision advantage, the Department of Defense should take the following steps:

■ DOD should distribute, disaggregate, diversify, and expand its SATCOM options by deploying constellations of LEO and MEO communication satellites to augment existing systems that primarily reside in GEO orbits. Proliferating satellites in multiple orbits will increase communications capacity and coverage, reduce latency, improve resilience against attacks, and create more options to meet mission-specific requirements.

■ DOD should aggressively develop and deploy optical inter-satellite links to connect its satellites while also selectively integrating optical communications terminals for terrestrial systems and users. Laser communications are key to forming space mesh networks that provide diversified connectivity paths to route information to, from, and through space at the speed, scale, and level of security needed for all-domain operations and to counter adversaries that threaten DOD's communications networks.

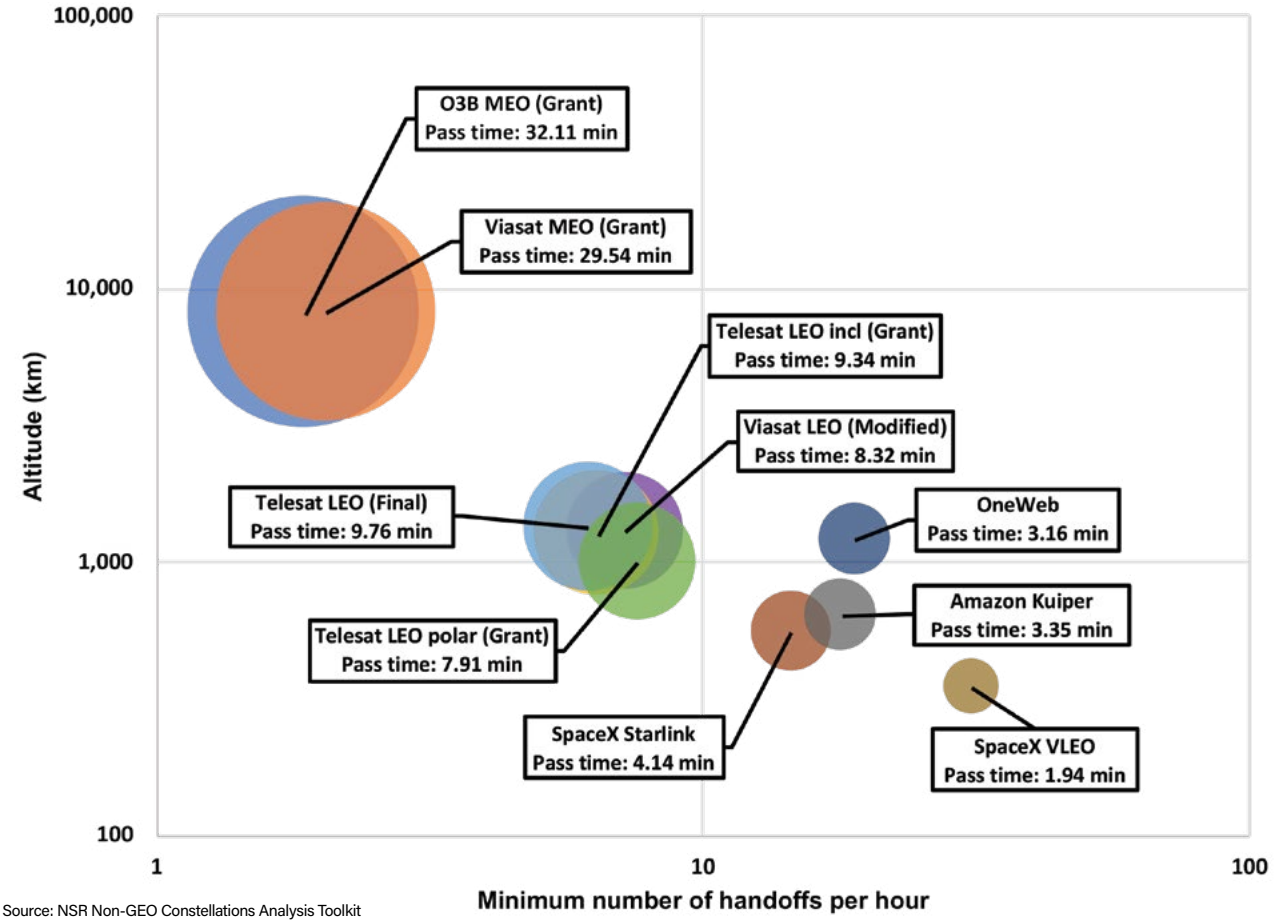
■ DOD should develop a terrestrial segment that allows it to fully realize the advantages of these new satellite networks and laser communications. This infrastructure will require phased array antennas capable of handling the rapid and continuous satellite beam handovers inherent to the operation of LEO and MEO constellations as well as terminals that can roam across different networks spanning multiple orbital regimes and operating over different frequency bands, waveforms, and security levels.

Collectively, these initiatives would establish a new U.S. SATCOM backbone that ties together all of DOD's networks and supports service-led JADC2 initiatives that enable all-domain operations. Updated SATCOM architectures enabled and boosted by laser communication will form the connective tissue that empowers U.S. global distributed operations in real-time. ✪

Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), is the Director of Research for the Mitchell Institute for Aerospace Studies.

Altitude, Speed, and Pass Time

The higher a satellite flies, the more time it is viewable from any point on Earth. The longer the pass time, the fewer handoffs are necessary in the midst of data transmission. How pass times and handoffs compare among commercial satellites.



Source: NSR Non-GEO Constellations Analysis Toolkit

Russian bombers, such as this Tu-95 that entered the Alaska Air Defense Identification Zone in 2020, are stepping up their intrusions in 2021. As of March, more than a dozen such incursions were recorded.

Revamping Homeland Defense

NORTHCOM's 20-year-old data analytic processes are undergoing a refresh.

By Amy McCullough Hudson

U.S. surveillance aircraft watch overhead as adversary forces move from one region to another, feeding imagery to a machine to analyze. Artificial intelligence (AI) sorts through the trove of data and quickly recognizes an abnormality in the number of vehicles moving through a parking lot. The AI queues both military and commercially available sensors to refocus on that location. Military leaders across the globe, and up the chain of command, are connected and able to see that information in real-time, providing the "decision space" needed to come up with deterrence options that hopefully limit the risk of accidental escalation.

That's U.S. Northern Command boss Gen. Glen D. VanHerck's vision for a new homeland defense design—and it's not that far from reality.

"I'm a firm believer that [someone], in the future, with the right data, at the right time, will win, whether that be in crisis, ... in conflict, or day-to-day competition," VanHerck told Air Force Magazine.

"Russia, and other countries, will absolutely take advantage of civil unrest in our country." —Gen. Glen VanHerck, US-NORTHCOM commander

NORTHCOM was created 20 years ago in the wake of the 9/11 attacks on New York and Washington, D.C., and though the threats have evolved significantly since then, the command still largely relies on the same analog systems and processes to share threat data and intelligence. Solutions are mostly regionally focused and still involve human analysts entering data into spreadsheets, verbally providing updates across operations centers, and pulling together PowerPoint slides to brief leaders.

For example, during the U.S. Air Force-led operation to evacuate Afghan refugees to safe havens in August, the operations center had to stand down every four hours so analysts could "review disparate spreadsheets and ensure numbers matched," according to an October white paper from the Center for Strategic and International Studies (CSIS).

Such a process might have been effective enough against a "low-tech, slow-moving adversary," but it

NORAD

Russia is probing U.S. air defense capabilities near Alaskan shores. Here, an F-22 Raptor assigned to Joint Base Elmendorf-Richardson, Alaska, intercepts a Russian Tu-95 Bear on June 9, 2020.

could prove "disastrous" in a conflict with a peer adversary like Russia or China, wrote Emily Harding, deputy director and senior fellow of the CSIS International Security Program, and Air Force Col. Matthew Strohmeyer, a military fellow at CSIS. Strohmeyer was the lead planner for the Air Force's first two Advanced Battle Management System (ABMS) on-ramps, and he planned three-more similar experiments for U.S. Northern Command before coming to the Washington, D.C.-based think tank.

"While analysts are assembling data and attempting to communicate, an adversary could be in the late stages of conducting a cyberattack that severs communications with far-flung forces, preventing a response," according to the paper "From Data to Insight: Making Sense out of Data Collected in the Gray Zone."

"A complete data picture for early, effective warning will be critical," they added.

Staff Sgt. Brittany Chase/DOD

Gen. Glen VanHerck speaks about the completed global information dominance experiment (GIDE) 3 at the Pentagon in July.

VanHerck, who is dual-hatted as the head of NORTHCOM and the North American Aerospace Defense Command, agrees. That's why he is pushing to modernize the United States' communication and warning systems to give leaders time to better define options before launching a kinetic response to potential threats.

"I don't believe that we can surround our country—or North America for that matter—with kinetic endgame defeat mechanisms," VanHerck told Air Force Magazine. "It's unrealistic and unaffordable."

EVOLVING THREATS

VanHerck said Russia remains the No. 1 threat to the homeland, because of capabilities it's developed that fall below the nuclear threshold aimed at disrupting, delaying, and degrading the United States' ability to project forces forward in a regional conflict.

As of the end of March, NORAD had conducted more than a dozen intercepts of Russian bombers and maritime patrol aircraft, an increase over previous years. The Russian aircraft sometimes loitered in or near the U.S. air defense identification zone for hours at a time. Russia also launched several disinformation campaigns in recent years, aimed at undermining U.S. democracy and breaking the will of the American people, VanHerck told Air Force Magazine.

"Russia, and other countries, will absolutely take advantage of civil unrest in our country," he said. "On a day-to-day basis, they fanned the flames of COVID vaccination policies out there, through disinformation campaigns, to make us—internally [in] our own nation—believe or not believe what they want us to" believe.

Although China today poses a much bigger threat to U.S. forces and allies overseas, it is only about five to 10 years behind Russia in terms of being able to kinetically strike the homeland, and it is "on par" with Russia in terms of nonkinetic capabilities, VanHerck said.

According to the Defense Department's annual report on China's military power, released on Nov. 3, China is building nuclear weapons significantly faster than previously anticipated, it already has a "nascent nuclear triad," and will field more than 1,000 nuclear warheads by 2030.

Rapid development of new stealth aircraft, the expansion of that aircraft's weapons-carrying capacity, and the shift of China's air and naval forces from a defensive posture to one of power-projection and long-range strike also is eroding the United States' long-held advantages in the air domain, according to the report.

The Financial Times reported in October that China had tested a nuclear-capable weapon that allegedly circled the globe before reentering the atmosphere at hypersonic speeds. Although the missile reportedly missed its target by more than 20 miles, it's clear China has made significant progress when it comes to hypersonic weapons.

Alexandra Baker, the Biden administration's nominee to be deputy undersecretary of defense for policy, told senators shortly after the test "there is a sense of urgency" for the U.S. to develop similar capabilities.

"They have pursued a strategy of seeking to blunt U.S. advantages over a number of years, not only in terms of hypersonics, but also in space, counterspace, [and] cyber," she said during her confirmation hearing.

INCREASING THE DECISION SPACE

Although VanHerck recognizes there are some scenarios where a kinetic strike may be a necessary first response, it should not be the default option. He wants to use domain awareness, machine learning, and artificial intelligence to get into an adversary's "cognitive space," to better understand what they are thinking, and give senior U.S. leaders time to come up with options that enable the U.S. to gain the operational and strategic advantage.

When VanHerck assumed command of NORTHCOM in August 2020, he wanted to build on what the Air Force was doing in its ABMS experiments, which already had some success connecting sensors and data in ways not done before. But the Advanced Battle Management System was focused on

Representatives from all 11 U.S. combatant commands participated in GIDE 3 at North American Aerospace Defense Command and U.S. Northern Command Headquarters, Peterson Air Force Base, Colo.

Tech. Sgt. Tommy Grimes

a kinetic endgame, and while VanHerck says this is important for the services, he wanted his team to move left of the threat and look instead for ways to prevent the threat from getting to the homeland in the first place.

"The combatant command was feeling an urgent need to increase our homeland defense capability and to try to meet that need, because the regular capability development process just wasn't developing it fast enough," Strohmeyer told Air Force Magazine.

The series of NORTHCOM-led experiments that followed, called the Global Information Dominance Experiments, or GIDE, are focused on enabling a globally integrated deterrence. Though NORTHCOM does not use the phrase joint all-domain command and control (JADC2) when talking about GIDE, VanHerck acknowledged that's what it is. JADC2, he said, can cover anything from the tactical to strategic level; his focus is on broadening the "decision space to create deterrence and de-escalation options, and if we must, defeat options."

Instead of focusing just on detecting, tracking, and engaging a cruise missile, for example, Strohmeyer said GIDE considered the entire life cycle of that cruise missile threat. What is its pattern of life? When was it placed on the launch platform? What was the launch platform doing before launch? How can machine learning and artificial intelligence help the U.S. better understand the normal day-to-day pattern of life? How does that information help the U.S. better understand when a potential adversary is planning to act against us?

"Rather than us just having to react to a detected cruise missile over North America, instead we could have machines that are giving us alerts, saying, 'Hey, I've seen in the last 24 hours a change in the pattern of life of the number of vehicles at this adversary bomber base. You might want to take a look at that,'" explained Strohmeyer, who planned the first three GIDE experiments. "Then a human can take that curated information, look at it and go, 'Oh, that is interesting. There's something going on here.' And we can combine it with other sources of information or intelligence, and then ultimately go, 'Yeah, they might be moving down the path of doing something that we don't want them to do.'"

Armed with that knowledge, multiple combatant commands can simultaneously work together to come up with proactive options "to deter that adversary from taking that unwanted action," Strohmeyer said.

GIDE 1, which took place in December 2020, was a tabletop exercise that involved four combatant commands. Participants took advantage of new technology that pored through historical satellite imagery and data from previous actions, and then alerted them to changes in an adversary's pattern of life. However, the focus was really on breaking through existing stovepipes, integrating that data, and finding ways combatant commands can better work together.

GIDE 1 allowed multiple commands to operate in a common collaborative environment where everyone was seeing the same warnings from the artificial intelligence at the same time.

"In the past, you didn't have combatant command collaboration happen until you're in front of the Chairman [of the Joint Chiefs of Staff] or the Secretary [of Defense]," Strohmeyer said. "We had combatant command collaboration starting at the very lowest level."

GIDE 1 was so successful, the second experiment conducted in March 2021 brought in all 11 unified combatant commands, and utilized live forces participating in an exercise occurring simultaneously in the Arctic.

GIDE 2 used live readiness data from the Air Force's Project Brown Heron, which is an effort to combine previously stovepiped data sets together. So, instead of having to make a phone call to learn what aircraft are available to move as they plan sorties, the information was already available in a common cloud-based data system.

The overwhelming response from the CCMDs was, "Why aren't we using this [operationally] now?" Strohmeyer said.

CHANGING THE CULTURE

Speaking at a Center for Strategic and International Studies virtual event in August, VanHerck said, "The tools that we demonstrated are ready to be applied at the operational to

Royal Canadian Air Force

Canadian air force CP-140 (top) long-range patrol aircraft flies in formation with two USAF F-16s and a RCAF CF-18 during NORAD's air defense exercise Amalgam Dart 21-02 in March. The exercise hones homeland defense skills as Canadian, U.S., and NATO forces operate together in the Arctic.

strategic level to create time and decision space." The challenge, he later told Air Force Magazine, is changing the regionally focused culture.

VanHerck often says that homeland defense doesn't actually start in the homeland. It starts with allies, partners, and other combatant commands working together to deter and defend forward locations, so a strike never makes it to the homeland.

GIDE 3, which took place in July, once again included all the CCMDs, as well as interagency partners like the Joint Artificial Intelligence Center (JAIC), and it brought in several allies and partners to observe.

During the experiment, a GIDE team aggregated early indications and warnings from 120 days of geopolitical events, using real-world alerts to highlight adversary actions, once again requiring collaboration across combatant commands. Leaders then used artificial intelligence to review deterrence responses.

In the conflict stage, a military Blue Force faced off against Red Force threats at Michigan's Alpena Combat Readiness Training Center, as a cloud-based computer network, accessible both in Michigan and at Tyndall Air Force Base, Fla., enabled participants to share data and demonstrate responses.

The focus of GIDE 3 was trying to understand how much earlier the U.S. can learn about competitor and adversary actions, Strohmeyer said. During the experiment, the JAIC also demonstrated its Matchmaker capability for "machine-enabled crisis deterrence and conflict defense," according to a NORAD/NORTHCOM release at the time. Strohmeyer said instead of the old PowerPoint and Excel spreadsheet analysis, machines provided "real-time options," though humans still made the final decisions. The team also partnered with the Defense Department's Project Maven, which uses machine learning to identify people and objects in intelligence imagery.

"I think today, especially with Russia and China, they're going to be global, all-domain problems, whether that be in day-to-day competition, or crisis, or conflict," VanHerck said. "There's no more regional problems, and so changing that culture first, I think, is important."

He said while DOD's strategies and operational plans are global and all domain, "the way we develop and design a force, budget, and acquire [capabilities, as well as] the way we train, should also be starting out with a global perspective."

REAL-WORLD APPLICATION

Col. David Morgan, NORAD and NORTHCOM's division chief for strategic analysis and experimentation, said the goal for GIDE 4 and beyond is to expand the involvement of allies and partners.

Though in the near term that likely will include Canada and NATO members, he said, "As the platforms develop, we are aggressively working on technical and policy issues to ensure our allies and partners can participate in future GIDE iterations."

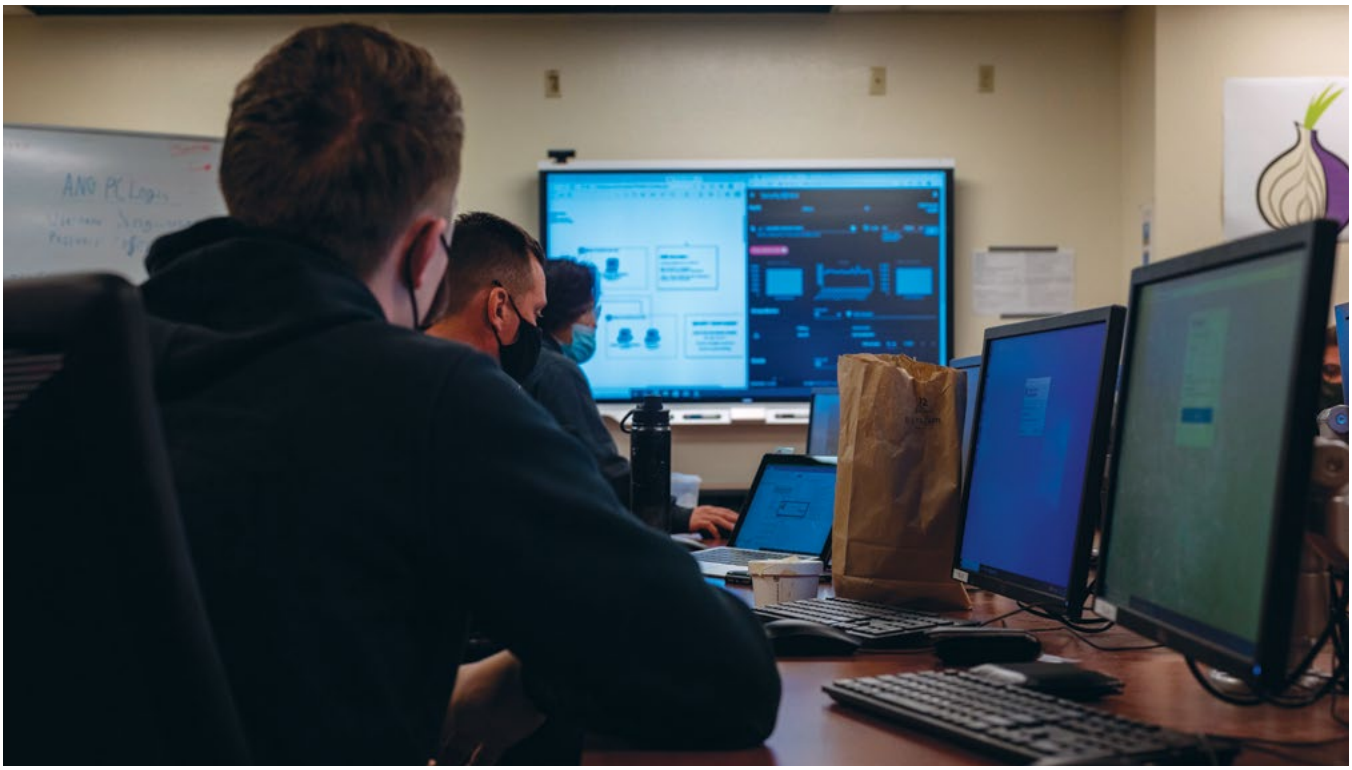
GIDE 4 is slated for early spring and will coincide with several already-planned U.S. and allied exercises, Morgan told Air Force Magazine via email.

Whereas the first three GIDE events primarily used AI and machine learning against real-world historical data gathered during "previous competitor activities," Morgan said GIDE 4 will focus more on the operational level.

"In GIDE 4 we are already applying machine learning and AI tools in real-time toward recognizing changes in the pattern of life to provide better indications and warnings earlier than traditional means have provided in the past," he said.

Through its work with Project Maven and the Joint Artificial Intelligence Center, GIDE continues to "challenge the traditional acquisition cycle," he added, with the goal of pushing new technology to troops faster.

"GIDE has demonstrated the power of software-based technology and the rapid development that can be achieved in teamwork with leading industry partners," he said. "Since GIDE 3, JAIC and Project Maven have developed new features and improved capabilities while working with users across the Department of Defense and industry. As planning continues, we expect GIDE 4 to provide a venue for demonstrating and experimenting with other related technology sponsored by the other combatant commands." ✪



Airman 1st Class Thomas Cox/ANG

Members of the 152nd Communications Flight and the Red Team from the University of Nevada, Reno's Cyber Club train together on cybersecurity skills and techniques at the university's Cybersecurity Center.

Hacking the Supply Chain

Cyber risk is everywhere—and it threatens every military system.

By Greg Hadley

Testifying before the Senate Armed Services readiness subcommittee in April, Dr. Raymond D. O'Toole Jr., then acting director of operational test and evaluation for the Pentagon, dropped a verbal bombshell.

"As the committee is aware, cybersecurity is the most pervasive threat vector, and DOD largely is not doing well on this front," O'Toole said. "Of the programs DOT&E assessed in [2020], virtually none were survivable against relevant cyber threats."

Rattled, Sen. Dan Sullivan (R-Alaska), the ranking member on the subcommittee, quickly followed up. "I hope our adversaries aren't watching this hearing. They often do watch these hearings. But what in the hell are we going to do to close that gap?" he said. "That is shocking and, well, concerning."

Six months later, Sen. Tim Kaine (D-Va.), the panel chair, recalled the incident while questioning Nickolas Guertin, the Biden administration's nominee to lead operational test and evaluation.

"Anything that's sitting out there on a network, anything that's moving a bit or byte around, is a cyber target."
—Kevin Fogarty, Dynetics Aerospace, defense and civil chief technical officer

"Senator Sullivan and I both looked at each other and said, 'Is this an open hearing?'" Kaine said of his reaction to O'Toole. "And the witness, Dr. O'Toole said, 'I got this cleared for delivery of testimony in an open hearing.' But it troubled us greatly."

The Defense Department's cyber challenges are enormous. Systems increasingly rely on software code, much of it incorporating open-source components. Growing dependence on cloud-based systems to host databases and computer workloads also expanded the Pentagon's attack surface. Conventional cyber defenses based on keeping hackers out of DOD networks have given way to new strategies built on protecting the data inside the network, because that's what hackers are after.

Some see the principal challenges as developing a more cyber-capable workforce, as O'Toole suggested; Guertin suggested the issue is more about integrating cybersecurity into the systems development process from the very beginning. The reality

is that in an increasingly connected world, every weapon system is a cyber target.

OUTLINE THE THREAT

As far back as January 2013, a Defense Science Board task force report, "Resilient Military Systems and the Advanced Cyber Threat," warned that adversaries could exploit cyber vulnerabilities to:

- Degrade and sever communications;
- Manipulate and corrupt data;
- Cause weapons to fail, and potentially; and
- Destroy weapons or systems.

China, Russia, Iran, and North Korea all see cyber as presenting an opportunity to counter American advantages in military technology by exploiting it as the soft underbelly of U.S. defense. A large-scale attack across infrastructure and the military, the report said, could "impose gradual wide scale loss of life and control of the country and produce existential consequences." For such an attack to occur, it added, "there must be an adversary with both the capability and intent to conduct the attack."

Klon Kitchen, a senior fellow at the American Enterprise Institute who worked on creating the U.S. Cyberspace Solarium Commission, said it's not hard to imagine today which adversaries might be so capable. "China has … a capability, and an intention, and a demonstrated history of leveraging its access to supply chains to gain access to information, to exfiltrate data, to insert vulnerabilities that they can leverage later," he told Air Force Magazine.

Kevin Coggins, a vice president at Booz Allen Hamilton and the head of its Positioning, Navigation, and Timing practice, said cyber vulnerabilities transcend the computer world and threaten the physical world, as well.

"It sounds real sci-fi, but you can literally stop things from working," Coggins said. "People used not to think of cybersecurity with respect to a weapon system, because you only saw what the weapon system did, right? *That* thing hits a target and blows a building up. *That* thing flies through the air, *that* thing orbits the Earth," he continued. "But those things are [also] computers. Every single one of them has a computer at its core and information coming into it and out of it. And that defines enough attack surface right there to start thinking about cybersecurity."

The F-35, as former Air Force Chief of Staff Gen. David L. Goldfein has said, is "a computer that happens to fly." Modern, digitally enabled weapons are networked to sensors and communications links in space. And Goldfein's dream of multi-domain command and control—what the Pentagon now calls joint all-domain command and control—is effectively a "military Internet of Things," as former Air Force acquisition chief Will Roper dubbed it.

The trouble is, there's no such thing as a hack-proof system. If it can be built, it can be compromised. Iran's cyber warfare unit famously captured control of an American RQ-170 surveillance drone a decade ago. The incident highlighted the potential vulnerabilities of such systems, as well as the fact that it doesn't take a world power to develop such capability. Meanwhile, China and Russia have honed their cyber skills, penetrating U.S. government and industry networks, exfiltrating unknown volumes of data, and raising the stakes in information warfare.

"The military writ large is in the middle of this pivot toward near-peer competition … but we've been there in the cyber realm for a while—a lot longer than we've been there in the kinetic realm," said Kevin Fogarty, defense and civil chief technical officer for Dynetics Aerospace. "So, as we turn our kinetic capability toward near-peer competition, we need to understand where we're at with our cyber capabilities and where our adversaries are. And then we need to understand the impact that has on the legacy systems that we've got out there, as well as the new systems we're procuring. Because anything that's sitting out there on a network, anything that's moving a bit or byte around, is a cyber target."

PROTECTING THE SUPPLY CHAIN

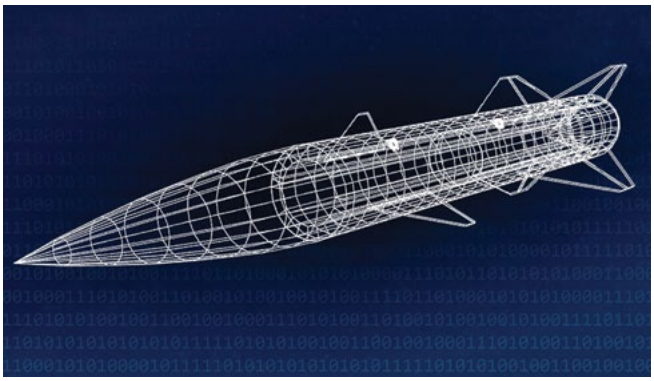
Cyber vulnerabilities begin in the development stage. "Obviously potential vulnerability goes up if you can steal the entire plans for weapon systems," said Laura Brent, a senior fellow in the Technology and National Security Program at the Center for a New American Security.

Securing contractors networks is really the very first line of defense. The Cybersecurity Maturity Model Certification establishes cybersecurity standards and training for contractors and is a good first step. Securing the digital supply chain, including computer chips and sub-assemblies made offshore, however, is another thing entirely.

"Most chips are not made in the U.S. anymore," noted Ann White, a principal at Booz Allen with a background at the NSA.

Airman 1st Class Alexander Merchak

U.S. Air Force Staff Sgt. Stephanie Dias, 60th Communications Squadron cyber transport systems technician, configures a network switch at Travis Air Force Base, Calif. The military used to focus on protecting its networks, but recent strategy tilts toward protecting the data stored and moving through the network.



Chris Quinlan and John James/USAF

Digital twins provide a virtual test bed for every aspect of a system, enabling engineers to envision how weapon perform as inputs change, including if bad data or malware is introduced.

"And so we're looking at how you identify vulnerabilities associated with the manufacturing process and that supply chain. How can they be switched out?"

Most of those parts are made in Taiwan, China, and South Korea; concern over parts manufactured in China is particularly high.

Specific vulnerabilities related to China's role in the supply chain are classified, but the implications of such a threat are clear.

"Imagine if [China] had gotten into the chip supply chain in such a way as to where they could turn off navigation systems in military aircraft," Kitchen said. "Or if they could disrupt communications capabilities at sea, or if they could throttle power on fundamental systems inside any of our platforms."

In the recent SolarWinds hack, Russia was able to compromise hundreds of companies and federal agencies, including DOD and cybersecurity specialist FireEye, which discovered the breach. The hackers penetrated the SolarWinds system and then bided its time, employing a long-term strategy to spread its malware by attaching it to a legitimate update, which then spread naturally to SolarWinds customers.

And even if the Pentagon is able to secure the IT systems of contractors and ensure the supply chain is safe, highly sophisticated attacks like that one are hard to detect.

"The user is a vulnerability … how the user interacts with the system," White said.

Clicking on deceptive links in emails or on websites, downloading files shared by a colleague (or apparent colleague), and taking other routine actions that anyone might experience in a normal workday can all result in accidentally enabling a cyber attack.

Once in the system, malware can exfiltrate data or manipulate data, causing a system to produce bad results, to crash, or to fail. "If you cause a processor on an autonomous drone or a missile or a sensor on a satellite to crash, there's no one there to hit a reset button," Coggins said. "And if you didn't design it to recover from that, it's done. It's toast until it resets and recovers."

The Stuxnet attack used to infiltrate and damage an Iranian uranium enrichment plant caused the plant's centrifuges to malfunction and effectively destroy themselves. Commonly attributed to Israeli and U.S. cooperation, it was one of the first known instances of a computer virus that directly impacted the physical world.

"Something very similar can be done in a whole host of systems, right?" Kitchen said. "I mean, you could shut down cooling systems, and therefore everything else that depends on those cooling systems within all these different platforms could overheat and stop working, right? ... There's essentially no shortage of ways that you can do bad things if you've got this kind of access."

CURRENT EFFORTS

The Government Accountability Office first identified cybersecurity as a high risk in 1997. Today, while overall security is greater and more effective than ever, the range of systems accessible to hackers has grown exponentially. A 2021 GAO report praised the Air Force's Cyber Resiliency Office for Weapon Systems for its servicewide guidance on how to define cybersecurity requirements for acquisition systems and how to incorporate them into contracts.

The Air Force's "System Security Engineering Cyber Guidebook" integrated cybersecurity into the development process, applying an approach similar to the "DevSecOps" mindset used in agile software development, where developers, security specialists and operators all work on new systems in parallel, rather than one after the other. And the crossover between cybersecurity approaches in software and hardware shouldn't end there, Fogarty said.

"The term 'zero trust' doesn't just apply to your computer network. That needs to apply to our weapon system architecture. … So we really need to look at those constructs, some of the guidance coming out, and make sure we translate those correctly from an IT world into a cyber-physical weapon system," Fogarty said.

Another approach from the IT world that should carry over to a weapon system's cyber defenses, Coggins said, is that of iterative updates, where cybersecurity is never considered perfected or finished.

"It's not just, 'give me a requirement for an iPhone, I'm going to build you an iPhone and deliver it.' It's, 'build me a capability that you can continuously upgrade and that can continuously pace the threat'—as the threat changes, it's easy to change the capability," Coggins said. "Historically, we haven't designed weapon systems to be updatable or easy to change."

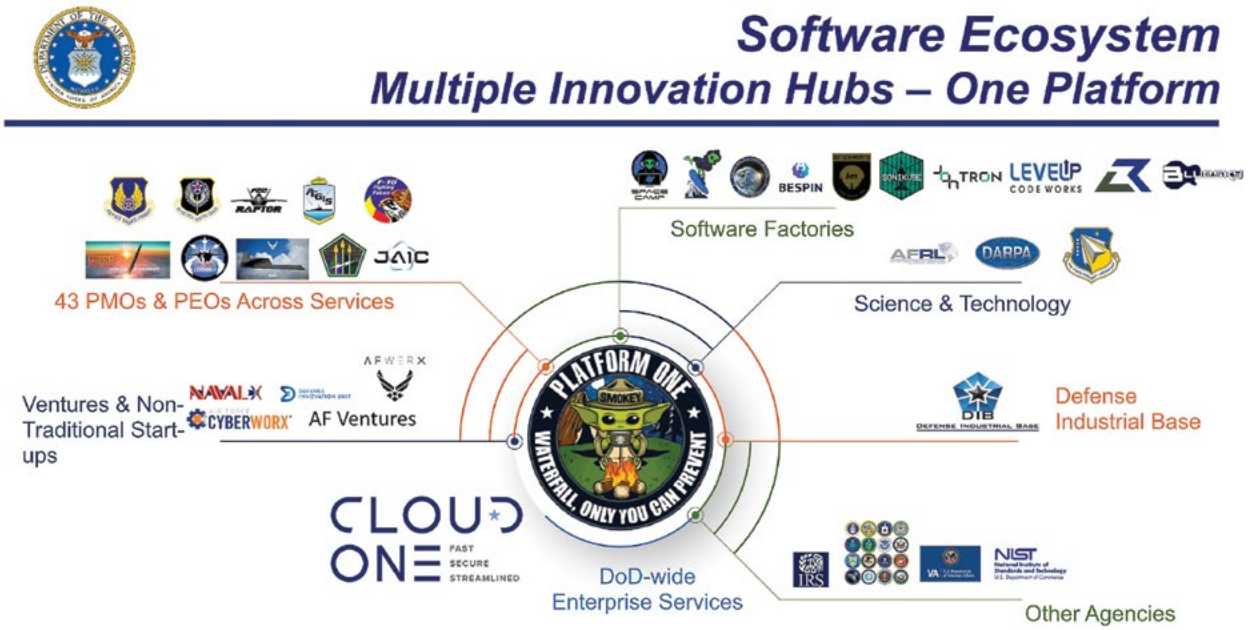
Like the GAO, Coggins singled out the Air Force for its efforts in that regard, specifically praising Platform One, a DevSecOps platform for software designed to be hardened against threats while still flexible for different programs.

From the hardware side, cybersecurity can also be enhanced by "digital twins," White added. Using a virtual replica of a weapons system through the development and testing phases allows agencies and contractors to "simulate attacks, simulate mitigations, and then evaluate their effectiveness," she said.

Overall, increased testing has been a central component of how Congress has tried to address the issue—the 2021 National

Staff Sgt. Andrew Sarver

The F-35A is more than a fighter airplane; it's a flying sensor and data center, able to accumulate and share troves of data and is built of millions of parts that must be sourced across a global supply chain.



USAF

Platform One merges top talent from across the U.S. Air Force using various factories (Kessel Run, Kobayashi Maru, SpaceCAMP, and Unified Platform). It is now an official DOD DevSecOps Enterprise Services team.

Defense Authorization Act required the Secretary of Defense to establish policies for periodically testing major weapon systems for cyber vulnerabilities, and the legislature has provided funding for pilot programs aimed at developing a cyber-capable workforce like O'Toole said the Pentagon needs.

Yet even with acquisition requirements, iterative updates, and increased testing, the threat remains so widespread, so pervasive that "it's important to realize that 100 percent security, whether that's cyber or otherwise, is probably not achievable," Brent warned. "So what is an acceptable amount of risk while still allowing achievement of mission critical functions?"

RISK ASSESSMENT AND RESILIENCY

Defining an acceptable level of risk for cybersecurity is especially critical given some of the realities the Pentagon and the Air Force face, like constrained budgets and legacy systems designed and built in a different era.

"I think a lot of our systems made assumptions in terms of … an IT system needed cybersecurity, but these systems with microcontrollers, processors in them that didn't connect to the internet, didn't need cybersecurity," White said.

And in a different time, the risks associated with that mindset weren't as great—systems were "stove-piped … they had their own command and control system with them," Fogarty said. "You could protect that system, or not protect that system, but there wasn't a lot of lateral movement an adversary could do."

Now, with JADC2 aiming to connect sensors and systems like never before, "you're only as strong as your weakest link," Brent said—even systems developed with cybersecurity in mind could be compromised by being connected to less secure systems. Fixing those less secure systems isn't as simple as a quick software update either.

"It's hard to push patches to older systems, because the act of putting the patch on them is hard, it's difficult," Coggins said. "The system may have to go back to a depot for someone to do it. In the new paradigm, you'll be able to do it in the field, and it saves a lot of time and money. We're trying to update many old systems right now. It may take five years to put one patch out."

Over time, the systems being developed now—the ones developed with security in mind, tested more rigorously in those areas, and capable of receiving iterative updates—will replace the older ones. But that will likely take years. In the meantime, there are ways to address the gaps.

For one, "not every vulnerability has to be fixed, right?" White said. "If it's not … operationally impactful, or the probability of it happening is very low, don't fix that, right? Fix the ones that we know our adversaries know about and that are easy to impact, easy to execute, and that have a high operational effectiveness."

Fixing the issue might not even involve deploying a software patch, Coggins added. Sometimes it's as simple as training the person operating the weapon system.

"A good example is there may be some telemetry data coming from the satellite that they don't pay attention to, because it's just been benign for 20 years," said Coggins. "We've flown GPS for a long time. But now there may be some indicators on the telemetry data of a certain attack that might have occurred, and so now you can detect it as an operator and then do something about it immediately."

In that example, the satellite's cybersecurity measures failed to prevent an attack—but the issue isn't quite as simple as success or failure.

"I think often we approach some of these challenges in binary, does it work/doesn't it work kind of ways," Brent said. "And the answer is, even if it doesn't work now, what is the time, how resilient is the system to be able to return into operation?"

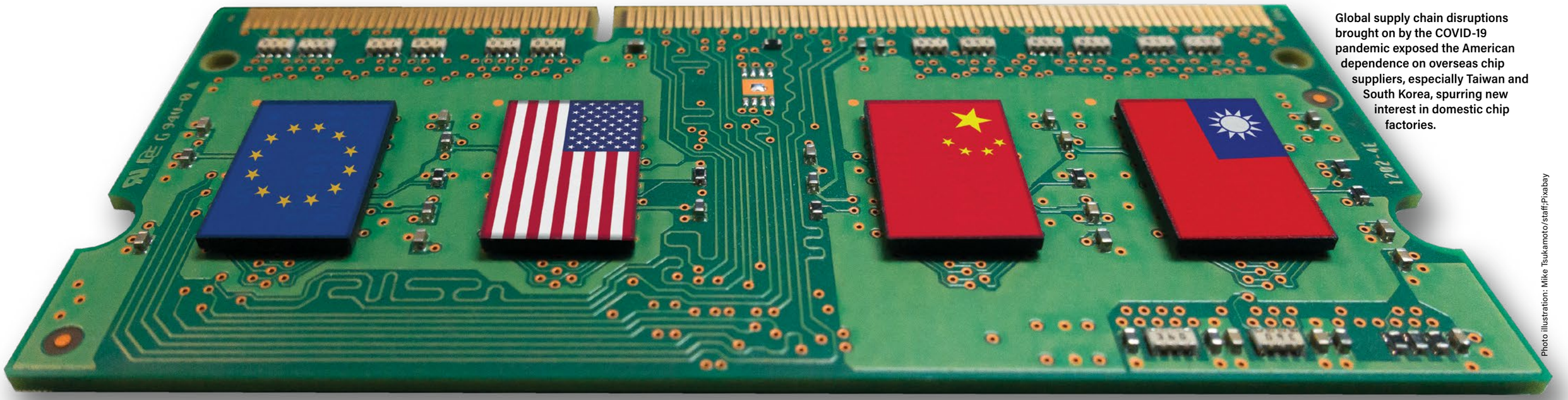
And it's not just the system that has to be resilient. The operator has to be able to use it even when circumstances aren't ideal—"It's not a matter of just knowing how to use your system, you've got to know how to use your system while the adversaries are actively attacking it," Fogarty said.

That speaks to a broader need, multiple experts said, for DOD to continue to develop its workforce to be digitally fluent across the board, not just in specialized fields. Such a force will be necessary as weapon systems become increasingly digital themselves.

"Cybersecurity is not just about the computer, right?" White said. "I have a computer in my doorbell these days, right? I have a computer on … the spotlight that I have in my house. As everything becomes a computer, we have to think a lot more about those requirements and what that means for us in terms of attack surface for our adversaries and how we develop hardening and mitigation against those attacks." ✪

Facing Down
Semiconductor Su pply Chain Threats

The lack of domestic chip supplies is a growing threat.



Global supply chain disruptions brought on by the COVID-19 pandemic exposed the American dependence on overseas chip suppliers, especially Taiwan and South Korea, spurring new interest in domestic chip factories.

Photo illustration: Mike Tsukamoto/staff;Pixabay

By Gordon Feller

It began with the onset of the global pandemic: a global shortage of medical equipment, from masks to gloves, surgical gowns, and hand sanitizer. First there was an oversupply of oil in 2020, driving the futures price to zero. More recently, we've seen oil and gas prices soar to levels not seen in several years. Disruptions spread, but the biggest and most far-reaching shortages have been in semiconductors, the computer chips used in everything that requires electronic controls or sensors.

COVID was a driver, including the increased demand for technology to support remote work: There were fires at key Taiwan and Japan manufacturing plants, reduced commercial air flights, which led to capacity problems, and deteriorating trade relationships, including U.S.-China disputes and the U.K.'s messy BREXIT from the European Union.

Apple delayed its iPhone 12; automakers shutdown or slowed factory production; China's telecom giant, Huawei—already embroiled in a dispute over its government ties and the security of its 5G technology—started stockpiling chips out of fear it would be cut off from the global chip market. And much of the world woke up to overdependence on too few companies and countries for the world's chip supplies.

"Semiconductors are more central than ever to our everyday activities and to the health of the global economy."
—John Abbott, Analyst, S&P Global Market Intelligence

Chip crises have struck the Pentagon in the past. In the 1970s, the Defense Department launched VHSIC, the billion-dollar Very High-Speed Integrated Circuit Program, to accelerate computer chip development; in the 1980s, it invested a similar amount in Sematech, which included matching industry contributions to try to revitalize domestic chip manufacturing after Japan arose as the world's leading chip supplier.

"I think we're going to be still dealing with shortages until we get to some reasonable supply–demand balance through next year," Intel CEO Pat Gelsinger said in an August interview with the Washington Post.

The company says global demand for semiconductors will only accelerate, driving demand for critical third-party components and materials. An Intel spokesperson said they "expect this to last for one to two years."

Now, Intel is investing $20 billion to expand manufacturing capacity in Arizona and another $3.5 billion to increase production in New Mexico. In addition to manufacturing its own chips, Intel created a new business, Intel Foundry Services, "to provide manufacturing and advanced packaging capacity" for its customers' chip designs. Building independent capacity in the U.S. and Europe, Gelsinger said, would help "rebalance global supply chains."

John Abbott, an analyst at S&P Global Market Intelligence, said the cyclical nature of the semiconductor industry lends itself to booms and busts, "with dips in the market having occurred roughly every five years since 1980." This cycle has seen a double dip, both in 2019 and again now. "Semiconductors are more central than ever to our everyday activities, and to the health of the global economy," he said. "As a result, supply constraints are holding back production in key market segments like smartphones, game consoles, automotive, healthcare, manufacturing, and defense."

Major aerospace contractors haven't faced the extent of shortages that slowed automotive production, at least not yet. But regional breakdowns in the supply chain have highlighted concerns.

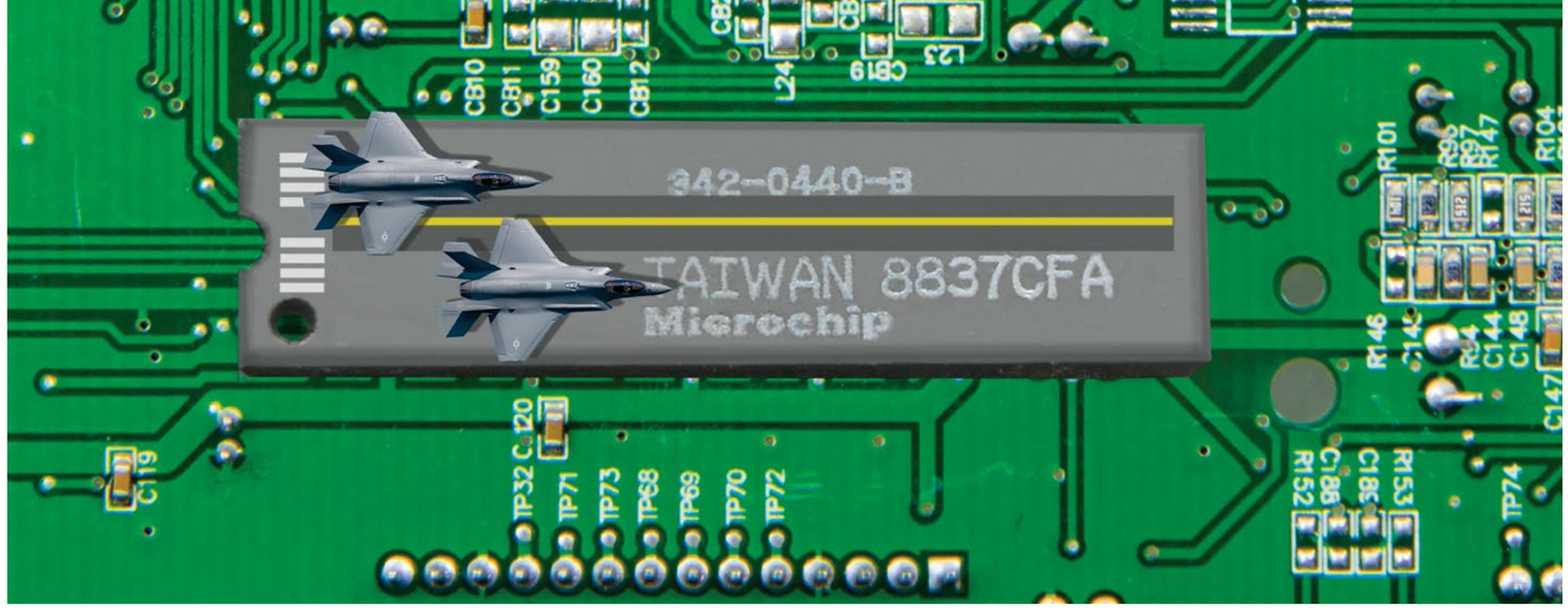
Abbott highlights several supply chain danger points:

■ **Supplier concentration.** Taiwan is home to TSMC (Taiwan Semiconductor Manufacturing Company), the single-largest chip foundry in the world, with roughly half the global market. Another large foundry, United Microelectronics Corp., is also in Taiwan. But Taiwan is at the center of a looming confrontation between China and the West.

■ **Return to localization.** If the pandemic did anything, it exposed the risks of concentrating too much manufacturing capacity in one small part of the world. That's why Intel is now investing in new U.S. and European capacity and TSMC has announced plans to build additional capacity, including a $12 billion chip fabrication facility (fab) in the U.S.

■ **Chip-making equipment.** This has long been a limiting factor and was a driving element of the Pentagon's Sematech program in the 1980s. Only one company (ASML in the Netherlands) has the extreme ultraviolet lithography machines needed to produce the most advanced microprocessors, with transistor geometries of 10 nanometers or less. A handful of other, mostly American companies, make machines for larger geometries, and the U.S. government has restricted their sale to China or to companies selling chips to China.

■ **Changing customers.** Chip companies have seen their biggest customers evolve over time, with hyperscale cloud providers, such as Amazon and Microsoft, and consumer device makers, such as Apple. Other growing markets are



The Taiwan Semiconductor Manufacturing Company is the single-largest chip foundry in the world, with roughly half the global market of high-end computer chips.

Mike Tsukamoto/staff; Stux/Pixabay Illustration; photos Raimond Spekking and Dave Jones; USAF

the plethora of connected devices, from smart thermostats to lightbulbs that make up the Internet of Things, and the growing automotive market.

■ **Market access.** Chip fabrication is expensive. It can take up to three years to reach production in a new factory, and pure fab companies, such as TSMC, rely on high volumes to recoup costs. Location, available skills, the surrounding ecosystem, and licensing issues all play a role in locating a facility.

■ **Just-in-time manufacturing.** Lean inventory practices, which took off in the 1980s as a means of cost control in major manufacturing, took a hit during the pandemic; late shipments idled factories, while canceled orders scrambled supply chains. Manufacturers and suppliers have yet to adapt.

Abbott believes "the shift toward worldwide globalization has been put on hold for now, and may not return," but technology development is too complex to be controlled by individual countries. The Pfizer vaccine makes a useful case in point, Abbott said: "It has 280 different components manufactured in 86 different sites across 19 different countries."

Retired Army Maj. Gen. John G. Ferrari, now a non-resident senior fellow with the American Enterprise Institute in Washington, D.C., said a commercial shortage inevitably spills over to affect the military.

"The chip shortage is absolutely causing issues within the military supply chain," he said. "These chips are in everything the military buys and, more importantly, they are embedded in the supply chain, also. In the very near term, military procurement cycles are slow, so we are not likely to see an impact immediately. But the impact will be felt over the coming months."

Ferrari said supply chain issues could have a disproportionate impact on startups and other smaller defense suppliers. "As the cost of these chips increase, and the time to get them increases, these nontraditional firms do not have the cash flow to weather the storm," he noted. "This is a potentially very large negative" with long-term effects.

More broadly, the fact that so many of these parts must be sourced from overseas is itself a matter for concern, he said. "The Defense Production Act and the ability of the [U.S. government] to prioritize chips for the military is very limited," according to Ferrari. "If there ever was [a] shooting war in the Pacific, our ability to quickly rebuild our arsenal and weapons would be severely impacted because it is likely that our supply chain from the Pacific would be interrupted. So this chip shortage may just be a sneak preview of what we are going to face down the road. It is also giving our adversaries a blueprint on how to hobble us going forward."

Dana "Keoki" Jackson, senior vice president and general manager at MITRE National Security Sector, said the "pandemic has highlighted U.S. and global risks to supply chains that extend beyond semiconductors, and an all-of-nation response is needed to address both near-term shortages and longer-term challenges." He recommends investing in domestic and allied nations' industrial ecosystems and providing incentives for sustained industrial base success, as well as "investing in the technology and workforce for the future."

Rory Green, TS Lombard's London-based head of China and Asia Research, said the crux of the supply problem is "an unprecedented demand surge because of the pandemic. The 'Zoom boom' led to increased sales of a range of semiconductor-intensive goods, from laptops to gaming consoles," he said. "The demand surge came after several years of low industry [capital investment] and generally falling sales, meaning supply was unable to match the ramp up in new orders. Industry is responding—but it takes approximately two years and between $10 billion to $25 billion to build a new chip fabrication facility."

In Green's view, "this looks like another 'Sputnik moment' for Western leaders: The growing importance of semiconductors in all parts of economic life, combined with increased superpower competition, is likely to lead to greater focus on reshoring of production to the U.S. and a gradual reorganization of supply chains to favor national security over production efficiency."

Daniel L. Dumbacher, executive director of the American Institute of Aeronautics and Astronautics, called semiconductors "a vital and threatened part of the secure supply chain." He said the U.S. government must analyze future semiconductor needs, identify potential supply gaps, and collaboratively work with industry to address needs.

One of the most astute analysts of this matter is Matt Bryson, senior vice president of Equity Research/Hardware at Wedbush Securities. He's examined three elements of the current semiconductor crisis. Here are some of his conclusions:

■ **Minimal Capacity Growth.** Foundry profitability, particularly for mature process capacity, has always been limited. With older foundries struggling to make money in recent years, they've underinvested in order to keep costs in check."

■ **Strong Demand from New Technologies.** Bryson thinks that "the adoption of 5G has driven up semiconductor content within handsets and telecom infrastructure, with adoption of the new technology ... occurred faster than expected." Other new technologies (including electric and intelligent autos, plus the Internet of Things) also require incremental semiconductor content, though the uptick in demand is a bit more modest.

■ **Poor Supply Chain Management.** The impact of shortages "is being exacerbated by order cuts at the start of COVID (due to demand uncertainty) as well as 'just-in-time' practices. This approach left companies with limited buffers when semiconductor availability became constrained.

Bryson thinks that the impact of these issues has, in turn, been amplified by the impact of COVID and two additional challenges—logistical (including port congestion and worker shortages) and manufacturing (due to factory limitations in Southeast Asia). These make some of the incremental work more difficult, such as packaging and productizing semiconductors, for instance.

Bryson doesn't think the semiconductor shortage is tied to locality of supply: "However, the extent of the impact combined with concerns around China's geopolitical ambitions and tensions in its relationship with the West has certainly led to increased focus on improving domestic supply. Increased focus of governments on where semiconductors are produced, and resulting subsidies to encourage domestic production, will lead to a shift in where semiconductor fabs (and semiconductors) are built."

Bryson predicts that "new capacity begins to come on around mid-2022, with output from new fabs really starting to kick in during 2023. So, my best guess is sometime second half of 2022/early 2023 is when chip scarcity subsides, though the exact timing will depend upon the product as well as general macro-trends—stronger worldwide economic trends naturally lift semiconductor demand, and vice versa".

While analysts have some deep insights, no one is better situated than manufacturing executives to understand the dynamics beneath the surface of this crisis. Ganesh Moorthy, Microchip Technology's CEO, says that the current supply/demand imbalance in the semiconductor industry, "is the worst I have seen in 40 years. In fact, I think the imbalance we have seen between supply and demand has never been this acute in all my history in the industry and it has continued to get worse over the last six months. The rate at which new orders are coming in is outpacing the capacity that we can bring on board. So clearly it is a constraint we are going to see through this year, most likely into next year."

Moorthy considers this time to be different than previous crises. "This has been brewing for some time. It starts all of the way back in late 2018 and early 2019 when the tariffs started to create headwinds for many of our customers. They could not absorb the tariffs and their end-consumers could not bear the prices, so our demand went down in 2019. As things began to improve, and supply chains realigned so that products destined for the U.S. could be built outside of China, the U.S. was hit by COVID through the first half of 2020. This added to pressure on the demand side, especially in the automotive, industrial and consumer sectors. They all stopped buying," he pointed out.

Moorthy has been thinking about the steps that need to be taken to ensure this never happens again: "On an ongoing basis, there will be supply and demand imbalances resulting from normal economic cycles. But there are also policy initiatives in the medium to long term that will be important to support a stronger U.S. semiconductor manufacturing infrastructure. Semiconductors are the foundation for our digital economy, and much of what we do depends on them. For both economic and national security reasons, it behooves the U.S. government to ensure the long-term strength and resilience of the American domestic semiconductor industry. This includes both R&D and manufacturing capability, which can be done through policy initiatives. This can be accomplished on the R&D side in the next one to two years. But the biggest issue is the manufacturing side, which will likely take at least three years to address—from when government initiatives are launched to when we see results at the industry level."

Semiconductor supply can be manufactured domestically for the aerospace and defense sector. This is increasingly seen as vital, due to concerns around hacking, counterfeit parts, and other issues. Moorthy is optimistic about these prospects: "We already build a fair amount in the U.S. for the defense part of our business. We have other proposals that we have made that can allow us to do more for the defense industry, we do have manufacturing in-house and most of it within the U.S. as well. There is the opportunity to do more but it has taken a long time to get where we are." ✪

Gordon Feller serves as a Global Fellow at The Smithsonian Institution's Wilson Center.

Solving America's Cyber Tech Workforce Shortages

National Security Concerns Drive AFA's CyberPatriot, StellarXplorers Programs.

By Scott King

CyberPatriot/courtesy

Students from the Bentonville Ignite Professional Studies team from Arkansas competed in Round 1 of CyberPatriot XIV 2021.

Rising cybersecurity threats and expanding reliance on computer networks and space-based technologies are fueling increased demands for science, technology, engineering and math (STEM) skills in both the civilian and national security sectors. The 2020 Cybersecurity Workforce Study conducted by ISC(2) found 40 percent of cybersecurity jobs in the United States remain vacant because the nation has too few cybersecurity professionals.

The nation also faces a shortage in engineering, math and other computer-related professions. Although the 2019 Global Engineering Capability Review ranks the United States No. 1 in engineering knowledge, it places the U.S. engineering workforce at 30th worldwide, far behind China (No. 7), Russia (14), and even Portugal (4) and Vietnam (10). The problem could soon get worse: the United States ranked 30th in math and 11th in science in the OECD's 2018 Programme for International Student Assessment of 15-year-old students worldwide, which concluded that only 20 percent of U.S. high school graduates were prepared for college-level STEM courses.

With the onset of the COVID-19 pandemic in early 2020, the need for a well-equipped cybersecurity workforce has only been accelerated.

"It's been said that the leap in digital transformation advanced about seven years, just in the year of 2020 alone, because of the pandemic," according to retired Maj. Gen. Kimberly A. Crider (USAF), a senior counselor and adviser to the Air Force Association. "That digital transformation happened so quickly it created a lot of risk because we didn't have a workforce ready to support the growing demand and capabilities that we've all become so dependent on. Meanwhile, there was about a 430 percent increase in ransomware attacks in 2020, as cyber criminals saw the opportunity to go after our data and information."

That's one reason why Crider is devoting a significant amount of her post-retirement time to help expand AFA's STEM programs: CyberPatriot and StellarXplorers.

As the nation's largest national youth cyber education program, CyberPatriot seeks to generate student interest in STEM education and careers through competition.

"CyberPatriot excites students about STEM education and cybersecurity from a very young age," Rebecca Dalton, Director of CyberPatriot's Engagement and Outreach, said. "[The program] engages students at a deeper level and helps them understand what they are truly capable of. Many students give CyberPatriot a try without having any prior knowledge of cybersecurity, but it's the excitement and awareness of the competition that motivates them toward becoming the next generation of the cyber workforce."

Now entering its eighth season, CyberPatriot's National Youth Cyber Defense Competition has grown to include more than 7,000 teams. During the competition, students work together to solve cybersecurity vulnerabilities in a provided operating system, all in hopes of advancing to the State, Semifinal, and National Final rounds. The last pre-pandemic season drew over 25,000 students.

CyberPatriot has inspired careers. According to its 2020 Participant and Alumni Survey, 84 percent of alumni respondents reported they went on to study and/or work in STEM-related fields. That's more than four times higher than the national average.

Monica Saraf, for example, was a six-time participant in CyberPatriot, who has since embarked on a career as a cybersecurity consultant after working as an intern at NASA's Goddard Space Flight Center.

"Originally, I didn't think I would be very interested in cybersecurity," said Saraf. "But after I tried CyberPatriot in the 7th grade, it became something I wanted to do for the rest of my life."

"This program was the start of something great for me," Victoria Chu, a four-time CyberPatriot participant said. "I went on to study computer science and electrical engineering and now, I even work a cybersecurity job. The topics I learned about in CyberPatriot gave me a great basis for the work I do today."

AFA's other STEM education initiative focuses on space-based technologies and teaches the basics of satellite launch operations and management.

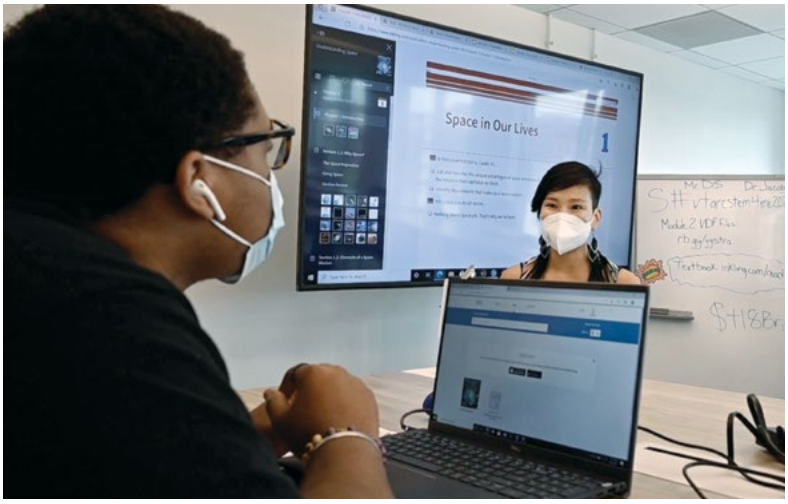
"StellarXplorers is focused on the problem-solving aspects

of space and getting students excited about being able to do physics concepts, without worrying about all the crazy, very intimidating math concepts that are often associated with it," said Julie Demyanovich, who manages the StellarXplorers competitions. "Students often come in with very little space knowledge, but they leave feeling confident in themselves and using the same software that engineers use on a daily basis."

The StellarXplorers program develops three specific skillsets: Orbit Planning, Satellite Design, and Launch Operations. Teams work together to accomplish tasks within these skillsets in hopes of qualifying for the National Final round, where they must balance and complete all three tasks within an eight-hour time period.

"We are building the future workforce for space exploration and space security," Demyanovich said.

"We want to inspire students to think of rocket science as an actual career they can pursue and make the field more approachable for students by having this really great competition available to them."



Mike Tsukamoto/staff

An instructor at the 2021 StellarXplorers Camp explains the theory of orbital spaceflight at the Basic Research Innovation Collaboration Center in Arlington, Va. Students worked on space systems simulation software used by real space professionals.

Former participants in the StellarXplorers program tend to agree.

"It's pretty eye-opening to see just how many components go into the entire satellite launching process and how many different considerations you have to take into account," Jennifer, a StellarXplorers participant, said. "Then to be in a mock environment of that and really show what I've learned over the years and be able to practice it with a team has just been incredible."

"I learned not just what goes on in the aerospace industry, but also the process of launching a spacecraft into orbit," said Ramus, another StellarXplorers participant. "In fact, it was also through StellarXplorers that I learned about an internship opportunity with Boeing that I was able to participate in last summer."

In addition to STEM, these competitions also foster leadership and communication skills that play a pivotal role in these fields, particularly in cybersecurity.

According to a survey by the Center for Strategic and International Studies (CSIS), 70 percent of IT decision-makers consider communication skills to be scarce among cybersecurity graduates. Additionally, more than half of the respondents said finding candidates strong in communication and team leadership was a struggle.

"The failure to develop these skills has a serious impact on the effectiveness of graduates once they enter the workplace," wrote co-author and CSIS Senior Vice President James Lewis. "The ability to work as a team is essential, since cybersecurity is rarely handled by single individuals. Problem-solving forms the very foundation of effective cybersecurity work and many graduates face significant obstacles troubleshooting real-world systems."

FUTURE WORKFORCE

Consequently, developing leadership and communication skills has been integrated into both the CyberPatriot and StellarXplorers programs.

"CyberPatriot has greatly impacted where I am now by showing me the most important part of all the jobs that I have worked at: teamwork," said Owen O'Dea, a participant in the 2019-2020 CyberPatriot competition. "Although often overlooked, a lot of teamwork is required within the industry."

"StellarXplorers was one of my first tastes of actually being in a cooperative environment where everyone is working toward the same goal," StellarXplorers participant Jennifer, said of the competition's collaborative nature. "So being able to work alongside other passionate people under responsible guidance helped me gain a better understanding of what teamwork truly is."

These programs are designed with an eye toward producing the future workforce in STEM-related fields our country needs, as the combination of technical and non-technical skills developed through AFA's programs make students more competitive when they enter the job market. This is primarily because their experience in these competitions is both practical and applicable to real-life work situations.

This bodes well for program participants as demand for STEM skills in the job market continues to grow. According to the Education Commission of the States, STEM jobs are projected to grow by 13 percent between 2017 and 2027, compared to just 9 percent for all other jobs.

Consequently, developing future employees to fill those jobs in both cybersecurity and space, has become a national imperative.

"STEM education is foundational to the operational field in the United States Air Force and in the United States Space Force, as their missions depend upon secure operations that rely heavily on information systems and the ability to access, use, and leverage data on a global level," Maj. Gen. (Ret.) Kim Crider said. "We need skilled cyber professionals that understand the connection between air, space and cyber, and need to be able to apply their skills to enable us to stay ahead of national security threats."

Gen. John W. "Jay" Raymond, Chief of Space Operations, USSF, shared a similar sentiment at last year's StellarXplorers competition, when he alluded to the future of our country's newest military branch.

"Creating an enduring advantage in space is not just about the spacecraft, it requires a robust pipeline of young talent," General Raymond said. "We need space professionals to ensure our nation can innovate at speed and create the next novel idea to achieve our enduring interest in space. …The Space Force encourages space-centric STEM programs to ensure we are both developing STEM skills and educating our youth on the critical role space plays in our daily lives. ✪

106 Years Old and Still Going Strong

By Scott King

John Nelson

Albert Maggini photographed during a celebration of his 106th birthday in California at the Charles M. Schulz-Sonoma County Airport in September 2021.

Al Maggini, who completed 35 bombing missions as a B-17 navigator with the Eighth Air Force in World War II, turned 106 recently and celebrated at the Charles M. Schulz-Sonoma County Airport in September. Air Force Association member Lt. Col. Ralph Wade, USAF (Ret.) worked to bring Maggini's achievements recognition. Wade is a member of the Tennessee Ernie Ford Chapter in California

"My [military] service began about three months after the war was declared," Maggini said. "My country needed me and there was no question about [joining], only on whether I serve in the Navy or the Army."

Maggini enlisted in the Army Air Corps and later became a cadet at the age of 27 after several years working in the investment business.

"I didn't get the chance to go to college because I graduated in 1933, at the bottom of The [Great] Depression," Maggini said. "My mother didn't have any money, so I went to work. I always had a feeling of being a little bit below all the rest of the guys who went to college, but the service didn't ask me whether I went to college or not. They just wanted me to navigate an airplane and that gave me a lot more confidence in my life."

"There must have been way over 2,000 guns and we had to fly through it," Maggini said. "But we couldn't take any evasive action because you got to stay on that line."

He recalled flying into heavy resistance, in particular on a mission to bomb an oil refinery in Leipzig, Germany. "There must have been way over 2,000 guns and we had to fly through it," Maggini said. "But we couldn't take any evasive action because you got to stay on that line."

Returning to the investment business after the war, he rose through the ranks at a Santa Rosa, Calif., firm, eventually becoming its director in 1967, and becoming an active fundraiser and board member for the Santa Rosa Memorial Hospital Foundation, for which he's raised an estimated $200 million over the years.

"If I had to do it over again, I would be very happy to do it over the same way," Maggini said. "When you go to work, whether it's in the military or not, you've got to go to work and put your heart and soul into doing the best job you can do. I always tried to do that."

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USAF; United Launch Alliance; Courtesy

1. Maj. Gen. Mason Patrick
2. A ULA Atlas V rocket launches from Patrick Space Force Base.
3. In 2015, a Patrick Air Force Base HC-130P/N prepares to refuel an HH-60G.

PATRICK

Late Bloomer

For 32 years, Mason Mathews Patrick (West Point, 1886) was a brilliant though somewhat obscure member of the Army Corps of Engineers.

Then came June 1918. That month launched him into what may be the most astonishing second act in modern U.S. military history.

The next nine years saw Patrick running a wartime air force, battling Brig. Gen. Billy Mitchell, lobbying Congress, opposing the General Staff, and acquiring military pilot wings.

Major General Patrick—namesake of Patrick Space Force Base, Fla.—is little celebrated or even known today, which is a shame.

He graduated second in his West Point class, 28 spots ahead of his friend, John J. Pershing. Patrick went to the engineer corps, "Black Jack" Pershing to the cavalry.

Thirty-two years later, Pershing was running the American Expeditionary Force in France, and Patrick—though he as yet had no clue—was about to become an Airman.

Pershing wanted him to "whip the Air Service into shape." Colonel Patrick knew nothing about aviation but he was a top-flight organizer. He reluctantly accepted, advancing to major general.

Patrick was a calm, disciplined leader. In a major coup, he succeeded in damping a bitter feud between Mitchell and Brig. Gen. Benjamin D. Foulois, whose mutual hatred had stymied war preparation.

Patrick imposed firm management. The Air Force, which had only four active squadrons when Patrick took over, had 45 by war's end.

Postwar, Patrick returned to his routine, but in 1921 he abandoned all hope of finishing his career as an engineer. The Air Service was in turmoil again, and Pershing, recently elevated to Army Chief of Staff, called once more on the sober engineer.

In October 1921, Patrick, at age 57, became Chief of the Air Service. His second in command: the fiery and ambitious Mitchell.

Mitchell immediately attempted to usurp Patrick's authority, but Patrick slapped him down and called his bluff on resigning.

Patrick, a consummate insider, was convinced that persuasion, not confrontation, would save the Air Service. Many agreed.

He took pilot training, passing all exams in June 1922 (at age 58) and winning newfound respect of skeptical Airmen.

Patrick won additional funding for the Air Service, promoted the 1924 around-the-world flight by Army pilots, and initiated an experimental flying organization at Wright Field, Ohio.

The engineer played a key role in creation of the Army Air Corps, a major step toward an independent service. In this he faced opposition in the General Staff and on Capitol Hill, but skillful maneuvering in the background produced results.

In 1926, Congress passed the Air Corps Act. It was, in a sense, a tribute to the methodical engineer who had stabilized the Air Service in the 1920s. He retired the next year.

The installation known for 70 years as Patrick Air Force Base was in 2020 renamed Patrick Space Force Base and handed over to the U.S. Space Force. Its main element, Space Launch Delta 45, controls launches from Cape Canaveral Space Force Station, a few miles north.

MASON MATHEWS PATRICK

Born: Dec. 13, 1863 Lewisburg, W.Va.
Died: Jan. 29, 1942, Washington, D.C.
College: U.S. Military Academy, West Point, N.Y.
Occupation: U.S. military officer
Service: US Army—Corps of Engineers (1886-1918 / 1920-21), Air Service/Air Corps (1918-19/ 1921-27).
Main Eras: World War I and Interwar Period
Years of Service: 1886-1927
Combat Zone: Western Front 1918
Final Grade: Major general
Awards/Honors: Distinguished Service Medal, Legion of Honor (France), Order of St. Maurice and St. Lazarus (Italy), Order of Leopold (Belgium), Order of the British Empire (UK)
Interred: Arlington National Cemetery

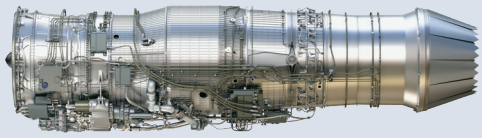
PATRICK SPACE FORCE BASE

Service: United States Space Force
State: Florida
Nearest City: Cocoa Beach
Area: Approx. 3.6 sq mi / 2,300 acres
Status: Open, operational
Opened as NAS Banana River: Oct. 1, 1940
Conveyed to USAF: Sept. 1, 1948
Opened as Joint Long Range Proving Ground: June 1, 1949
Renamed Patrick Air Force Base: Aug. 1, 1950
Renamed Patrick Space Force Base: Dec. 9, 2020
Current owner: Space Operations Command (USSF)
Former owners: (USN) Naval Air Operational Training Command, (USAF) Air Proving Ground, Air Research and Development Command, Air Force Systems Command, Air Force Space Command.
Home of: Space Launch Delta 45

The future of the F-35 is adaptive

Designed, built and tested with the U.S. Air Force, GE's XA100 is the world's first flight-weight, three-stream adaptive cycle engine. The XA100 transforms mission capability by enabling in-flight transitions between a high-thrust mode for maximum combat power and a high-efficiency mode to extend mission range.

The engine's three-stream architecture provides a step change in thermal management capability to accommodate next-generation mission systems. Add in advanced materials and components to enable world-class efficiency and durability, and the XA100 is ready to deliver a generational change in performance, keeping the F-35 relevant decades into the future.



geaviation.com/XA100