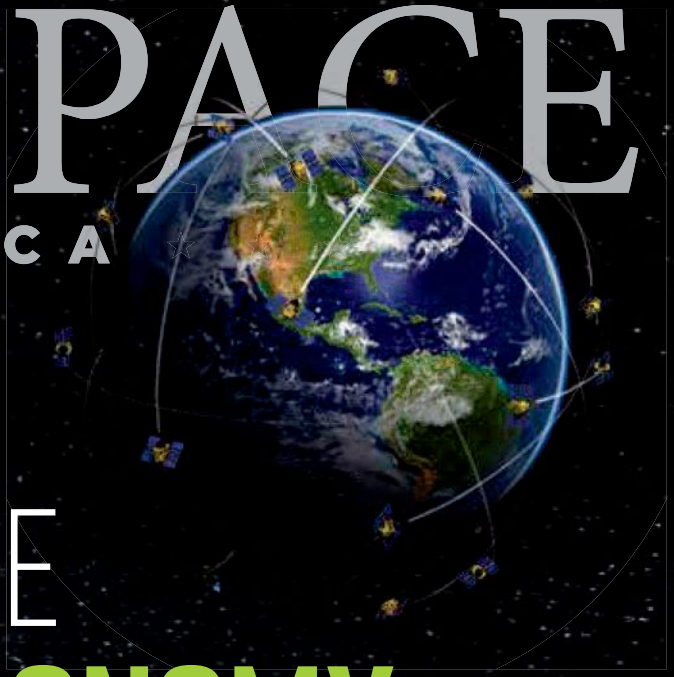
AEROSPACE
★ ★ ★ AMERICA



PROTECTING THE OFF-PLANET ECONOMY

Entrepreneurs want the U.S. Space Force to expand its reach to deep space. The risk of debris raises questions about what the force can do to keep the peace. **PAGE 18**

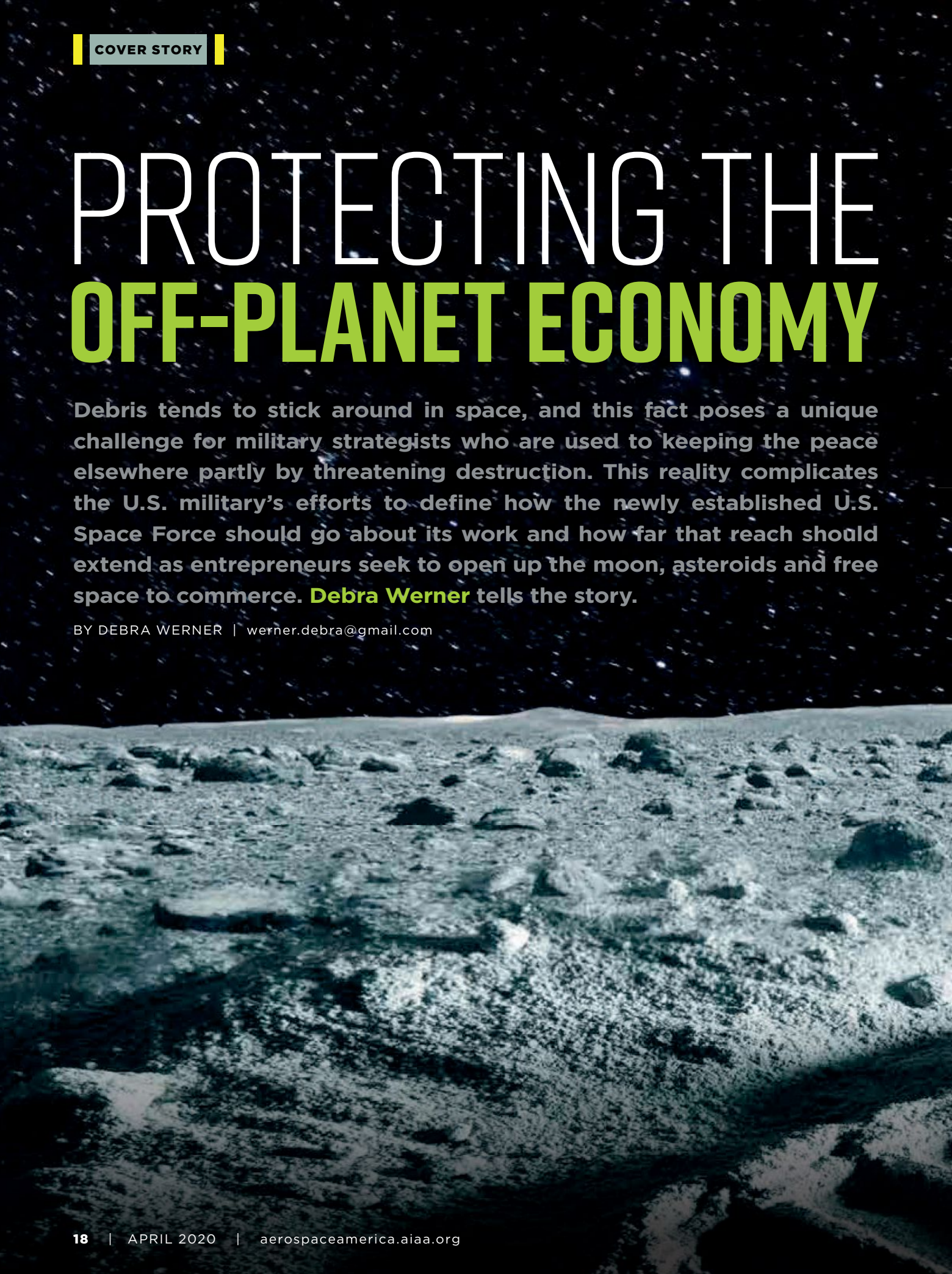
APRIL 2020 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

AIAA
SHAPING THE FUTURE OF AEROSPACE

PROTECTING THE OFF-PLANET ECONOMY

Debris tends to stick around in space, and this fact poses a unique challenge for military strategists who are used to keeping the peace elsewhere partly by threatening destruction. This reality complicates the U.S. military's efforts to define how the newly established U.S. Space Force should go about its work and how far that reach should extend as entrepreneurs seek to open up the moon, asteroids and free space to commerce. Debra Werner tells the story.

BY DEBRA WERNER | werner.debra@gmail.com



France has a bold idea for deterring uncomfortable dances like the one in January between a school-bus-sized U.S. spy satellite in low-Earth orbit and a pair of smaller Russian satellites, one of which approached within 13 kilometers of the American satellite, prompting the U.S. satellite to fire its thrusters to scoot away.

After a similar experience with Russia in 2018, French Defense Minister Florence Parly announced that starting in 2023, France will guard its military satellites with nanosatellites equipped with lasers capable of temporarily blinding cameras. "If our satellites are threatened, we will consider dazzling those of our adversaries," Parly said in a speech last July.

The U.S. hasn't described how it will defend its satellites, but in December the country indicated a stronger focus on space defense when U.S. President Donald Trump signed a massive defense bill establishing the U.S. Space Force as the sixth service branch of the country's armed forces. The first test for Space Force did not take long. The Russian maneuver in January was "unusual and disturbing" and that brought "the potential to create a dangerous situation in space," said Space Force Gen. John "Jay" Raymond, chief of Space Force operations and head of the multiservice U.S. Space Command, in an email to me. Raymond didn't elaborate, but he may have been referring to the risk of a collision that would scatter dangerous debris through critical orbital altitudes for American satellites and those of other countries.

This was not the first such encounter. In 2017, a pair of Russian inspector satellites released a high-speed object that "exhibited characteristics of a weapon," Raymond said in the same email.

Such is the troubling context in which legions of entrepreneurs in the U.S. and abroad plan to extend today's Earth-centered space economy into deep space by establishing factories, fuel depots, mining operations, human settlements and more.

The U.S. created the Space Force partly with commerce in mind, although at least for now the area of responsibility of U.S. Space Command, which controls the new force, goes no farther than geosynchronous orbit. "From the beginning, our space economy was a big piece of what the president and the vice president wanted us to focus on," says Air Force Maj. Gen. William J. Liquori Jr., who heads the strategic requirements, architectures and analysis office for the Space Force. Liquori was also the space policy director on the White House National Security Council staff from 2016 to 2018.

As yet, there is no consensus among strategists and entrepreneurs over exactly what the U.S. Space Force or similar organizations in other countries should do to protect the developing space economy. Some question whether even the strongest military forces can, without diplomacy and laws, achieve the desired stability and security for commercial enterprises.

Small step toward a grand vision

So far, not much has changed with creation of the U.S. Space Force. Email addresses are being updated with "ussf" in them, and some personnel in

CONTENTIOUS SPACE

The U.S. is the latest country to establish a space force, partly to protect the burgeoning space economy. However, actions in orbit suggest the major space powers have been working on technologies to attack each other's satellites.

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

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

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

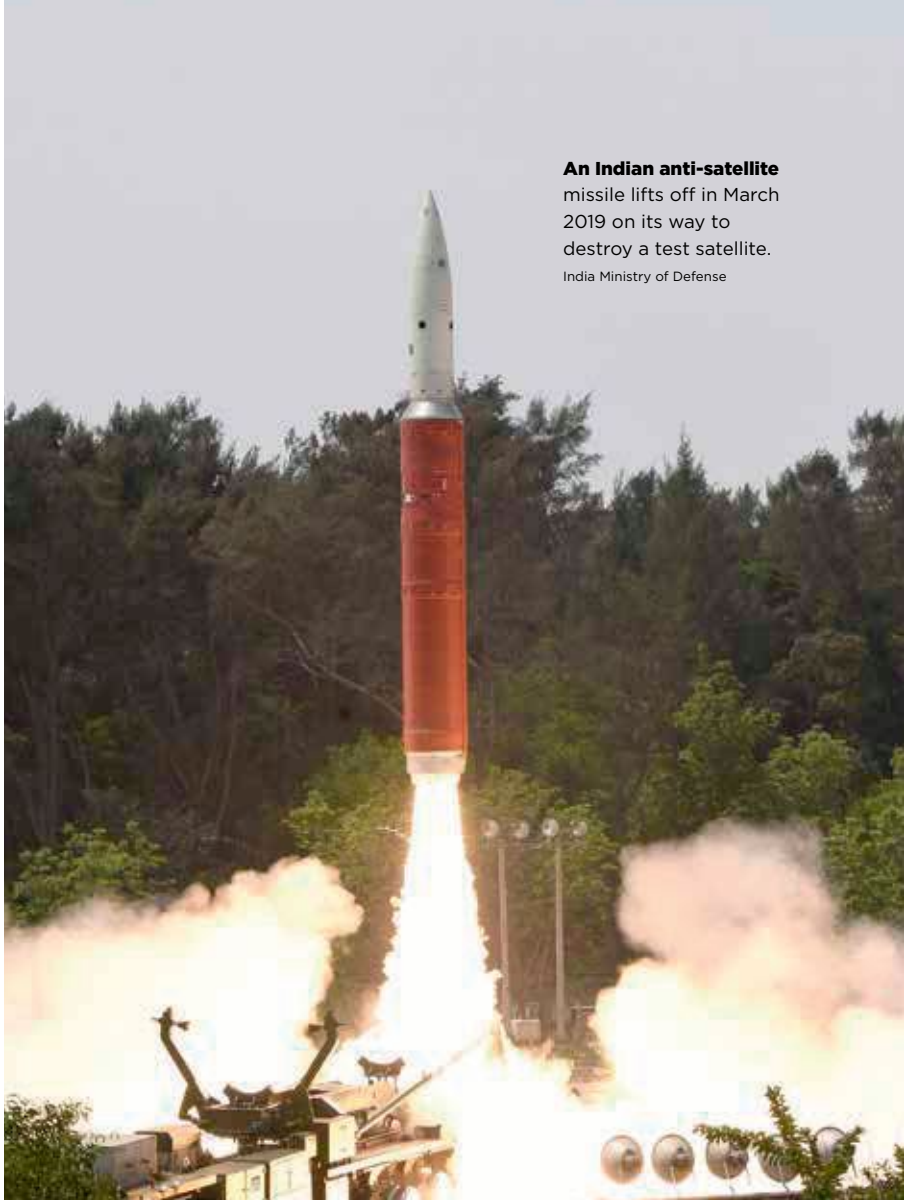
FEBRUARY 2014
U.S. Air Force declassifies plans to launch surveillance satellites to near-geosynchronous orbit to maneuver near "objects of interest" for enhanced surveillance. Two Geosynchronous Space Situational Awareness Program satellites launch in July.

California and Colorado will switch to Space Force uniforms in a bureaucratic transition that will unfold over the next 18 months. The transition will touch Joint Task Force Space Defense in California, where today mainly Air Force personnel but also those from other services monitor large screens as they figure out how to defend the country's missile warning, GPS, National Reconnaissance Office and communications satellites. The transition also will reach the Combined Space Operations Center, where Air Force personnel and those from other services and coalition partners make sure military satellites are tactically tuned to the needs of troops in the field.

Some want a U.S. Space Force with a mission far beyond protecting and operating satellites circling Earth.

One of them is Simon "Pete" Worden, the retired U.S. Air Force brigadier general who headed NASA's Ames Research Center in California for nearly a decade. The long-term imperative for the new force should be "providing a predictable, stable environment for economic development beyond Earth orbit," says Worden, who has been sharing that vision since he co-authored the book "Whither Space Power: Forging a Strategy for the New Century" in 2003.

Worden thinks a lot about the moon, in particular. Entrepreneurs and government agencies have set their sights on lunar resources, beginning with water ice in the permanently shadowed craters of the moon's south pole. NASA aims to send astronauts to explore the region by 2024 as part of Artemis, the lunar program named for Apollo's twin sister in Greek



An Indian anti-satellite missile lifts off in March 2019 on its way to destroy a test satellite.
India Ministry of Defense

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

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

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

JUNE 2017
Russia launches Kosmos-2519, a satellite to inspect other satellites. Kosmos-2519 releases a small satellite in August, Kosmos-2521. Then, either Kosmos-2519 or Kosmos-2521 releases a high-speed projectile. The U.S. reports the activity to the United Nations Conference on Disarmament in 2018.

mythology. Meanwhile, China, which has emerged as the top U.S. rival in deep space, has its eyes on the same region. If all goes as planned, China's Chang'e 6 lander will collect samples from the lunar south pole in 2023 or 2024 before establishing a robotic research station a few years later.

"We are within a decade of a human settlement on the moon," Worden says.

He thinks Space Force should protect these settlers.

Expanding the domain of the force to deep space seems only natural, says retired Air Force Lt. Col. Peter Garretson, a senior fellow for defense studies at the American Foreign Policy Council, a Washington, D.C., think tank. "Space commerce is going to expand to the moon and asteroids where there are millions of times the natural mineral and energy resources that we have on Earth," Garretson says. "Because of the potential for wealth and the ability of that wealth to change national power, it's typical that the flag follows trade."

Another advocate for a strong Space Force is Dennis Wingo, CEO and president of Skycorp, an aerospace engineering firm. He says Space Force should keep tabs on space weather, defend Earth from asteroids and back up future commercial mining rights on the moon or asteroids. To preclude what he calls a "space Pearl Harbor," Wingo thinks the Space Force should gradually replace its geosynchronous military satellites with equipment on Mars, the moon or in free space. Spreading them out would make it more difficult for an adversary to attack them all at once than if they were confined to geosynchronous orbit.

▲ **Gen. Jay Raymond**, chief of space operations for the U.S. Space Force and commander of U.S. Space Command, displays the Space Force's uniform nametape.

U.S. Air Force

Today's Space Force is a long way from wielding that kind of power over such a vast area of responsibility. The U.S. is just now catching up with others in forming a space organization to consider such issues. Russia in 2015 created the Russian Aerospace Forces by merging its military satellite and missile defense organizations with its Air Force. China established the People's Liberation Army Strategic Support Force in 2015 to oversee space warfare, cyber activities and electronic warfare. France created a Space Command in 2019 and reorganized its Air Force into a single Air and Space Force.

Emiliano Kargieman, CEO and founder of Satellogic, an Argentine company that operates Earth imagery satellites, predicts that as nations begin mining operations in space, they are likely to create

CONTENTIOUS SPACE TIMELINE *CONTINUED*

OCTOBER 2017
Russian military satellite Luch/Olimp approaches French-Italian military communications satellite Athena-Fidus. French defense minister calls it an act of espionage.

MARCH 2019
India destroys its own military satellite, Microsat-R, in low-Earth orbit with an anti-satellite missile fired from the ground.

JANUARY 2020
Russia's Cosmos 2542 satellite and a smaller satellite ejected from it in November move within 13 kilometers of USA 245[1], a National Reconnaissance Office Satellite.

space forces of their own, though not necessarily with that name.

Unsettled role

What might the U.S. Space Force do in deep space? During his February State of the Union speech to Congress, U.S. President Donald Trump, implied that members of the U.S. Space Force might one day go to space. The moment came when Trump asked the 13-year-old grandson of a Tuskegee Airman in the audience to stand. Introducing the eighth-grader, Trump said the boy "has always dreamed of going to space" and "has his eyes on the Space Force."

In reality, the Pentagon has no plans to send members of the Space Force to space. Keeping boots on the ground does not trouble advocates of a strong Space Force. Worden sees the force's most important task, initially, as tracking and surveilling spacecraft in orbit and activity on the surface of celestial bodies.

The Space Force also will need the ability to quickly intervene in a conflict, but that intervention will be robotic in the near term, Worden predicts. In short, rather than Starship Troopers or Space Guards patrolling commercial sites, the men and women of the Space Force are likely to remain Earth-bound for years to come, Worden and others say.

The U.S. Navy was something of a template for the new force. In fact, Raymond's title — chief of Space Force operations — was inspired by the Navy's chief of naval operations role. Garretson, the think tank analyst, compares the work of the Space Force to how the U.S. Navy ensures free passage of commercial ships at sea. "The U.S. Navy protects U.S. interests on the high seas on a daily basis but not because it stands next to and babysits every ship," says Garretson. "In fact, the U.S. Navy couldn't possibly stop an anti-ship missile from striking a U.S. tanker or container ship," he adds. Deterrence keeps the peace: "Everyone knows the U.S. Navy has the ability to retaliate."

If deterrence becomes the mission, the question is what form that deterrence should take, given that space debris, unlike the remnants of a retaliatory strike at sea, does not sink to the bottom and cannot be easily hauled out of the way. One piece of debris can collide with another, putting into play the Kessler Syndrome, which says that once debris reaches a certain density, pieces will bang into each other and shatter in an unstoppable cascade of collisions. Certain orbits would be rendered useless for satellites or for spacecraft transiting those orbits to deep space or back with people or cargo.

Would the Space Force ever go on the offensive with some kind of kinetic weapon? The answer is not exactly no. Liquori puts it like this: "We have no desire to weaponize space." After all, he adds,

Law manual seeks to reduce odds of space war

Legal scholar Ram Jakhu sees a need for a clear, objective guide to military space laws that would help prevent space-faring nations from stumbling into a war in space.

An associate professor at McGill University's Institute of Air and Space Law in Montreal, Jakhu and colleagues are compiling a law manual to clarify issues addressed separately — and at times differently — by a range of law bodies and international treaty provisions.

The publication will be called the Manual on International Law Applicable to Military Uses of Outer Space, or the "McGill Manual" for short. The manual will be a practical resource for militaries around the world, and also a resource for identifying laws that are needed but don't yet exist.

From McGill's campus, Jakhu's team has orchestrated the consensus-gathering project. Space law experts from 17 countries, including China and Russia, are drafting the manual, their activities coordinated — but not dictated — by Jakhu's team at McGill. The manual will collect and clarify all laws and treaties directly or indirectly applicable to military uses of space during peacetime, the goal being to reduce the odds of hostilities breaking out over a misunderstanding.

China, India, Russia and the U.S. have each now demonstrated anti-satellite weapons by shooting down one of their own satellites, and so Jakhu wants countries to hit pause before something happens to trigger a conflict.

So many vital aspects of modern life rely on the security of satellites that with "all the militarization" happening, including the establishment of the U.S. Space Force, all parties need a grip on the ground rules upfront, he says.

The experts — 38 in all who will be listed as contributors — meet for periodic workshops on their various continents to debate and finalize about 60 so-called rules that will make up the manual. The experts are from universities, institutes, companies, foundations and military branches; they are experts in space law, international law and military law advised by technical experts on spacecraft and the space environment.

Even those who work for a government are expected to be independent and make objective contributions. Of the seven experts taking part from China and Russia, six are from higher-education institutions and one is from a Russian company.

"Nobody is directing us. Nobody expects us to do something for them," Jakhu says. All experts must reach a consensus on the text.

Rules that apply to military uses of space might not seem overtly military. For example, where does airspace stop and space begin? Other rules might be more clearly tied to military uses. Is it legal for countries to test anti-satellite weapons by destroying their own satellites, risking the spread of debris? In space, in particular, what constitutes an act of self-defense?

The contributors plan to meet in April at the University of Mississippi to debate the few rules still to be finalized. Jakhu hopes the manual will be published before the end of 2020.

"If we're stuck fighting a war in space, that's going to be a very, very serious business for humanity," Jakhu says.

— Amanda Miller

▲ **SpaceX's launch of 60** Starlink satellites from Florida in January was the first overseen by the airmen of the 45th Space Wing since they became part of the U.S. Space Force.

U.S. Air Force

"no one wants a shooting conflict in space that's going to create debris that has the possibility of polluting that environment and making it unusable for all of us."

Deterrence

Some analysts hope that nations will see the wisdom of forging an international consensus against destroying equipment in space, whether that destruction were with weapons stationed in space or via anti-satellite missiles launched from the ground.

That consensus won't come easily. One at a time, the space-faring nations have taken it upon themselves to prove their ability to destroy satellites in orbit with missiles launched from ships or land. The most recent demonstration was by India. In March 2019, Prime Minister Narendra Modi announced that one of its anti-satellite missiles destroyed a target satellite launched a few weeks earlier. The shootdown put India in the league with China and the U.S. as having demonstrated an ASAT missile, although the U.S. has always maintained that its 2008 Operation Burnt Frost shootdown of a falling spy satellite was about protecting people on the ground from a hydrazine explosion.

For retired U.S. Air Force Gen. Robert Kehler, all this fascination with ASAT missiles reminds him of a pediatrician distracting a patient with a stuffed blue bear. "At some level, direct-ascent anti-satellite weapons are the blue bear," Kehler says. There are more effective weapons that could be applied in space. "Network disruption, cyber activities, jamming and other things can be just as effective without creating debris," Kehler says.

If U.S. military satellites are attacked, retaliation will not necessarily occur in space. Instead, the attack "will be met with a deliberate response at a time, place, manner and domain of our choosing," Liquori says. The counterattack could occur on the ground, at sea, in the air or in cyberspace.

Missing ingredients: Law and diplomacy

Analysts who opposed creation of the U.S. Space Force, or were agnostic to it, say the Trump administration should increase its focus on diplomacy. In the other war-fighting domains (land, air and sea), a network of laws and diplomatic channels help to keep the peace, admittedly not perfectly. When fighting breaks out, laws and diplomatic channels lessen the damage of war.

Something similar to the United Nations' Convention on the Law of the Sea for the space domain would be far more helpful "than someone coming in with guns blazing," says Daniel Faber, CEO of Orbit Fab, a San Francisco startup that wants to establish refueling stations in orbit.

Mary Lynne Dittmar, executive director of the Coalition for Deep Space Exploration, says the Law of the Sea is a promising template because it includes a systematic approach to dispute resolution and a focus on peaceful settlement of disputes. "I want to see the continued evolution of this sort of rules of engagement," says Dittmar, who is a member of the U.S. National Space Council Users' Advisory Group, a panel of aerospace industry, researchers and scientists who offer advice and opinions on federal government space activities.

Without such a construct, some observers fear

that kinetic attacks will always remain tempting to militaries. Consider a war between Russia and NATO or one between the United States and China, or between India and China, says Brian Weeden, program planning director for the Secure World Foundation, a Washington think tank that promotes sustainability in outer space. "There will be a lot of incentive to use destructive weapons against satellites," predicts Weeden, who argued against creation of the Space Force.

The discussion of weapons in space leads to the question: Wasn't space supposed to be free of them? It's true that the 1967 Outer Space Treaty prohibits nations from placing nuclear weapons or weapons of mass destruction in orbit. It also bars testing and deployment of weapons on the moon or other celestial bodies. But there is no ban on conventional space-based weapons. Nor have nations agreed on any rules for satellites approaching one another. "When is it OK, when isn't it OK and how do you communicate your intention?" says Laura Grego, a senior scientist in the Global Security Program at the Union of Concerned Scientists in Massachusetts who opposed creation of the Space Force. "If you get too close, is using a weapon ever considered self-defense?" Resolving those questions and turning them into an international agreement will require diplomacy and negotiation, but that is not happening, says Grego.

Diplomats of competing nations tend to reprimand each other for missile tests or satellite stalking, but that is not negotiation. Indeed, after the Russian satellites approached the U.S. spy satellite in January, the U.S. government "raised its concerns directly with Russia through diplomatic channels," says Raymond, the Space Force general.

Regarding ASAT missile tests, little if any progress has been made to stop them before someone's test goes awry. India reportedly constructed its test so that the intercept would happen at low altitude and the debris would fall to Earth quickly. But a mistake or miscalculation by a country could pollute certain orbits for years.

The Trump administration recognizes the ASAT problem. "Right now, the greatest threat to satellites is not from weapons in outer space, but rather from ground-based anti-satellite weapons that are designed to destroy, damage or disrupt the normal functioning of objects in outer space," Ambassador Robert Wood, U.S. permanent representative to the Conference on Disarmament, said in Geneva in August. Instead of seeking to hammer out a treaty, the United States wants to work with international organizations to encourage transparency and confidence-building measures and to define best practices, he added.

In the view of Grego and Frank Rose, a senior fellow for security and strategy at the Brookings Institution, a Washington think tank, and assistant secretary of state for arms control, verification and compliance during the Obama administration, the United States has not done enough to negotiate those confidence-building and transparency measures.

Regarding stationing conventional weapons in space, the record shows that the Conference on Disarmament has for two decades been unable to reach consensus on whether to ban them, Rose says, adding that he does not expect progress in the foreseeable future. China and Russia have drafted a treaty aimed at preventing nations from stationing weapons in space, which the United States has rejected, saying the language does not resolve the ASAT missile issue.

A big question hovers over these issues and the future of the Space Force: Will Donald Trump be re-elected in November? Neither of his likely competitors has expressed enthusiasm for the new force.

Of course, with or without a service branch, whoever is president after January 2021 will face the familiar challenge of creating a stable, secure environment in space. ★

▲ **A modified tactical** RIM-161 Standard Missile 3 (SM-3) launches from the U.S. Navy Aegis cruiser USS Lake Erie in 2008. The missile destroyed a non-functioning National Reconnaissance Office satellite about 247 kilometers over the Pacific Ocean.